

# Working Towards Sustainable Commutes: An Analysis of Cyclists on Caltrain and BART

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## Abstract

The San Francisco Bay Area is a hotbed of cyclist activity. People cycle for enjoyment, sport, and as a method of transportation. Cycling as a form of commuting is beneficial to society because it reduces the number of cars on the road, leading to less pollution and less congestion. Many people who commute by bike use regional rail transportation systems, including Caltrain and BART, to make their trips more efficient. This project examines which group of factors is most significant in differentiating train-riders who cycle from those who do not: Demographic Characteristics, Commute Facts (e.g. distance traveled and length of trip) and/or Commuters' Perceptions. Through a combination of 600 surveys and seven interviews, I capture commuters' motivations for cycling to the train. I use these data to explore the rationale for traveling with or without a bike. I find, through the use of *t*-tests, that cyclists' perceptions of their commutes differ greatly from those of non-cyclists; however, there are surprisingly few differences in riders' Demographic Characteristics and Commute Facts. I use a logit regression to demonstrate which of these three categories contribute to peoples' decisions to commute with a bike. The most significant variables are within the Commuters' Perceptions category, showing that commuters' attitudes are highly correlated with the likelihood that they cycle. Cyclists indicate that they encounter more negative experiences than non-cyclists. This paper also discusses the design of Caltrain and BART as a possible explanation for many of the problems that cyclists face during their daily commute. The interviews describe many of the problems that cyclists encounter, such as getting "bumped" and the need for additional bike space. By identifying parameters that influence some commuters to cycle, this paper provides insight into developing a more bike-friendly policy and design for Caltrain and BART.

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## **Chapter 1: *Motivation and Background***

### **I. Introduction**

Combining rail transit with cycling is one of the most sustainable ways to commute large distances. There are two primary commuter rail systems in the Bay Area: Bay Area Rapid Transit (BART) and Caltrain. These rail systems are responsible for carrying roughly 390,000 people to and from work every day, including about 10,000 people who also travel with a bicycle (Spindler, 2002). Why do such a small percentage of commuters choose to cycle to and from the train stations? Using data I collected from cyclists and non-cyclists, I find that the attitudes of commuters play a larger role than their demographic characteristics or their commute logistics (e.g. distance from train stations and time traveled) in determining the likelihood that a commuter chooses to be a cyclist.

There are four primary modes of transportation to and from train stations in the Bay Area: walking, biking, driving, and busing. For most commuters, walking to and from a train station is not an option because the distance is prohibitively far. The vast majority of commuters must take one of the other three modes for at least one part of their morning commute. People who elect to commute via bus and/or car to the train station cause many negative externalities. Cars, buses, and private shuttles cause large amounts of pollution, noise, and congestion within dense urban centers. Pollution, in addition to degrading the visual appeal of a city, has adverse health effects, including cancer and asthma. Noise often causes discomfort and can reduce property values. Congestion is an example of the tragedy of the commons (Hardin, 1968). Because there is no marginal cost, people over-consume road space, resulting in the slowing of traffic. Traffic is inefficient because it forces drivers to consume excess fuel and waste their time. Intra-city commutes by car or bus yield negative externalities, ultimately leading to a lower quality of life for all who live, work, or visit urban areas.

Commuting by both train and bicycle represents a more sustainable alternative than commuting by car. Because BART is a fully electric system, it does not yield pollution within the city. Although Caltrain is diesel-powered, it generates a modest amount of pollution as it travels; however, both Caltrain and BART yield less pollution per passenger mile than a car or a bus (Vuchic, 1999). Bikes do not yield the negative externalities that cars do and, provide further positive effects on commuters. Bikes promote fitness and a health-conscious society. Bike to train commutes are a good alternative to driving a car and using public transportation. However, cyclists depend on the trains for traveling long distances in a timely manner. This paper examines why only some people in the San Francisco Bay Area who use commuter rail choose to use their bikes. To what extent do the attributes and characteristics of cyclists differ from those of non-cyclists?

To increase the number of commuters who ride bikes requires an understanding of who cyclists are, which attributes they have, and what problems they face. In my research, I find that cyclists' attributes, characteristics, and preferences differ greatly from those of non-cyclists. By identifying cyclists' characteristics and perceptions, designers and planners can create more bike friendly environments.

My research will focus on why people choose to combine rail and bicycle transportation, thereby leading to a better understanding of ways to accommodate cyclists on trains. With the information gathered from my research, I will analyze the existing design and public policy pertaining to cycling in the Bay Area. Special attention will be given to methods of designing more cycle- friendly policies and more efficient integration of cycling with public rail transport.

In order to demonstrate the importance of rail transit and cycling, I first address previous literature pertaining to the ways automobiles have affected our cities. It is impossible to discuss alternative forms of transportation without analyzing the importance of the most prevalent method of commuting: the car. Since most people in the US use a car as their primary form of transportation, I

systematically show the large social cost of the automobile. I compare the car to other methods of transportation to highlight its shortcomings and its impact on urban landscape and life.

In the second part of this paper, I introduce my methods of collecting the data and conduct empirical tests as to whether cyclists differ from non-cyclists. The comparisons illustrate the differences between the two groups, allowing for further analysis to discover which of those variables are significant to cyclists. I show that cyclists differ from non-cyclists across a wide array of factors, indicating that cyclists may have different traits and perceptions that motivate them to bike.

Lastly, I estimate the probability that a given rail transit commuter is also a cyclist by conducting a logit regression with the data collected in the surveys. I divide the data into three categories (All Trains, Caltrain and BART) to evaluate the effects that given characteristics have on the likelihood that a commuter is a cyclist. The regressions I generate render some of the variables statistically significant, thereby differentiating cyclists' attributes and perceptions from those of non-cyclists. I find that the statistically significant parameters in predicting the likelihood that a commuter is a cyclist are a person's attitude and perceptions of the train system, rather than their demographic characteristics or commute facts. I conclude with a discussion of train systems' designs and cyclists' descriptions of their commuting experience. By focusing on the obstacles and frustrations that cyclists face, I show why a minority of people choose to bike and explore how these problems arise.

## **II. Literature Review**

Both transportation planners and academics have analyzed public transportation in efforts to increase ridership. Over the past 20 years, cities have worked to increase ridership by including special accommodations for cyclists (Saelens, Sallis, & Frank, 2003). Many cities in the San Francisco Bay Area attempted to smoothly integrate cycling with public transportation (Pucher & Buehler, 2009 and Reynolds, 2005). However, many cyclists are still discontent with road regulations and public transportation accommodations (Blickstein & Hanson, 2001). More research must be conducted in the

Bay Area to investigate why people use bicycles as a form of transportation and what their current needs are. My research will help guide the future planning and policy of Caltrain and BART to meet the needs of those who bicycle.

In some cities, cyclists are being crowded out by other forms of transportation, which has resulted in the formation of cyclist groups in attempts to resist these pressures. Kidder (2008) argues that cyclists are a crucial element of the urban landscape. His research sheds light upon the marginalization of the bike messenger, a phenomenon that makes bicycle traffic less common in the city. Blickstein and Hanson (2001) also address the rights of cyclists in cities by analyzing the Critical Mass movement in San Francisco, where once a month cyclists fill the streets of San Francisco to celebrate cycling and assert cyclists' right to the road. Blickstein and Hanson's work concludes that current public transport and road laws do not accommodate the cyclist adequately, leading to a marginalization of cyclists on the streets. These two sources provide valuable insight into the struggles of a cyclist in the city.

Policy also plays an important role in motivating people to cycle. Hanson and Young (2008) and Timperio, Crawford, Telford, and Salmon (2004) independently demonstrate how policies in Arlington, Virginia and Melbourne, Australia affect the rate of cycling. Furthermore, their research demonstrates how critical city planning is and the large role that public policy has in the design process. However, relatively few studies have taken a qualitative approach to understanding why people elect to cycle to work. These researchers neglected to explore the motivations behind why people choose to bicycle and instead analyzed the discourse from a city planner's perspective.

Other studies have attempted to predict ridership levels on BART, but did not focus on cyclists in particular. For example, McFadden (1974) used principles of behavioral economics and econometric modeling to examine which factors contribute to people's decisions to use public transportation. Using BART data from the 1970s, he focused on distance and income as predictors of whether or not a person

would choose to commute via BART. He conducted a binary logit regression to see the difference between the two populations (BART users and non-BART users) in efforts to predict ridership levels (McFadden, 1974). This paper differs from his report in that it focuses on cyclists in particular. However, McFadden's research sets a precedent for using economic tools in analyzing commute behavior.

Economist Parody's (1977) paper, "Analysis of Predictive Qualities of Disaggregate Modal – Choice Models," further proves the effectiveness of using logit models in predicting commuter behavior. He examines the predictive accuracy and ability of disaggregate behavioral demand transportation models. He concludes that most demand models can be used to predict future behavior (Parody, 1977). Parody shows that the models created to predict commuter actions and preferences were still applicable years after they had been formed. Their predictions were surprisingly accurate, and reaffirm the validity of using economic analysis for future transportation modeling.

Many studies have examined the effects of land use and attitudinal characteristics on travel behavior in the diverse San Francisco Bay Area. For example, "A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area" looks at design and socio-economic components in peoples' methods of travel (Kitamura, Mokhtarian & Laidet, 1997). Kitamura et al. (1997) attribute some of peoples' travel behaviors to their attitudes towards the environment and personal health. However, these researchers do not explore cycling as a phenomenon; rather, they analyze the automobile, walking and public transit.

Health, convenience and the environment are some of the primary forces motivating many cyclists (Timperio et al., 2004). Hanson and Young (2008) provide a great foundation for understanding the discourse. They address the way Arlington, Virginia was able to create an effective biking policy for the city. The authors analyze the government's role in planning the design of cycling routes. Another article, written by Saelens et al. (2003), focuses on the environmental impacts of cycling. Since many people in the Bay Area are environmentally conscious, it makes sense that this concern would play a

large role in their motivations for cycling. However, this has not yet been quantitatively shown. According to Nankervis' (1999) research, the weather in the Bay Area is conducive to cycling. The winters are not severely cold and the summers are long and mild. This type of environment provides people with more opportunity to cycle. These studies have shown that weather, health, and environmental consciousness are factors that cyclists take into consideration. I hypothesize that most people who take public transportation have some of the same concerns, but for many, there exist limitations on the extent to which they can act on them. I undertook this research to get a better idea of what these limitations are and how they can be alleviated.

Previous researchers have established effective models and methods for studying transportation issues, but most of their models and discussions cannot be applied to the Bay Area. Through their analyses of different locations and transportation systems, it is evident that the choices that commuters make are site-specific. Additionally, each researcher addresses commutes and commute choices through different academic lenses, including economics, anthropology or sociology. Unlike previous works, I use a mixed methods approach to analyze the complex issue of transit modal choice. Most previous research is either purely ethnographical or quantitative, resulting in a fragmented story.

### **III. Problems with the Car**

Cycling is one of the most sustainable ways to commute and move about a city, but the automobile dominates urban centers. Cars occupy large amounts of space while they are parked and in motion. They also require large amounts of infrastructure and yield many negative byproducts, including noise and pollution. Parking, roads, and the noises associated with automobiles lead many people to construct homes far away from streets with lots of traffic; this, in turn, causes people to commute further and become more dependent on their cars. Lastly, automobiles destroy the continuity of cities, resulting in less walkable and livable environments.

Congestion makes urban environments more frustrating to live in because commuting is very time consuming. The Bay Area has become one of the most congested places in the United States resulting in large commute costs in terms of both time and money. Traffic is a function of density; as density increases, so does traffic. However, there are other variables in determining the amount of congestion. If we assume that space is fixed, as is often true in cities, the size of the vehicle is one of the leading factors in causing congestion. Because roads cannot be widened, the large number and size of vehicles elevates congestion levels. The larger the vehicle, the more congestion it creates. There is little incentive for any one commuter to change his vehicle size because he does not receive any direct benefit. However, all others trapped in the traffic jam will benefit from his decision to use a smaller vehicle. The problem exists because there are few incentives for drivers to buy smaller cars or give up their cars altogether. In fact, many policies incentivize driving.

In the 1950s and 1960s there was a huge expansion of the United States road network to better accommodate automobiles. The effects of the expansion can be seen all over the United States; however they are especially apparent in cities. In San Francisco, Interstate 80 cuts through the city, dividing many neighborhoods. Recently, many neighborhood groups have pushed to remove parts of freeways to reunite the city. By removing segments of the post-World War II freeway system, citizens have been able to make their cities more contiguous. For example, Hayes Valley, a neighborhood in San Francisco, was redeveloped after a section of I-80 collapsed in the 1989 Loma Prieta earthquake. The roads were redesigned, and streets such as Octavia Boulevard were constructed in the place of the freeway. The people of San Francisco pushed to demolish sections of the freeway to create streets that could better accommodate cyclists, buses, and pedestrians. However, highways CA-1, I-80, and I-280 still cut through the city and reduce livability by making areas less inhabitable as a result of noise, pollution, and reduced walkability. These high-speed corridors reduce the significance of public transportation, and invite people to make long-distance commutes into the city.

The Bay Area's dependency on automobiles also pollutes the region which causes health problems and contributes to climate change. Throughout the United States, cars emit roughly one-fourth of all airborne pollutants (U.S. Environmental Protection Agency, 2010). Tailpipe emissions, which include carbon dioxide, carbon monoxide, nitrogen dioxide, and particulate matter (PM), adversely affect the livability of cities (Jacobson, 2002). For example, increased concentrations of aerosols 2.5 micrometers in diameter or less (PM2.5) are associated with higher levels of asthma, bronchitis, and other chronic conditions (U.S. Environmental Protection Agency, 2002). Additionally, the pollution contributes to climate change, as one of the largest components of tailpipe emissions is carbon dioxide. Thus, tailpipe emissions affect both health and climate negatively, reducing the health of cities.

City livability is adversely affected by the constant noise associated with cars. The speed at which cars travel generates an abundance of sound that deters people from the area. To mitigate the abundance of noise near freeways, many cities have erected sound barriers (also known as sound walls). These walls are typically formed of either concrete or stone, and are very costly to construct. The cost to society of the noise is reflected in the pricing of housing. Economists have analyzed the effects of noise pollution and found it to be a substantial factor in the value of a home (Hill, William, & Guay, 2008). For example, a home by a freeway is worth much less than the exact same home on a small suburban street. The housing price differential represents the increased value that people place on being far from automobile noise.

Many city planning agencies focus on accommodating automobiles. For example, many cities have historically required a minimum number of parking spaces per building (Palo Alto Comprehensive Plan, 1999). Recently, some very progressive cities, such as Portland and San Francisco, have limited the number of parking spaces per building. In most cities, particularly in historical centers, there is not enough space to accommodate all of the cars that wish to park. Historical cities were not designed to

accommodate the car, resulting in a lack of space for storing them. The park spaces and parking lots divide the city; they are large obstacles that people avoid.

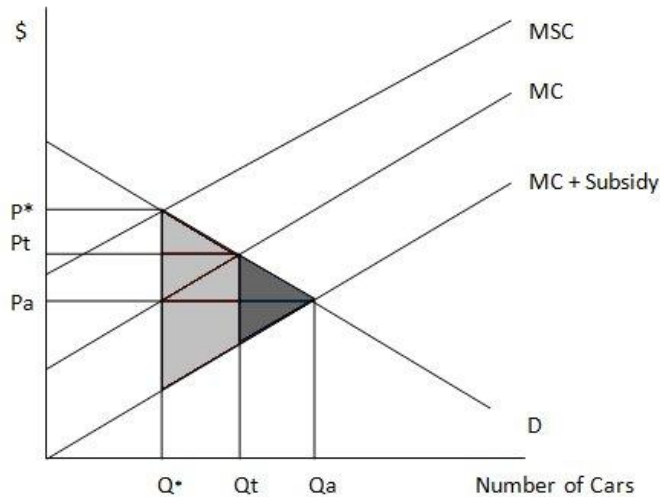
Parking lots destroy the continuity of urban spaces and detour transportation via foot or bike. Parking lots are large deterrents to pedestrians for two reasons: firstly, they are not aesthetically pleasing and secondly, they tend to be very large. They are obstacles that people want to avoid. People do not want to visit urban centers to look at cars; rather, they are there to experience the architecture, shops and other people. Parking lots do not offer any of these traits. They detract from the space because they are not engaging. The size of parking lots also decreases the walkability of urban centers because of the vast amounts of space they require. People are less inclined to walk to and from stores that are surrounded by parking lots because it takes so long to walk through them. This is particularly apparent in suburban settings (see picture below). In some situations, the parking lot is more than twice the size of the structure that it was constructed for. Ideally, many parking lots should be constructed underground or above first floor retail to obscure them from view, thereby making spaces more continuous. It is easy to see that once large parking lots are constructed people become more reluctant to walk and more likely to drive.



*Newpark Mall in Newark Ca. (courtesy Google Maps)*

Currently, individuals do not realize all of the social costs associated with their ownership of an automobile. Since people are not facing the full costs, society as a whole must bear the negative effects of overconsumption. People over-consume the resource of space because it is provided at minimal cost. Since parking is frequently subsidized, people overuse their cars. Drivers are not paying the marginal cost (MC) of parking; rather, they are paying at a far lower rate. Moreover, the marginal social cost (MSC) of driving and parking one's car is much more than the rate that drivers pay. This increases the size of the dead weight loss (DWL), which can be observed in the graph below. The dark shaded area is the dead weight loss from the subsidization of automobile use. With the addition of the MSC in the equation the area increases (in the graph below the sum of both shaded areas represent the total DWL). Society pays a very high price for the subsidization of automobile use.

Graph 1



This graph illustrates how subsidizing parking increases the number of cars. The shaded regions show the total DWL, representing inefficient levels of consumption. If the market were efficient it would be operating at  $P^*$  and  $Q^*$ . However, with the subsidization and the neglect to account for the externalities, the market operates at the inefficient levels of  $P_a$  and  $Q_a$ .

The most prevalent way of commuting is not sustainable, and it detracts from the livability of urban areas. Efficient alternatives are needed to reduce people's dependence on the automobile. In the Bay Area, the combination of commuter rail and cycling creates a valid alternative to commuting by car.

#### **IV. The Benefits of Alternatives**

In comparison to cars, bikes and trains yield few negative externalities. Bikes and trains are more space-efficient than cars and do not have large environmental impacts. Bikes blend into the urban fabric of cities because they travel at "human" speeds. Trains glide through dense urban areas with minimal impact whether traveling above or below ground. When compared to cars, bicycle and commuter rail infrastructure occupy a minimal amount of urban space. Using private motor vehicles may sometimes be faster than cycling or riding the train; however, this decision comes at a great social cost.

Some people choose to cycle as their primary method of commuting for environmental reasons. People cycle to reduce their carbon footprint and minimize their environment impact. It is widely believed that the private automobile has had a huge impact on the environment. One of the most efficient ways to reduce one's greenhouse gas emissions is to cycle. Cycling strikes a balance between minimizing one's own pollution and commuting.

In comparison to other forms of motorized transportation, rail transit is the most efficient. Electrically powered trains, like BART, yield very little CO<sub>2</sub>, SO<sub>x</sub>, and particulate matter (PM) (Numan & Kenworthy, 1998). Commuter rail systems, such as Caltrain, are not quite as efficient as electric trains, but they are still much more efficient than the automobile. In the US, on average, rail transit only uses .74 mega joules per person per kilometer. In comparison, an average car in the US will require 3.52 mega joules per person per kilometer. This means that rail transit is 4.76 times more energy efficient than cars (Numan & Kenworthy, 1998). The reduction in fuel consumption translates to a minimization

of pollution. Train systems pollute more than cyclists, but trains are a much more sustainable way of commuting in comparison to cars.

Some people elect to cycle rather than own a car for health reasons. Many commuters use bikes because they are able to accomplish two daily tasks at once. The average American commutes roughly 1.2 hours per day (Litman, 2010). People who travel by bike or by combination of public transport and bike are able to exercise on their way to work. For many people, biking to work is the preferred method of transportation because they are able to save time in the long run. For example, people who value being in good health will allot a portion of the day to exercising. However, gyms are costly and require a substantial time commitment. It is much cheaper, in both the direct cost of the gym membership and the opportunity cost of the time of going to the gym, to exercise on the way to work.

Bikes are much more space efficient than cars and can operate within existing infrastructures. However, cyclists have not been taken into serious consideration in many city plans until recently (Palo Alto Comprehensive Plan, 1999). Bicycle storage and parking is small in both size and cost in comparison with automobiles. Often, new spaces do not have to be created for cyclists to park their bikes. Bike racks can be integrated with sidewalks. Because cyclists do not need a 10-foot by 20-foot pad for parking, cities that emphasize cycling rather than driving are much less crowded. The bicycle also provides a practical solution to many traffic problems. Compared to other forms of personal transportation, bicycles occupy minuscule amounts of space. A commuter who travels via bike rather than a car will reduce congestion. As a result, all of society benefits from a traveler's decision to commute via bike rather than car.

In comparison to cars, trains are also very space efficient methods of transporting people. If a motorist drives to and from work for a total of three miles during the typical commute time, his car will occupy up to 25 times as much space as a trip made by bus, and more than 60 times as much space as a train. During non-commute hours the ratio is halved (Vuchic, 1999). These large differences are

attributed to both the space required during the commute and the storage of the vehicle before the return trip. Rail transportation infrastructure uses space efficiently, allowing for higher density and more livable cities.

One of the largest pitfalls of cycling is the limited range of travel; however, rail transit can mitigate this problem. Without sufficient density, sustainable modes of transportation are less effective. The demand for public transit is often not large enough and self-powered modes of transportation may not be fast enough for sprawling cities. Space must be used efficiently to reduce the importance of the automobile by making other forms of transportation faster, easily accessible and efficient. Rail transit is critical to making long distance commutes feasible for commuter cyclists. When trips exceed distances that cyclists are willing to ride, a combination of cycling and public transportation is a logical alternative. Another obvious short-coming of cycling is maintaining high speed over long distances. A 20 minute car ride at highway speeds can take hours on a bike. In order to make long distance commutes (over seven miles) feasible for cyclists, public transportation plays an important role. Both bus and rail transit can aid the cyclist in reaching his/her distant destination. In the San Francisco Bay Area, rail transit is the most prevalent and most commonly used form of transportation for cyclists.

Within dense urban areas, cycling is one of the most efficient forms of transportation. Cyclists can avoid many of the obstacles that cars face. On average, for commutes under one mile, it is faster to ride a bike than it is to drive a car, assuming that you are getting your car out of a parking lot and parking it in one (Litman, 2010). Cycling is also particularly efficient in large cities. For example, San Francisco is less than eight miles wide, and it is the second densest city in the US. Given the city's width and that the average speed of a cyclist is ten miles per hour (see Table 5 in Chapter 2), it is possible to ride a bike across the entire city (from the San Francisco Bay to the Pacific Ocean) in under an hour. In times of traffic, it can take longer in a car to make the same commute.

The personal and societal benefits of commuting by bike and/or train are substantial. Cyclists contribute to urban settings by providing eyes on the street and have few if any environmental impacts. Similarly, rail transit yields few emissions per passenger mile and blends into urban areas. Neither of these modes significantly contribute to congestion and both are accessible to nearly all Bay Area populations.

## **V. History and Bike Accessibility of Both Systems**

### Caltrain

The railroad corridor between San Francisco and San Jose was constructed by the San Francisco and San Jose Rail Roads. This commuter system allowed people to quickly travel from most cities along the Peninsula to San Francisco. San Francisco, San Mateo and Santa Clara counties financed the project, and the first trains began to run in 1863. It only took two hours to commute from Palo Alto to San Francisco. The right-of-way was then purchased by Southern Pacific seven years later. For the next 100 years, the lines were maintained and operated by Southern Pacific. Southern Pacific was able to make profits from the commuter rail system up until the 1970s. With the popularization of the automobile, resulting in a decrease in ridership, Southern Pacific found that the commuter service was a liability. In 1977, Southern Pacific “petitioned the state Public Utilities Commission and then the Interstate Commerce Commission to discontinue the Peninsula Commute Service” (Caltrain). A long and bitter fight ensued between San Francisco, San Mateo, Santa Clara counties, Caltrans and Southern Pacific. The five interest groups decided that Southern Pacific would become the contractor and the public agencies would cover most of the operating costs. Caltrain is still largely run and funded in this way.

In September of 1992, Caltrain introduced a limited “Bikes-on-Board” program. Later in 1995, the number of bicycles allowed per train was increased to 24, making Caltrain the least restrictive and most accessible rail system to bicyclists in the country (Caltrain). In April of 2002, Caltrain received funds for the Baby Bullet service and a BART connection at Millbrae. This investment yielded a spike in

ridership levels and revenue. The following year, the station at Millbrae was completed, allowing passengers to transfer from one system to the other. With the addition of this station, it became possible for people to travel all over the Bay Area. Both Caltrain and BART benefited from the connection station (Caltrain).

The Caltrain system runs the length of the San Francisco Peninsula and is responsible for transporting roughly 37,000 commuters daily. About 2,700 of these passengers take their bikes aboard the train. The peninsula is dotted with stations between San Francisco and Gilroy. However, the majority of the stops are between San Francisco and San Jose. As Caltrain was originally designed as a commuter service system, the majority of its trains run during commute hours: between the hours of 7am to 10am and 4pm to 7pm, Caltrain has multiple trains running every hour. During non-peak hours, Caltrain only has trains departing every hour. This type of structure limits Caltrain to commuters because the trains do not run frequently enough to serve as an alternative to the car for the majority of the day.

Caltrain has developed a series of high-speed trains that operate during commute hours. The trains are officially called “Baby Bullet express trains,” but passengers often refer to them as either bullet trains or express trains. These trains provide expedited service during peak hours between San Jose and San Francisco. Bullet trains do not travel at physically higher speeds than normal trains, but they are faster because they do not stop at all of the stations. Caltrain has attributed most of its success to this type of train service.

A large portion of Caltrain’s passengers drive their cars to the stations and take the train for the rest of their commute. Caltrain has parking facilities at 28 of its 32 stations, each spot costing only one to three dollars for 24 hour period (Caltrain). As such, the system makes driving easy and affordable for those commuters who wish to use Caltrain for one leg of the trip.

Caltrain allows passengers to bring their bikes onboard the trains when there is space available. Caltrain operates two types of passenger cars: Gallery cars, often referred to as the “old style car,” and

Bombardier cars, often referred to as the “new style cars.” Caltrain uses special train cars for cyclists. These cars, specially designed for cyclists, were originally passenger cars. Caltrain transforms the cars by stripping out the majority of the seats to create room for bicycles. Caltrain also has two different types of these bicycle-specific train cars. The Gallery cars can hold 40 bikes and the Bombardier cars can carry 24 bikes. All Caltrain trains are equipped with at least one bike car. Some of the trains are equipped with a second bike car, providing even more space for bikes. Only some trains have this service and it is not reliable. According to Caltrain, “Caltrain crews will strive to maintain this customer enhancement; however, the second bike car is not guaranteed because of equipment maintenance and other operational needs” (Caltrain). This disclaimer makes it difficult for cyclists because they are not sure if the train they are expecting will have adequate accommodations.



*Interior of an old style bike car*

There are two ways to store bikes at most Caltrain Stations. Most cyclists use the traditional-style bike racks, which are at every station, to store their bikes if they do not want to bring them on the train. However, theft and vandalism are large problems at many stations. As a result, many cyclists do not feel comfortable leaving their bikes unattended, especially overnight (Daniel). Cyclists have an

alternative to leaving their bikes out in the open. Caltrain passengers can purchase bike lockers. These lockers are large three foot by five foot by three foot boxes that people can store their bikes in. The bike lockers cost \$33 for six months, plus a \$25 refundable key deposit. These facilities allow cyclists to safely store their bikes. The only problem with the locker system is the limited supply. Both types of parking spaces are in high demand at popular stations, such as Palo Alto. It can be difficult for cyclists to find places to park their bikes at these popular stations.



*Bike Lockers at the Palo Alto Station*

## BART

Like Caltrain, the primary purpose for the construction of BART was to transport people into and out of San Francisco. After World War II there was a huge influx of people into the Bay Area. At this time the automobile was beginning to take root as the preferred method of transportation. Many Bay Area civic and business leaders began to fear the ever growing congestion of the freeways. In particular, the bridges across the bay were perceived bottlenecks. A new method of moving people from the East Bay into the city was needed. "In 1947, a joint Army-Navy review Board concluded that another connecting link between San Francisco and Oakland would be needed in the years ahead to prevent intolerable congestion on the Bay Bridge" (BART). The board proposed that an underwater tube devoted exclusively

to high-speed electric trains should be constructed to ease the pains of population growth (BART). The commission stated, "If the Bay Area is to be preserved as a fine place to live and work, a regional rapid transit system is essential to prevent total dependence on automobiles and freeways" (BART).

The system was designed to efficiently move people into and out of San Francisco from the surrounding edge cities. The majority of BART's 350,000 daily riders take the train into San Francisco. On the peninsula, BART has one track that runs from Millbrae into the city. On the eastern side of the city, the East Bay, BART tracks fan out into four fingers. These lines travel through most major East Bay cities such as Berkeley, Oakland, Richmond, and Fremont. The BART trains start running around 4:30am on weekdays and close for the night around 12:15am. During commute hours, BART has trains that run through most major stations every ten minutes. During non-peak hours, trains run either every 15 or 20 minutes.

BART does not accommodate motorists to the same extent that Caltrain does. By only providing parking spaces for motorists at suburban stations, BART is able to minimize the cost of running the systems at its densest stations. BART's most frequented stations, in the heart of San Francisco, do not have parking facilities. Even some of BART's stations in edge cities, like the Downtown Berkeley station, do not have parking places, thereby reducing the cost of running the system. To provide parking, the upfront costs are huge, and the marginal costs of maintenance and policing costs thousands of dollars a year (Shoup, 1997). However, BART provides large parking lots for customers who travel to and from the extremities of the system. Since the far eastern stations of the systems are located in low density areas, BART assumes that people will have to travel to the stations by car.

Another difference between BART and Caltrain is the manner in which each system accommodates cyclists. BART only permits cyclists to board the trains during non-peak commute hours. BART argues that it is not safe to have bikes in the passenger cars when the cars are crowded (in case of an emergency). Cyclists are prohibited from efficiently using this system during the most relevant

commute times. When cyclists board the trains, they are not provided with a designated bike car; rather the cyclists are responsible for holding onto their bikes for the duration of the journey. Some train cars have areas next to the doorways that are designated for cyclists and handicapped patrons, but the majority of the time, cyclists will not be able to access such spots, and instead balance their bikes in the aisle of the car.



*A cyclist on BART holding her bike*

The differences between Caltrain and BART are significant, creating a different type of ridership experience for both cyclists and non-cyclists. The ridership levels indicate that BART is a more popular system, but Caltrain has a higher percentage of cyclists. By collecting data from cyclists, I am able to explore who the riders are and how the train systems facilitate their commutes.

## **Chapter 2: *Data, Interviews and Findings***

### **I. Methodology**

To explore how cyclists' Demographic Characteristics, Commute Facts and Perceptions differ from those of non-cyclists, I compare cyclists on Caltrain and BART to one another and to their respective non-cyclist populations. The two train systems are very different, as are the populations that use them. I seek to better understand whether all cyclists share similar traits and perceptions of their train systems. Caltrain has the highest cyclist to passenger ratio in the United States (Spindler, 2002). BART, on the other hand, has a much lower cyclist to passenger ratio. The ratio is much closer to the average for the United States, making it a good system to compare to Caltrain. Additionally, the two systems operate in roughly the same area, as both service people moving in and out of San Francisco. The designs of the two systems are rather different, but both attempt to accommodate cyclists. These attributes make the systems commensurable.

To understand the relationship between cyclists and public transport, I used a mixed methods approach to collect data. I used 600 self-designed surveys to capture a large number of commuters' opinions, and I conducted interviews to further explore some of the emerging trends. I rode Caltrain and BART for ten consecutive weeks during morning commute hours (5:00 am to 10:00 am) to gather data on cyclists who ride the trains. Since subjects had ample time to discuss their commutes while riding the trains, I was able to deeply explore their reasons and motivations for cycling.

In order to limit sample bias, I systematically selected the subjects for surveys. The surveys were distributed to everyone in the train cars. I always started at one end of the train car and worked my way down the aisle. I asked every commuter, as I proceeded down the aisle, if he/she would be willing to fill out a survey. I introduced myself as a Stanford student who was studying commute habits. Additionally,

I told each commuter that they would remain completely anonymous and that the survey would take approximately ten minutes to fill out.

Before I began to collect data, I ran a series of pilot surveys. In total, I collected over 40 pilot surveys which I used to further develop my methodology and identify improvements that could be made to the questionnaire (Appendix A). Additionally, I asked commuters for their input at the end of the survey by leaving space for additional comments. Many commuters helped me develop relevant questions by making recommendations at the end of the survey. I also used trends in these surveys to fabricate my questions for the interviews. These 40 surveys were not used for any final calculations presented in this paper; they were merely for exploratory purposes.

The first interview I conducted was with Daniel<sup>1</sup>, an urban designer who also teaches at Stanford University. I requested his participation outside the random sampling of other interviewed subjects. After meeting Daniel in a class, I learned that he is a commuter cyclist who rides Caltrain on a regular basis. I believe he has interesting opinions about the design of the train because of his experience in the field of urban design and work as an academic. I used his insights to develop some of the interview and survey questions.

For the rest of the interviews, I randomly selected cyclists to delve deeper into some of the trends in the data. In order to ensure that the sample of interviewees was random, I chose ten surveys (five to be distributed to Caltrain riders and five to be distributed to BART riders) and marked them. I then shuffled them into their respective stacks. When I distributed the surveys to the cyclists I kept a watchful eye out for the surveys with the marking. If I gave a marked survey to a cyclist, I asked him, upon collecting the survey, if he was willing to take part in an interview. I was turned down by four of the potential interviewees.

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<sup>1</sup> All names of interview subjects have been changed to preserve their anonymity.

There were only a few differences in the methodology in gathering data from non-cyclists. I developed two types of surveys, one for cyclists and another for non-cyclists, because some questions did not pertain to both populations (Appendices B and C). The modified survey for non-cyclists was specifically designed with questions to target their decision not to cycle. Non-cyclists were also told that the purpose of gathering data from their commute was to compare it to cyclists; whereas I told cyclists that I was interested in their daily commute and reasons for cycling.

The final surveys have three types of questions: fill-in the-blank, check-the-box, and circle-a-number. Many variables, such as Duration of Trip, Income, and Board/Arrival Distance, are continuous and were reported in the fill-in-the-blank format. Because these numbers are self-reported, they are subject to large estimation errors due to commuters' inaccuracy in approximating distances and time. It is likely that some of the participants do not know the number of miles between their home and the train station. As a result, many of these recorded numbers may not be accurate. The check-the-box questions are binary. Subjects were asked to check a box for gender, accessibility to a car, and if they work while they ride the train. Other questions use a Likert scale<sup>2</sup> to record riders' perceptions and preferences. All subjects circled a number on a scale from one to five to represent their feelings about the service they were receiving and their perception of cycling.

I did not travel to every train station on BART and Caltrain; instead, I strategically focused the distribution of the surveys. On Caltrain, I rode nearly the entire length of the rail service, between the 4<sup>th</sup> and King Street Station and San Jose Diridon. I selected this portion of the stations (roughly 80%) because this is the most commuted segment. The six stations that I did not observe only receive very limited service because ridership levels are so low in these areas: only five trains visit these stations per day. Despite the fact that patrons boarding at these stations were not sampled near their boarding stations, they still appear in the sample. Many of the people who board at the excluded station travel in

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<sup>2</sup> A Likert scale is a type of psychometric scale, which uses number to measure subjects' perceptions, preferences, and tastes. The scale I use ranges from one to five. A rating of a five corresponds to an intense feeling.

to San Francisco. On BART, I focused on trans-bay commutes because all of the BART lines travel under the San Francisco Bay through the same tunnel. This allowed me to limit sample bias by randomly getting on and off trains between Civic Center and West Oakland. By randomly getting on and off trains at these two stations, I had equal probability of sampling all trains regardless of their destination. Both my sampling techniques on Caltrain and BART minimize biases.

Throughout the data collection process I faced many obstacles, including restrictions from Caltrain and BART and resistance from commuters. Both Caltrain and BART have policies about soliciting to their passengers. I resorted to befriending the conductors to gain access to the commuters. Additionally, some passengers ignored me and others were very hesitant to take part in the surveys. Since non-cyclists were not the “true” subjects of the research, merely a control group, it is likely that they did not feel as interested in it. About 95% of cyclists and 75% of non-cyclists agreed to partake in the research. The response rates show that non-cyclists were not as interested in the research as cyclists. As a result, they had a higher probability of turning down the survey.

After riding the trains and collecting data, I ran *t*-tests to determine how the four populations (Caltrain cyclists, Caltrain non-cyclists, BART cyclists, and BART non-cyclists) differ. I conducted *t*-tests for the means of the variables of interest to determine the relationships between the populations. My null hypothesis was that the means did not differ. After determining whether the relationship between the variables of interest were statistically significant, I was able to return to the summary statistics to examine the absolute differences between the means.

The following analyses of interviews and tables present a cross-sectional dataset that I created to identify characteristics unique to cyclists on Caltrain and BART. The dataset contains over 300 surveys of cyclists (about 150 from each train system) and over 300 non-cyclists (again, about 150 from each train system). All of the fieldwork, including surveys and interviews, was conducted during the spring and summer of 2010. The first surveys were distributed in June and the last surveys were collected

during August. All of the surveys were distributed to train riders during weekday morning commute hours. The first interviews were conducted in May and the final ones took place during July. The dataset is divided into three major topics: Demographic Characteristics, Commute Facts (e.g. distance traveled and duration of trip), and Commuters’ Perceptions (e.g feelings and attitudes about commute).

**II. Commuter Mode Choices**

The non-cyclist population is composed of three sub-categories: walkers, public transportation users (PT) and drivers. The following tables, based on the surveys, outline the composition of non-cyclists’ modal choices.

Table 1: Board Mode

	Walk	PT	Drive
Caltrain	29.5%	22.8%	47.7%
BART	32.2%	19.2%	48.6%
Average	30.9%	21.0%	48.1%

Table 2: Arrival Mode

	Walk	PT	Drive
Caltrain	47.7%	38.3%	14.1%
BART	78.9%	15.6%	5.4%
Average	63.3%	27.0%	9.8%

There are two tables because people have to travel to the train station from their place of origin and from the train station to their final destination. For example, a hypothetical commuter could take a bus from her house to the Caltrain train station, ride the train, and then walk from the train to her office. For the remainder of the analysis I treat each side of the commute as if it were independent of the other side. Thus, a person who drives to a train station may use any form of transportation beyond that point in order to get from the train station to work.

Each sub-category is composed of multiple small groups. The “walking” population included people who walked, skateboarded, and scootered. The “public transportation” population includes

people who used buses, private shuttles, Muni trains, and either BART or Caltrain to travel to the train. For example, it is possible that I surveyed a Caltrain rider who used BART to get to Caltrain. This person's board mode was coded as public transportation. All commuters who use public transportation also have to walk for part of their journey. I assume that all people who ride a bus to a train station had to walk to the bus stop or train station. Even though public transportation riders walked for a portion of their trip, the trips are only coded as public transportation users because it was their primary mode of locomotion. Lastly, the "drivers" sub-population consists of people who drove themselves, carpooled or used a cab. The "drivers" category was created to capture information about people who use a private automobile.

From these summary statistics one deduces that a large percent of the population drives to the train station and a very small percent drive from the train station to their destination. Both BART and Caltrain provide parking spaces at most of their stations. This allows many people to drive to the stations and leave their cars there. Parking at most stations costs between one and three dollars per day. There are relatively few people who drive from the train station to their final destination. Most of these commuters in this sample are using cabs, but a few have a car waiting for them at their egress station. The dataset that I collected takes into account only the morning commutes, excluding potential patterns that may have been observed during alternate commute times. All of the surveys were conducted during morning commutes when most people are going to work. It is possible that commuters own a car and leave it at their egress station; however this is rare.

It is much more likely that a given commuter walks from his / her egress station than walks to the ingress station. Since a majority of commuters work in San Francisco and other edge cities, they tend to be traveling into dense areas. These dense areas provide enough demand to support many train stations in close proximity (O'Sullivan, 2007). Consequently, people do not have to travel as far from the train station to their destinations, and therefore most people are easily able to walk from the train station to their workplace. This assertion is supported by the data. The median egress distance for non-

cyclists is only one mile, whereas for ingress, it is two miles. Logically, since downtown San Francisco employment is much denser than the majority of the suburban housing, it is often quicker for train riders to walk from the train station to work rather than from their houses to the train station.

### III. Demographic Characteristics

For most variables in the Demographic Characteristics category, the differences between cyclists and non-cyclists are small, showing that these parameters do not have a significant impact in determining the probability that a given commuter is a cyclist. The data in Table 3 show the demographic variables of interest for both cyclists and non-cyclists on Caltrain and BART. These characteristics are not easy for any one individual to change, and they vary widely between individuals. Therefore, these variables may indicate that a certain characteristic has a strong correlation with choosing to cycle.

Table 3: Summary Statistics of Demographic Characteristics

	Caltrain Cyclists	BART Cyclists	Caltrain Non-cyclists	BART Non-cyclists
Gender (% Male)	78%	69%	43%	45%
Age (Years)	36.1	32.4	33.4	35.3
Education-Some HS	2%	3%	1%	3%
Education-HS Grad	1%	5%	6%	6%
Education-Some College	11%	16%	26%	18%
Education-College Grad	39%	42%	42%	48%
Education-Grad School	47%	35%	25%	25%
Valid License	97%	89%	88%	90%
Car Available for this Trip	73%	45%	64%	67%
Annual Income (\$)	89,304	47,248	78,503	72,380
Own Bike	100%	100%	49%	61%

One of the most significant findings from the surveys is that the cycling community is dominated by males. On any given Caltrain, 78% of the cyclists are males. This is drastically different than the percentage of non-cyclist riders: only 43% of non-cyclists on Caltrain are males. The difference between the two means is statistically significant at the .01 level. The story between BART cyclists and non-cyclists is similar. Again, the difference between the two means is significant at the .01 level. The

Gender composition difference between cyclists on both systems is only significant at the .05 level and the difference between non-cyclists is not statistically significant. In other words, there is no significant difference between the Gender compositions between the two train systems; BART non-cyclists are just as likely as Caltrain non-cyclists to be male. The Gender composition of non-cyclists for the two systems is also similar. Despite the fact that a comparable number of males and females are commuting via Caltrain and BART, cyclists who use the trains are primarily male, indicating that this parameter may be able to explain part of the difference between cyclists and non-cyclists.

Age may not play a significant role in people's decisions to commute on a bike. One would imagine that a strong correlation exists between age and athleticism (Schuit, 1999). Since younger people tend to be more athletic than older people, it would seem that younger populations would be more likely to bike to a train station. Surprisingly, the survey results, displayed above in Table 3, disagree with this hypothesis. The Age difference between cyclists and non-cyclists is substantial within each train system, but the directions of the differences are inconsistent across the systems. The cyclists who use Caltrain are, on average, roughly three years older than Caltrain non-cyclists. In contrast, cyclists who use BART are about two years younger than BART non-cyclists. This inconsistency illustrates that Age may not factor into Bay Area commuters' decisions to ride a bike. Because the differences in Age are conflicting across the two systems, it is unlikely that this variable is significant in differentiating cyclists from non-cyclists.

The education distribution for the four populations (see Table 3) shows that cyclists are more likely to have attended graduate school than non-cyclists. Additionally, the sum of college graduates and graduate school attendees is also higher for cyclists than non-cyclists. However, this trend is inconsistent. The educational breakdown for Caltrain riders is more extreme than BART riders. While Caltrain cyclists are the most educated group, Caltrain non-cyclists have the lowest probability of graduating from college or attending graduate school. The educational distribution is more homogenous for BART riders

than for Caltrain riders. Even though more cyclists attended graduate school than non-cyclists, there is not a consistent trend showing that cyclists have achieved higher levels of education.

Though income between cyclists and non-cyclists is drastically different, the direction of difference is opposite for the two systems. On Caltrain, cyclists have significantly higher incomes (at the .05 level). There is more than a \$10,000 difference between mean incomes. Some of this difference can be explained by Age and by Gender. Being male is often positively correlated with higher income (Korpi, 2006). Additionally, age and income have a positive relationship. Thus, it is likely that some of the differences between mean incomes can be explained by the correlation between Income, Age and Gender. Even after accounting for variation in groups, the difference is still statistically significant. The data tell a conflicting story for BART. On BART there is over a \$25,000 difference in annual incomes between cyclists and non-cyclists. However, in this case, cyclists earn a substantial amount less than non-cyclists (this is significant at the .01 level). The same line of reasoning pertains to the correlation between Income and Age. Non-cyclists on BART are older and have higher incomes than cyclists. Even after controlling for the correlation between the two, Income remains a significant variable. The Income variable is not consistent across train systems, but it is still of interest because there are such large differences in Income between cyclists and non-cyclists.

It is likely that cyclists who use Caltrain and BART have dissimilar socio-economic standings because of the income disparity. If the cyclists actually have different social standings, it is logical that they also have different needs. Perhaps cyclists on BART have a different reason for riding the trains than cyclists on Caltrain. This may lead to the conclusion that many BART cyclists may have to ride the train because they do not have any other mode of transportation.

The vast majority of train riders have a driver's license, regardless of whether they are cyclists. 97% of cyclists on Caltrain have a valid driver's license. Of the other populations, roughly 90% of commuters have a license. Moreover, the difference between the means of BART cyclists, Caltrain non-

cyclists, and BART non-cyclists is not significant. These data show that obtaining a license is not a larger problem for cyclists than non-cyclists. Therefore, this variable is not a sufficiently explanatory parameter since it does not differentiate cyclists from non-cyclists.

The data collected in the variable Car Available for this Trip provide additional support for the idea that cyclists on Caltrain and BART are motivated by different factors. BART cyclists do not have the same access to cars as Caltrain cyclists. It is likely that a portion of each cyclist population has made a conscious decision not to purchase a car. Similarly, it is safe to assume that a portion of the cyclist population would like to have access to a car but does not. It is very unlikely that all cyclists want to bike. Some may be forced into cycling because they cannot afford to own a car. It is possible that more BART cyclists are forced into riding a bike, rather than driving a car due to exogenous factors such as income.

The Demographic Characteristics category contains few variables that consistently differ between cyclists and non-cyclists. Gender was the only parameter to emerge that differed between cyclists and non-cyclists regardless of train system. The only other variable of significance in this section was Income. Even though the Income variable was not consistent across train systems, the magnitude of the difference between cyclists and non-cyclists cannot be ignored. Therefore, the Demographic Characteristics section is only able to indicate the significance of two variables.

#### **IV. Commute Facts**

The variables in the Commute Facts section do not adequately explain the difference between cyclists and non-cyclists. The only possibly influential parameters are the Distance and Duration of commuters' trips. However, these variables are highly correlated. Table 4 presents the data that pertain to people's Commute Facts. These variables are grouped together because they illustrate the different aspects of the average rider's commute. They are largely based on where the commuter lives and where he/she is traveling to. It is not easy for commuters to change these variables.

Table 4: Summary Statistics of Commuters' Facts

	Caltrain Cyclists	BART Cyclists	Caltrain Non-cyclists	BART Non-cyclists
Purpose (% Work)	96%	84%	87%	86%
Works on the Train (% Yes)	44%	15%	43%	24%
Incentive (% Yes)	48%	28%	38%	42%
Board Distance (Miles)	3.60	2.64	3.77	5.22
Board Time (Minutes)	13.70	12.37	19.12	19.83
Arrival Distance (Miles)	2.27	2.41	3.60	1.96
Arrival Time (Minutes)	13.92	12.12	18.45	12.66
Duration of Trip (Minutes)	64.85	49.49	77.59	58.57
Drive Duration (Minutes)	46.07	35.02	48.94	44.37

In this study, the purpose of one's commute likely has little influence over a commuter's decision to use a bike. By intentionally sampling people during commute hours, I am able to minimize the number of people who are not traveling to/from work. Commuters indicated their purpose for commuting by filling in an open ended question. Students and people traveling to work were placed in the same category and were assigned the value one. Thus, the percentages above show the proportions of patrons that were either going to work or to school. The remaining people were traveling for an alternative purpose. Of the four groups, Caltrain cyclists have the highest percentage of people traveling to work (96%). Roughly 85% of the other populations are traveling to work. There is no clear line between cyclists and non-cyclists or BART and Caltrain users.

The results for whether commuters work while they ride the train show that the largest difference is between Caltrain riders and BART riders, not between cyclists and non-cyclists. Caltrain riders are much more likely to work while on the train than BART riders. This result can be attributed to the design of the trains. Caltrain is much quieter, smoother, and more comfortable than BART, which also tends to be much more crowded during hours of commute. During morning commutes, all Caltrain riders are able to find a seat. However, on BART roughly half of the passengers may be forced into standing because there is not enough space for everyone to sit. As a result, the environment within a Caltrain car is much more conducive to working in than that of a BART car.

Some of the Caltrain cyclists I interviewed take advantage of the train's environment by working while traveling. Peter, an Adobe employee, is never "on the clock," instead he just has assignments that he must complete. Using Caltrain saves Peter time by letting him work while commuting, thereby allowing him to leave work early. Kurt's work does not provide any direct incentive to commute via bike and public transport. However, Kurt, like Peter, is not required to check in at his work place. He is given tasks rather than a time requirement. This provides him with flexibility and an incentive to work efficiently. Kurt is able to reduce the amount of time he spends in the office because he is able to work on Caltrain. By using rail transit to commute, he can work on his laptop, and complete about an hour's worth of work during his commute.

The data on whether a commuter receives some sort of monetary incentive from his or her place of work are relatively scattered. The only statistically significant difference is between Caltrain cyclists and BART cyclists. Caltrain cyclists have the highest probability of receiving a subsidy from their work. On the other hand, BART cyclists have the lowest probability of receiving aid. This result mimics the findings from the analysis of the Income variable. To reiterate, Caltrain cyclists have the highest incomes whereas BART cyclist have the lowest incomes. It is likely that high salary jobs may also provide additional work benefits. Typically these benefits come in the form of healthcare, dental care, or paid vacation. It appears that there is also a positive correlation between funds for traveling by train and high-paying jobs. Thus, income and receiving incentives for riding the train might be collinear.

Some highly paid individuals' workplaces provide either indirect or direct incentives to commute via Caltrain and bike. Allen, a Caltrain cyclist, began using public transportation to commute to work because the cost of owning a car became too great. Once Allen's job stopped paying for his parking, he found it too expensive to park in the city. Unlike Allen's workplace, Adobe provides Peter and the rest of its employees with free parking. The employer does not create a disincentive to drive to work; instead it provides Peter with free Caltrain tickets. Because he does not drive to work, he is able to avoid putting

extra “wear and tear” on his car, and as a result, he saves money. Cyclists on BART echoed the sentiments of many Caltrain cyclists. John, a BART cyclist, bikes because his work does not provide him with parking. He figures that he can save a lot of money by cycling. For all three of these cyclists, their places of employment provide some sort of incentive to leave their cars behind.

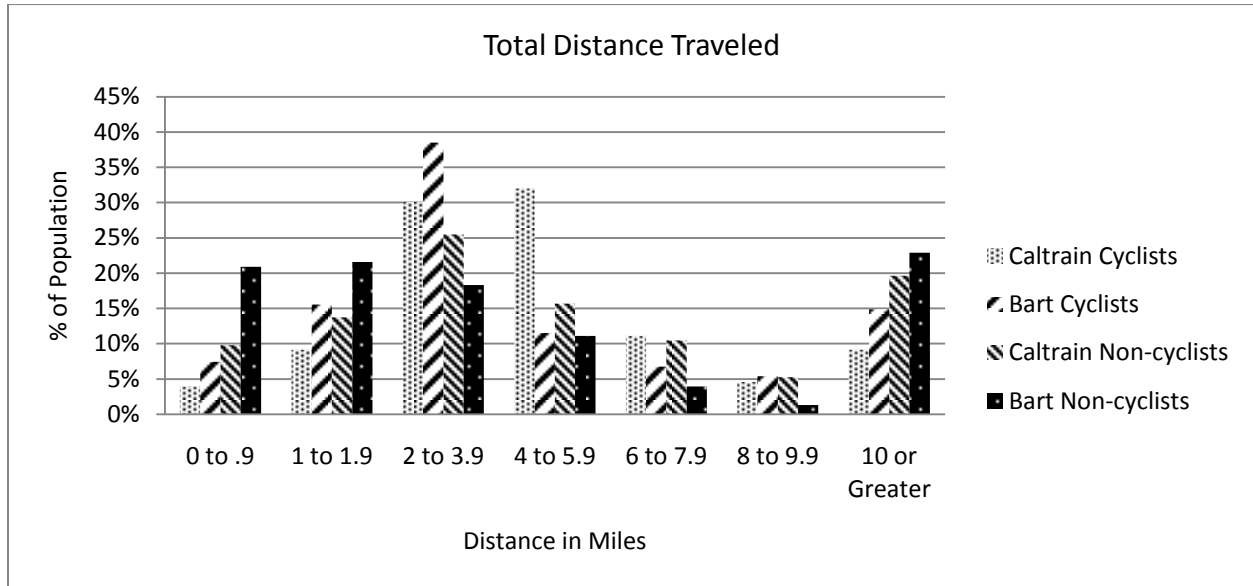
In all four populations, commuters report that it would be faster for them to drive to their destination rather than take the train. The difference between the duration of the trip and drive duration range between 14 minutes and 29 minutes. BART cyclists appear to travel for the least amount of time, whether they use the train or drive. On the other hand, Caltrain non-cyclists have the longest commutes, whether they drive or take the train. In all scenarios, the average train ride is longer than the average drive.

However, most cyclists believe that integrating cycling with Caltrain saves time. Kurt, like most cyclists, values his time highly and believes that taking the train is much faster than driving to work. When asked about his motivations to cycle, he simply replied, “I live too far away from work to drive.” With his combination of bike and train, it takes Kurt about an hour to travel to his workplace from his home. When I asked him if taking a car is faster, he replied that without traffic it would take him about half an hour. Later on in the conversation, I asked him how long it would take him to drive to work with traffic. He figured it would take a little under an hour. It is actually faster for him to drive to work, yet he believes that cycling and taking the train will save him time in the long run. By using his bike and the train, Kurt is able to exercise and work during his daily commute, thereby reducing the time he would otherwise dedicate to work and exercise. When it comes to measuring the total time spent commuting, the fact remains that for both the average cyclist and non-cyclist, driving would be faster than taking the train.

In comparing the distance and time traveled, the different subcategories of non-cyclists should not be lumped together. It is deceptive to average the distance and time that a person takes to walk to a

train station with the distance and time that another commuter drives. To see how cyclists compare to non-cyclists, the distance that people travel needs to be explored to account for large variances in the non-cyclists category. The following graph displays the distributions of distances that commuters travel in all four groups.

Graph 2



The above graph shows how the distributions of total distance traveled outside of the train vary by population. The distributions of the cyclist populations are clustered around traveling between two and six miles, whereas the distributions of the non-cyclists are much more dispersed. A similar pattern emerges for the total time that commuters travel.

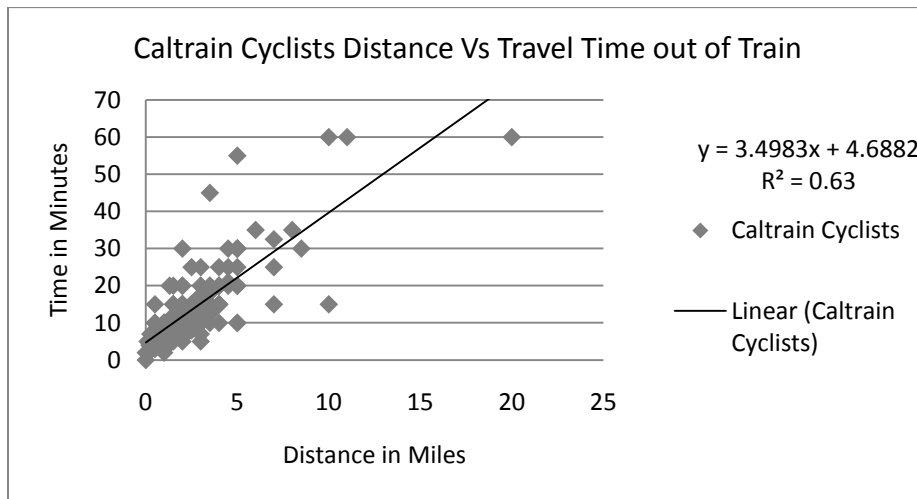
Time vs. Distance

Depending on modal choice, the time it takes to travel a given distance can vary widely from day to day. To understand the average times and distances presented in Table 4, the data need to be further divided and analyzed as shown in Graph 2. I find that for people who choose to bike or walk to their destination, there is a high correlation between the duration and length of the trip. By contrast, for travelers who commute via public transportation or car, there is a much weaker relationship. The

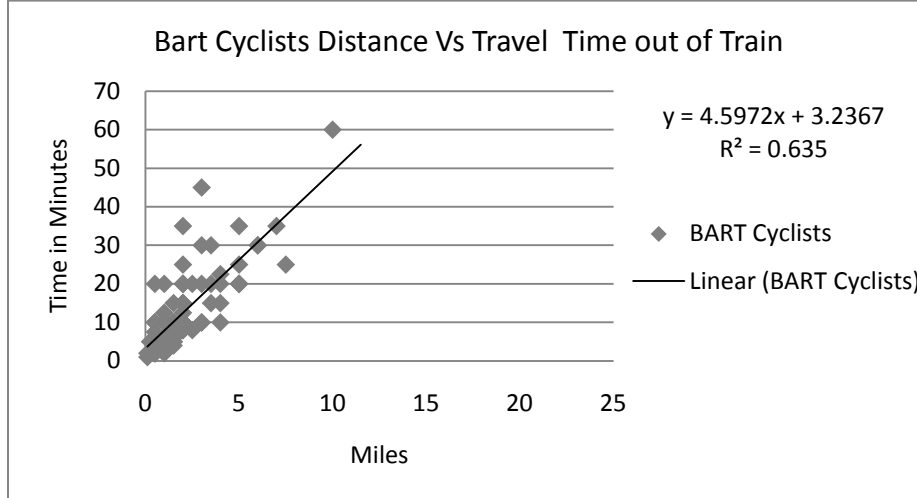
following regressions show the correlation between the distances that commuters travel outside of the train systems and the amount of time it take them to travel that distance. All four of the following graphs depict the relationship between time and distance for different types of commuters.

As with all of the other data, the following data represented in the graphs below were self-reported by the subjects. As a result, the dataset contains some responses that may not be realistic. Additionally, the data were filtered for responses that were not plausible (these responses were omitted). Over 95% of the data collected are represented in the following regressions. These graphs plot the total distance traveled (excluding the miles covered while on the train) against the amount of time it takes (excluding the time on the train).

Graph 3



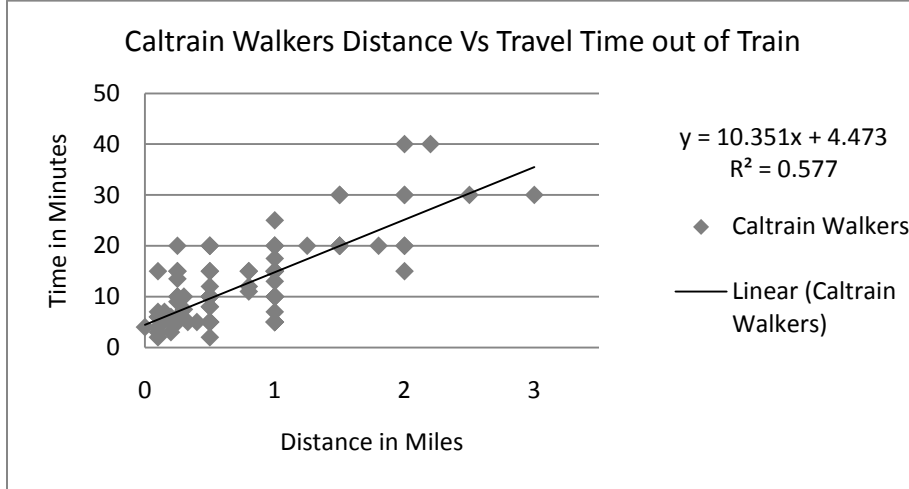
Graph 4



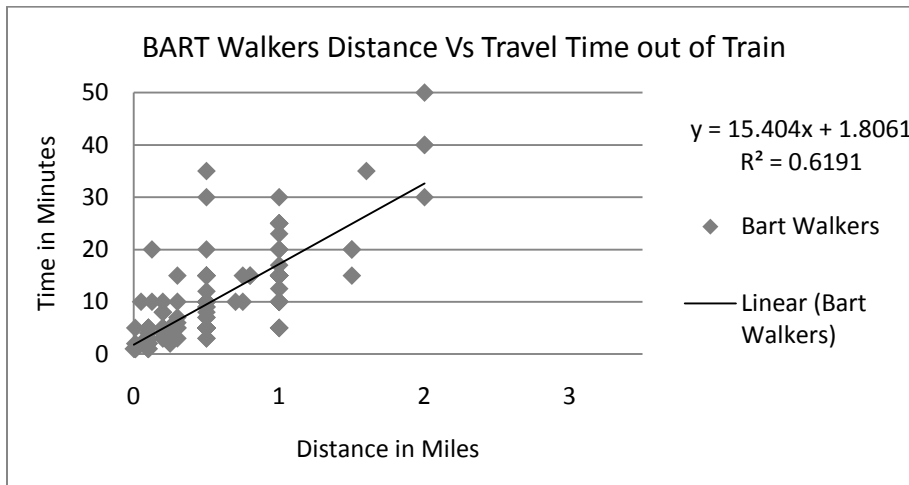
The data represented in both graphs are very similar. The linear regressions show that there is a strong correlation between number of miles and amount of time traveled. In both graphs, the linear regressions and  $R^2$  values are very similar. This fact is notable because the train systems operate in different areas, but the  $R^2$  and linear regressions of Distance against Time are similar.

To put Graphs 3 and 4 in perspective, one needs to compare them to travel times and distances of other modes of transportation. The following graphs (Graphs 5 – 10) show comparable regressions for alternative modes of transportation. The following graphs also differ in an additional way. In the above regressions, cyclists bike on both sides of their train commute; however, most people who use other modes of transportation will not use the same method of transportation on both sides of the journey. For example a person may drive his/her car to the train station, ride the train, and then walk from the train to the final destination. Since only 25.5% of non-cyclists on Caltrain and only 29.4% of non-cyclists on BART use the same mode of transportation on both sides of the trip, the following graphs do not combine both sides of the commute. Rather, each side of the journey is treated independently.

Graph 5

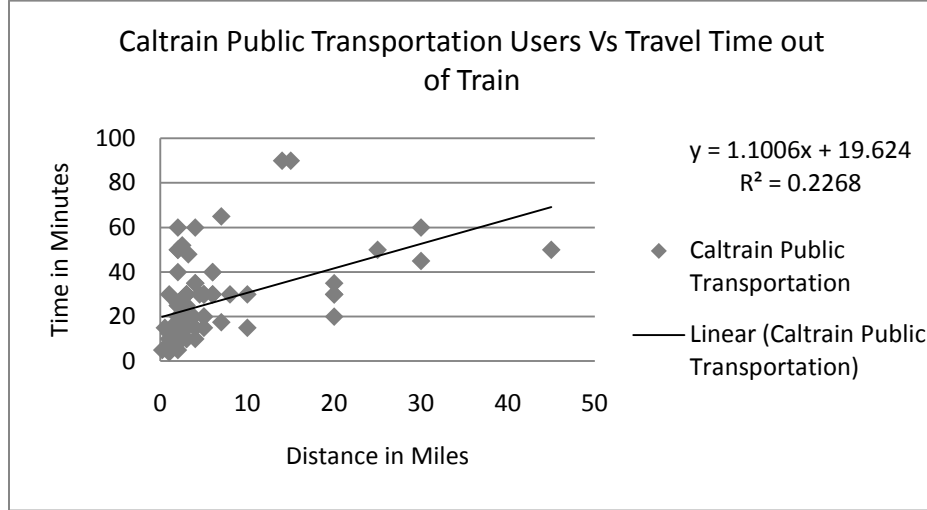


Graph 6

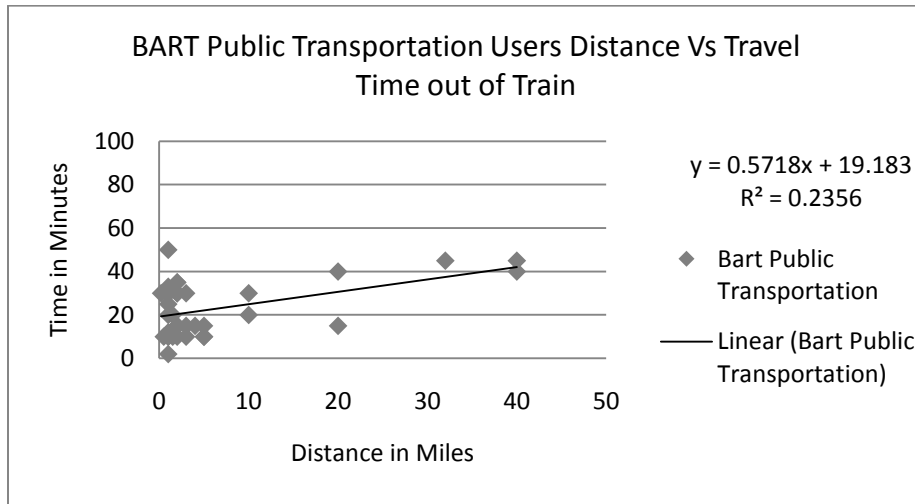


Graphs 5 and 6 compare the distance walked by Caltrain and BART riders to the amount of time it takes them to walk that distance. The  $R^2$  values generated in both Graphs 5 and 6 are very similar to one another and to those of Graphs 3 and 4.

Graph 7



Graph 8

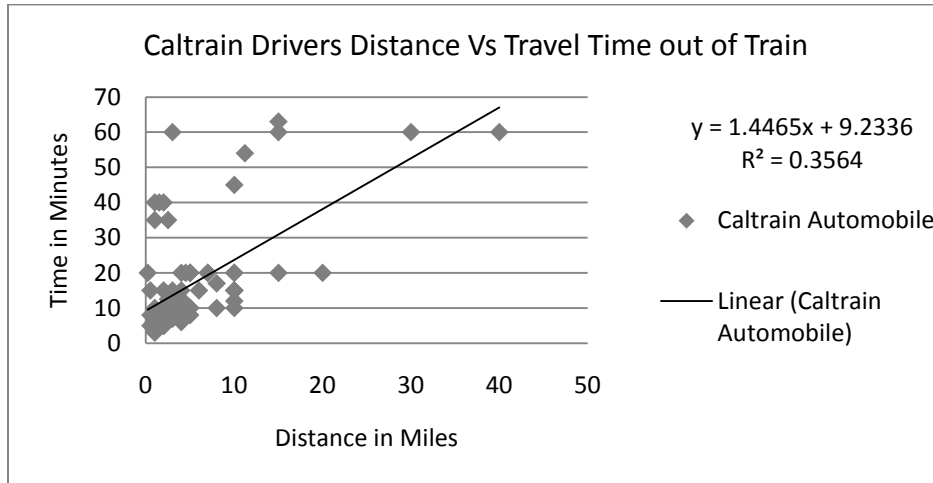


Graphs 7 and 8 compare the distance traveled by Caltrain and BART riders on public transportation to the amount of time it takes them to travel that distance. The  $R^2$  values are not very similar to those of the regressions in Graphs 3 and 4.

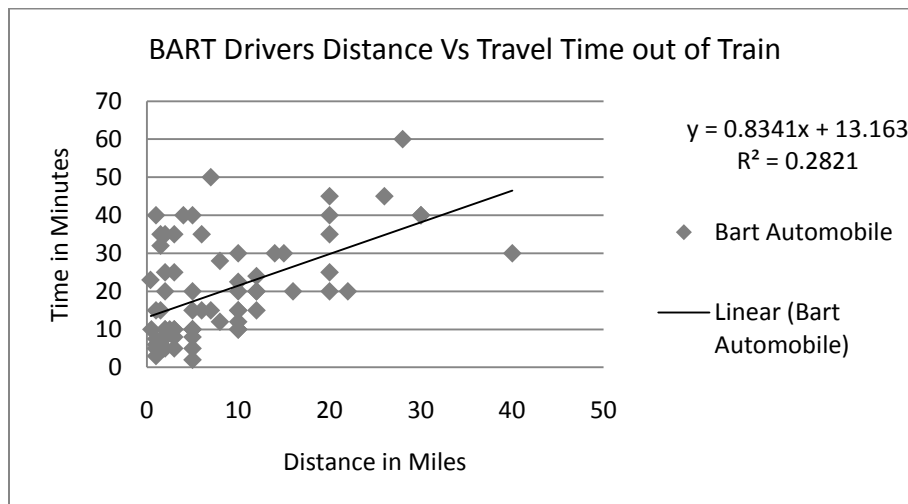
Unlike the regressions for cyclists and walkers, the linear regression for public transportation users is not as accurate. The regression does not explain the data as well. This could mean that there are more variables when traveling via public transportation in comparison to walking or cycling. For both train systems, the regressions are remarkably similar. This shows that the expected time to travel a

given distance is independent of which train system is chosen. Moreover, the  $R^2$  values are similar, showing that the data fits the trend to the same extent in both cases.

Graph 9



Graph 10



Graphs 9 and 10 compare the distance driven by Caltrain and BART riders to the amount of time it takes them to drive that distance. Again, the  $R^2$  values are not very similar to those of the regressions in Graphs 3 and 4.

Surprisingly, the regressions for traveling to and from train stations for automobile users differ between train systems. The correlation between time and distance is stronger for Caltrain motorists than for BART motorists. The difference in regressions can also be seen in the Y-intercept and slope of the linear regressions. The graph for BART travelers has a smaller constant (Y-intercept) and a steeper slope. This difference can be partially explained by the difference in average speeds for drivers.

The regressions above do not fully explain what variables contribute to the length of a journey. There are obviously more independent variables that contribute to the length of a trip. These variables may include the amount of traffic on a given day and average speed. The average speeds of cyclists and non-cyclists for Caltrain and BART are shown below.

Table 5: Average Travel Speeds Outside of Trains (mph)

	Cyclists	Walkers	PT Users	Drivers
Caltrain	11.2	3.7	14.7	23.4
Bart	10.0	3.4	17.6	25.4

Some of the differences between the average speeds for cyclists, walkers, public transportation users and drivers, can be explained by the environment that they travel in. The types of terrain differ between the two groups and the amount of traffic differs by region. Since BART and Caltrain do not operate in exactly the same region, it is logical that the environments surrounding their station can be quite different. This can help explain the difference in average speeds for the four categories.

Table 6: Median Travel Speeds outside of Trains (mph)

	Cyclists	Walkers	PT Users	Drivers
Caltrain	10.8	3.2	10.0	20.0
Bart	10.0	3.0	12.0	24.0

The median travel speed for all groups is lower than the averages, showing that the data are skewed right. The average is susceptible to outliers whereas the median is not. Therefore, outliers on the high side pull the average speeds up. The category that was most susceptible to outliers was public transportation. The percentage change between the mean and median is nearly 50% for both Caltrain

and BART users. This shows that there is a wide range of public transportation options and variables that affect travel speeds.

Table 7: R<sup>2</sup> Values for the above Regressions

	Cyclists	Walkers	PT Users	Drivers
Caltrain	0.63	0.58	0.23	0.36
Bart	0.64	0.62	0.24	0.28

The R<sup>2</sup> values, presented above, show the degree of correlation between the duration of a commute and the distance traveled. For both systems, cyclists and walkers demonstrate the strongest correlation between time and distance traveled. On the other hand, the correlation between time and distance traveled is the weakest for public transportation users. Automobile drivers fit in between walker/cyclists and public transportation users. The automobile category also has the largest discrepancy between Caltrain and BART.

Some of the discrepancies between Caltrain and BART users' R<sup>2</sup> values, especially for drivers, may be explained by the variety of roads and terrains that drivers encounter. BART has 104 miles of track, whereas Caltrain has 77 miles of track. Since the BART train system is larger than Caltrain and covers a larger geographic region with wider ranges of population densities, it is likely that part of the weaker correlation can be attributed to the number of explanatory variables. The terrain and types of roads that Caltrain riders encounter are more homogeneous than the ones BART commuters experience, because the entire length of Caltrain's track is on San Francisco Bay Peninsula. This is just one of many variables that can help explain some of the differences in the R<sup>2</sup> values.

The R<sup>2</sup> values for cyclists and walkers are much higher than those of public transportation users and drivers, showing that cyclists and walkers have more consistent commutes. For walkers and cyclists, the majority of their trip can be explained by the distance traveled. However, parameters other than Distance have a large effect on commutes made by drivers or public transportation users. Public transportation users' and drivers' trip durations are highly dependent on other variables, such as traffic.

Traffic is also dependent upon speed limits, number of intersections, day of the week and so forth. Because there are so many variables to consider when predicting the amount of traffic, it is very difficult for most commuters to calculate the duration of their commute. This shows that public transportation users and drivers have a larger variance for any given commute. Cyclists' and walkers' commute times are better explained by the distance traveled, reducing the overall variance of commute duration.

Since there is such a high correlation between the Duration and Distance of a given commute, only one variable can be used as a possible explanation. For the remainder of this paper, I treat the total Distance covered outside of the train as a variable that also accounts for the duration of the trip. The only plausible explanatory variable to emerge from the Commute Facts section is the total Distance traveled outside of the train.

## **V. Commuters' Perceptions**

In the two previous sections, Demographic Characteristics and Commute Facts, the data show that there are relatively few observable differences between cyclists and non-cyclists. The only variables to emerge as interesting are Gender, Income, and Distance. These parameters do not tell a very compelling story because they are not able to differentiate a cyclist from a non-cyclist by themselves. Just because a person is male and lives close to a train station does not necessarily mean that he is also a cyclist. Therefore, other variables need to be included to determine which factors motivate and differentiate cyclists from other commuters.

The variables in the Commuters' Perceptions section are better explanatory variables than those in the previous section because there are more significant differences between cyclists and non-cyclists in this category. The table below displays the averages of data on commuters' perceptions of their commute. The data were collected in Likert scale form and averaged to generate the values. The table indicates that there are large differences between cyclists and non-cyclists across many parameters, notably Stress and Satisfaction. The Stress variable indicates the amount of stress riders experience

while on the train, and the Satisfied variable accounts for riders’ level of satisfaction with their train system. The table is broken up into two sub-categories to show that questions only apply to non-cyclists and to differentiate between rationale and feelings.

Table 8: Summary Statistics of Commuters’ Perceptions

	Caltrain Cyclists	BART Cyclists	Caltrain Non-cyclists	BART Non-cyclists
Easy to Cycle	1.86	2.32	3.72	3.74
<b>Motivational Factors to Take the Train (and Ride a Bike)</b>				
1 = not very influential, 5 = very influential				
Money	2.90	3.08	3.17	3.27
Environment	4.07	3.96	3.50	3.61
Traffic	4.29	3.92	4.23	4.37
Pleasure	3.90	3.98	2.92	2.88
Time	2.43	3.07	2.59	3.38
Convenience	3.33	3.78	3.59	4.09
Comfort	3.12	3.09	3.29	3.35
Dislike of the Car	3.11	3.17	2.59	2.30
<b>Feelings about Commute</b>				
1 = not very, 5 = very				
Satisfied	3.75	3.49	4.13	4.11
Stressed	2.17	2.64	1.88	2.13

While cyclists find that riding a bike to and from train stations is easy, non-cyclists believe that it would be difficult. The reasoning behind the differences lies in perception. The variable Easy to Cycle is possibly the most significant variable, as it pertains to people’s perceptions of commuting with a bicycle. All commuters were asked to gauge the difficulty of traveling with a bike. The participants rated their feelings on a one to five scale. A one represents the belief that it is easy to integrate cycling into their commute, whereas a five represents the belief that it is very difficult to make cycling a part of the daily commute. Cyclists on Caltrain find traveling with bikes to be easy, whereas cyclists who use BART do not find it quite as easy. On average, both Caltrain and BART non-cyclists believe that introducing a bike into their commute would be slightly difficult. There appears to be a significant difference in actual difficulty and perceived difficulty of using a bike on both train systems.

### Motivational Factors to take the Train

To understand how the mindsets of cyclists and non-cyclists differ, we can compare their motivations to take the train. Table 8 above shows which factors motivate people to choose their transportation option, whether it is solely the train or whether it is the train and a bike. All participants were prompted to rate the factors listed in Table 8 on a one to five scale. A score of one represents a factor that is not very influential, whereas a score of five means that the factor is highly influential. The variables Health and Exercise are only applicable to cyclists because most non-cyclists do not exert a substantial amount of physical energy (i.e. they use other forms of public transportation or drive on the other legs of their commutes).

Even though BART cyclists have lower incomes than non-cyclists, it is non-cyclists who report being motivated by money to ride the train. One would expect BART cyclists to be most strongly motivated by money because this group's average income is substantially less than the other groups (see Table 3). However, non-cyclists, who have over a 33% higher income compared to BART cyclists, are more strongly motivated by monetary factors. It is interesting that this variable does not follow the pattern of the annual Income variable. Since the Money variable is not constant with the findings from the income analysis, it is likely that it is not a strong explanatory variable.

The environmental benefits of commuting via train are more important to cyclists than to non-cyclists, showing a clear divide between the two groups. Table 8 clearly shows the role environmental concerns have in motivating cyclists. In an interview, Daniel, a 41 year old male urban designer, mentioned environmental factors as an incentive for cycling. Daniel is motivated to continue to travel via Caltrain and bike because he feels "it is the right thing to do." Daniel, like many other professionals in the Bay Area, is very concerned about the environment; therefore he uses a combination of cycling and riding public transportation to minimize his carbon footprint. Daniel is very concerned about living sustainably and designing sustainable ways of life.

All groups are motivated by Traffic to ride the train, indicating that this variable is not a sufficient explanatory agent. O'Sullivan (2007) shows that most people are very impatient and do not want to spend any portion of their commute time motionless. On average, commuters would rather travel at a constant rate than travel at the same average speed but have a portion of the time spent motionless (O'Sullivan, 2007). This psychological finding sheds light on the notion that cyclists are more averse to waiting. A cyclist will not have to wait in traffic as much as a person who decides to commute by public transit or car to the train station. However, a person who commutes by car or public transportation will often achieve a higher average speed, even after accounting for lost time due to traffic.

For both the Convenience and Time variables shown in Table 8, there is only intra-train system variation. On both Caltrain and BART the non-cyclists place more emphasis on the Convenience variable than the respective cyclist population. Non-cyclists may have a lower tolerance for inconvenience. Convenience may be less important to cyclists because cycling is not often perceived as "convenient." Since the Easy to Cycle variable already supports this claim, the Convenience variable does not add any information. Cycling is more physically taxing than either driving or using public transportation. It logically follows that people who do not like to exert large amounts of energy to commute would be more sensitive to the Convenience element. Additionally, cyclists, for their respective systems, are not as motivated by time as non-cyclists. This shows that cyclists are less sensitive to the total duration of the trip, but this only holds true for intra-train system comparisons. Therefore, there is not a clear distinction between cyclists and non-cyclists in aggregate.

The Pleasure and Comfort variables differ greatly between cyclists and non-cyclists, showing that they are relevant in explaining the difference between the two groups. There is a clear distinction between cyclists' and non-cyclists' perceptions of their commutes. Cyclists derive greater amounts of pleasure from their morning commutes than non-cyclists, probably because they are able to exercise as

part of their commute. However, these data do not distinguish whether cyclists derive pleasure from riding their bikes or from riding the train. For non-cyclists the data only pertain to riding the train, so this number can be used as a baseline for comparison, assuming that cyclists are not inherently more pleased than non-cyclists. This leads me to believe that the differential between cyclist and non-cyclist pleasure derivation is due to the enjoyment of cycling. A similar logical argument can be applied to the Comfort variable. Cyclists report being less comfortable than non-cyclists, which seemingly contradicts the findings from the Pleasure variable. If the non-cyclists represent the baseline case, then the discomfort that cyclists incur must be attributed to their bikes. My data do not show when the cyclists are experiencing higher levels of discomfort because the survey question did not differentiate between discomfort while cycling and discomfort while using the train. The following chapter will further dissect this issue by analyzing when the cyclists are uncomfortable. The clean divide across train systems for both the Pleasure and Comfort variables implies that these perceptions are significantly different for cyclists.

Many cyclists dislike traveling by automobile because they find it inconvenient, creating a distinct divide between cyclists and non-cyclists. The difference in means is significant between the cyclists and non-cyclists populations, showing that cyclists have a stronger distaste than non-cyclists for the personal automobile. These results are echoed in cyclists' perceptions of the automobile recorded in the surveys. Kurt, a Caltrain cyclist, gets very frustrated when he drives because of all of the traffic and the stress of finding parking. Peter, also a Caltrain cyclist, hates searching for parking, and finds that riding his bike eliminates that problem. For commuting around the city, the bike gives Peter more flexibility than the car.

### Feelings about Commute

The second section of Table 8, titled "Feelings about Commute," explores the differences between commuters' feelings about the train services, and shows how these feelings differ between

cyclists and non-cyclists. Commuters were asked how satisfied they are with the train system and how stressful is it to ride the train. Again, a rating of a five indicates that the rider feels either very satisfied or stressed. The *t*-tests were conducted to determine whether the values collected in the surveys differ amongst the four populations.

Cyclists who use either Caltrain or BART are less satisfied with their respective train system in comparison to non-cyclists. The mean values of the Likert scales illustrate the differences in satisfaction between cyclists and non-cyclists. These means are statistically different at the .01 level. The lack of satisfaction can be attributed to a large number of factors. One of the possible explanations for these statistics is the design of the train systems. Cyclists may struggle with the design of the trains and stations because both BART and Caltrain were designed with the pedestrian in mind. Cyclists often have to carry their bikes up and down stairs and risk not being able to board the trains because of inadequate bike facilities. These types of struggles and worries are likely to induce lower levels of satisfaction. The Satisfaction variable captures a compelling correlation between perceptions and cyclists.

On both Caltrain and BART, cyclists find commuting on the train to be more stressful than non-cyclists, indicating that this may also be a significant variable. It is likely that cyclists experience higher levels of stress while riding the train because they have to worry about their bikes. In the small window of time in which patrons get on and off the train, cyclists have the added difficulty of moving their bikes as well and finding a space for their bikes on a crowded train car. Likely, these factors explain why cyclists find riding the train to be more stressful than their counterparts.

Through this analysis, some variables emerge as statistically significant across the cyclist and non-cyclist categories. In particular, ten variables of interest have emerged: Gender, Income, Stress, Satisfied, Easy to Cycle, Environment, Pleasure, Comfort and Distance. Having discovered that these variables differ between cyclists and non-cyclists, I can model the relationship between these variables and the likelihood that a given commuter is also a cyclist.

## Chapter 3: *Statistical Model and Discussion*

### I. Empirical Framework

My assumption is that commuters choose their mode of transportation to maximize their utility. Demographic Information, Commute Facts, and Commuters' Perceptions serve as the independent variables in determining the probability that a given commuter is also a cyclist. As shown in the previous chapter, most of the distinct difference between cyclists and non-cyclists are within the Commuters' Perceptions category with relatively few variables of interest in the other two categories. In this model, the likelihood that a person cycles is based upon the following independent variables. Let  $V_i$  be the probability that consumer  $i$  chooses to commute with a bike and  $\epsilon_i$  be the error term.

$$\text{logit}(V_i) = \ln(V_i/(1-V_i)) = D_i'\beta + C_i'\gamma + P_i'\tau + \epsilon_i$$

$D$  is commuter  $i$ 's demographic information. This vector is comprised of commuter  $i$ 's gender and annual income. Based on the summary statistics, shown in Table 3, I expect that being male will be significantly correlated with being a cyclist. The Income variable is more complex because the relationship between cyclists and non-cyclists differ depending on the train system. I observed that cyclists earn much less than non-cyclists on BART, but found the opposite to be true for Caltrain. Thus, the Income variable will likely be insignificant for a regression with both train systems, but may be important for regressions that only apply to one system.

$C_i$  captures train riders Commute Facts. The variable  $C_i$  contains the distance traveled during the commute less the distance covered by the train. It is likely that cycling is a valid mode of transportation if participants are traveling to a station that is too far to walk to and too close to drive to. Of course, "too far" is a subjective term that will vary for each person. To control for the distances that all types of commuters travel, I created dummy variables. I use selected intervals (typically two miles) to target certain populations (i.e. walkers, public transportation uses, drivers and cyclists). In creating the

intervals, I assumed that walkers would not be traveling very far and drivers and public transportation users would be commuting larger distances. Thus, these dummy variables will be able to control for the distances that all commuters are traveling. I use the total distance traveled of 0 to 1 miles as the reference group to avoid multicollinearity.

P is commuter *i*'s perceptions, which include seven variables that capture attitudes towards commuting. These variables were shown to differ greatly between cyclists and non-cyclists in the previous chapter. The variables are: Stress, Satisfied, Easy to Cycle, Dislike of Cars, Environment, Pleasure, and Comfort. This category contains most of the variables in the regression because this area had the most distinct variation between cyclists and non-cyclists.

The model above will outline the likelihood that a person who is commuting on Caltrain or BART is also a cyclist. Statistically significant variables will highlight which attributes, demographic characteristics and perceptions play an important role in commuters' decisions to travel with a bike. The outcomes of the regression show a correlation between some of the variables and the probability of being a cyclist.

## **II. Results**

I find most variables to be statistically significant in at least one of the three variants of the regression. However, some of the variables in the empirical framework are necessary for this likelihood model, such as Environment. Six variables are significant in all three regressions, three of which are dummy variables for Distance. The other three are from the Commuters' Perceptions category, implying that commuters' attitudes are the most important variables. The following regressions show how cyclists differ from non-cyclists and the differences between the two systems.

Table 9: Results from Regressions  
Commuter Choice Equation Estimates

Variable	All Trains	Caltrain	BART
gender	1.13988*** (0.372492)	2.184576*** (0.775614)	0.5447988 (0.557368)
income	-0.00494 (0.003090)	0.00747 (0.005740)	-0.0311*** (0.007780)
stress	0.5967381*** (0.204235)	0.4208739 (0.345691)	0.8895938*** (0.333115)
satisfied	-0.757519*** (0.224305)	-1.398406*** (0.489684)	-0.4965416 (0.315190)
easytobike	-1.349816*** (0.163899)	-2.034295*** (0.347379)	-0.9747387*** (0.246488)
dislikecar	0.3043307** (0.130788)	0.1146534 (0.215232)	0.5439867*** (0.202506)
environment	-0.1738296 (0.172636)	0.0495947 (0.306289)	-0.3390789 (0.256934)
pleasure	1.267115*** (0.193536)	2.196526*** (0.450977)	1.234811*** (0.280998)
comfort	-0.567562*** (0.190472)	-0.691508* (0.353797)	-0.5392745** (0.267628)
distance_1~2	1.781431** (0.794998)	1.53636 (1.350365)	1.89143 (1.200068)
distance_2~4	2.375302*** (0.744263)	2.6707548** (1.258625)	3.052936*** (1.167321)
distance_4~6	2.385008*** (0.792985)	2.95922** (1.353839)	2.586956** (1.273604)
distance_6~8	1.537255* (0.868915)	0.6246221 (1.398855)	3.146721** (1.525241)
distance_8~10	3.003331*** (1.006389)	2.7450868* (1.600284)	5.7724*** (1.888608)
distance_10+	0.8617962 (0.788581)	0.3819404 (1.564288)	1.385426 (1.239206)
_cons	0.8064083 (1.566479)	0.6651889 (2.920212)	-0.5638676 (2.406420)
R <sup>2</sup>	0.5807	0.7096	0.6115

\* Significant at the .1 level  
 \*\* Significant at the .05 level  
 \*\*\* Significant at the .01 level

Income is measured in 1,000s of dollars.

Distance i~j represents the total distance that a person travels outside of the train. I~j is a range in miles.

Stress, satisfied, easttobike, dislikecar, environment, pleasure and comfort are measured on a Likert scale (values one through five). A higher value corresponds to a more intense feeling.

The most statistically significant variables in every regression are the perception of how difficult it is to cycle and the pleasure derived from traveling. The Easy to Cycle variable has a negative relationship with the probability of cycling. In absolute terms, cyclists believe that it is easier to bike to and from train stations than non-cyclists. There is a negative relationship between the Likert scale value and the probability of being a cyclist. The Pleasure variable is also significant in all three regressions, showing that cyclists derive more pleasure from their commute in comparison to non-cyclists.

The Comfort variable is also statistically significant in every regression, but not to the same degree as Easy to Cycle or Pleasure. The magnitudes of the coefficients are smaller than those of Easy to Cycle or Pleasure, showing that this variable is not as important.

Only some dummy variables that control for Distance are statistically significant in all three regressions; however all of them are positive. Only Distance 2-4, Distance 4-6 and Distance 8-10 are significant in all three regressions. It is interesting how Distance 6-8 is only significant in two of the regressions. Additionally, every Distance variable is positive, showing that if a commuter will travel (in total) more than one mile to and from train stations, there is an increase in the probability that he/she is a cyclist.

Since distance has a positive relationship with the probability of being a cyclist in every interval, it does not provide much insight into why people cycle. The results indicate that people who travel over a mile to and from stations are more likely to bike than people who travel less than a mile to and from stations. This aspect of the result is consistent with the model because some non-cyclists, primarily walkers, travel short distances. It is logical that a person who travels less than a mile would walk rather than bike. However, the results in Table 9 are not completely consistent with the data observed in Graph 2. Thus, one would expect the Distance variable to become negative at high values. However, this is not the case. Therefore, the Distance variable, albeit statistically significant, does not provide much insight into why some commuters choose to cycle. The regression results show that any distance

between one and eight miles has a positive relationship with the probability of cycling in the All Trains regression.

The Gender variable, although it is significant in two of the regressions, can be explained by the differences in preferences between men and women.

Table 10: Summary Statistics of Preferences by Gender

	Female	Male
Physical Effort	2.99	2.85
Appearance	2.44	2.31
Time/ Distance	3.52	3.48
Stress/ Hassle	3.79**	3.50**
Lack of Safety	3.42***	2.96***
Weather	3.72*	3.46*
Luggage	3.27**	2.87**
Bike Facilities	2.62	2.75
Enjoy other modes	3.20**	2.83**
* Significant at the .1 level		
** Significant at the .05 level		
*** Significant at the .01 level		

In Table 10, women consistently rate the variables as more influential than do men, giving reason for the gender ratio observed in Table 3 and the significance of the variable in two of the regressions in Table 9. All of the values in Table 10 were collected from non-cyclists. The participants were asked to rate the extent to which each variable factored into his/her decision to commute without a bike. A value of five represents “highly influential” whereas a one means “not influential.” Women perceive physical effort, appearance, time/distance, stress/ hassle, danger, weather, and luggage as more troublesome than do men. Only five of the nine variables are statistically significant, but the data show that women would feel more inconvenienced by riding bikes than would men.

The most statistically significant difference between men and women’s reasons for not cycling is the perceived lack of safety. The difference in means is significant at the .01 level and the absolute difference between them is 0.54. The absolute difference is fairly large considering the fact that the

Likert scale used to record commuters' preferences is only five point scale. The interviews also support this finding. Of the four women I interviewed, all but one brought up their concerns with safety. One woman on BART stated, "I'm sure more women would bike if the streets were safer" (Laura). This variable, among others, shows that women are more sensitive to the negative aspects of cycling.

The results of the regression indicate that Demographic Characteristics and Commute Facts categories are not convincing explanatory agents. Rather, the Commuters' Perceptions aspect of the regression is the most influential, showing that the largest difference between cyclists and non-cyclists lies in their perceptions of their commutes.

### **III. Discussion**

The results of the regression show that cyclists tend to have worse experiences on the train than non-cyclists, yet they are still more pleased with their modal choice. Variables such as Stress, Satisfied, and Comfort indicate that cyclists may be exposed to more negative experiences during their commute. Some of the high stress, unsatisfying and uncomfortable experiences may be explained by what is expected of cyclists and by the design of the train systems.

#### Train Car Design

Some of these negative experiences that cyclists face can be traced back to the design of the train cars and to the design of the train systems. Train car design affects the way people perceive the systems and the relationship between conductors and commuters. Caltrain has two types of car designs, whereas BART only has one. Caltrain and BART are attempting to accommodate cyclists in very different ways. Caltrain segregates cyclists from other commuters, whereas BART treats cyclists just like other passengers. While systems have elements that assist cyclists, neither system has made commuting with a bike as easy as commuting without one.

Caltrain has two generations of train cars that have different designs to accommodate the passengers' bicycles. In the old cars, there is more room for the bicycles as they stack next to each other

in a long row for nearly the entire length of the car. On the new cars, the bikes still stack; however there is more seating for cyclists, further limiting the number of bikes that will fit on the car. Many of the riders prefer the old cars because the bike racks are “better and easier to use” (Allen).

The new train cars have many amenities that the old cars lack, but this comes at a great cost to cyclists. As discussed earlier, there are significantly fewer spaces for bikes in the new style train cars, but there are also some redeeming qualities. Allen, a 41 year old Caltrain cyclist, prefers the new style car because there are more amenities. He likes the new cars because there is a bathroom in each car. Additionally, the floor is much lower than the floor in the old cars. As a result, it is much easier to lift one’s bike into the train. Rather than scaling the stairs that elevate passengers three feet on the old style car, the new cars are only about one and a half feet above the platform. For all passengers, including cyclists, it is much easier to board the train.

However, most cyclists have a strong preference for the old style train car. Peter, middle-aged white cyclist, prefers the design of the old style Caltrain bike cars to the new one. He likes the idea that only cyclists ride in the old style bike cars. The new cars have more creature comforts, but the old cars are more efficient. Twice as many bikes can fit on the old style cars. Kurt, a white male cyclist in his mid-thirties, also prefers the old style bike cars to the new ones. He thinks it is easier to get bikes on and off because there are more bike spaces. Because there are more bike spaces on the old cars, it is easier to arrange the bikes. However, both types of cars use the same system of stacking the bikes. Yet, all of the bike racks are next to each other on the old style car. On the new style cars, the 24 bike spots are divided by eight passenger seats. This makes it very difficult to efficiently arrange the bikes.

Many cyclists find the design of the bike storage facilities inadequate. The cars were not designed to handle the number of bikes that are constantly being loaded and unloaded from the train. Daniel is not happy with either the old or new style train cars, but he prefers the old ones to the new ones. According to Daniel, “at least on the old style you have a fighting chance of getting your bike on,

whereas on the new style there are very, very few spots for bikes.” On both types of train cars, cyclists are required to stack their bikes against other bikes along the walls of the car. Most cyclists have a tag attached to the seat of their bike that states the station that they will be getting off at. This primitive system “works” according to Daniel, but is not the best that it could be. A reshuffling of the bikes is often required at most stops to allow people to get off of the train with their bikes. Frequently, a cyclist who is getting off at the next station may have his bike four or five deep in the stack. To get his bike out, the cyclist will have to move the other four bikes. This is a stressful and time-consuming endeavor. Daniel states that the commute can be so stressful that “it makes me just not want to ride my bike basically, or not want to take my bike.” It is likely that other riders hold such sentiments, leading them to use other modes of transit. These train cars could be redesigned to eliminate such problems.

BART’s train cars are designed very differently than Caltrain’s, which both eliminates many problems and creates a new host of issues. BART, unlike Caltrain, does not have stairs between the platform and the train cars. Passengers must scale stairs to get onto the train platform, but do not have to manage a gradient change to get from the platform onto the train. This design makes it easier for cyclists to enter and exit the cars. However, since the majority of BART’s track is either above or below ground level, cyclists have to scale at least 20-25 stairs. Mike, a 22 year-old BART cyclist, thinks that getting his bike on and off of train platforms is a hassle. However, he continues to cope with the poor design because parking at BART stations is even worse (Mike). Mike simply has to choose between the lesser of two difficulties.

As discussed above, BART does not have bike cars; rather, there are some spaces designated for bikes within each train car. Each car has two spaces specifically for bikes. Many cyclists also use handicapped spaces for bike storage, if there are not any handicapped passengers aboard the car. In total, if no handicapped passengers are on the train car, roughly four bikes can comfortably fit on each car. Frequently, passengers who are not handicapped sit in those spaces. If the spaces are occupied,

cyclists stand with their bikes in the aisle or near the doors of the car. One BART cyclist, named John, stated that he would prefer a system similar to Caltrain's. He dislikes the lack of space designated for cyclists and believes that more people would bring their bikes on BART if they had space dedicated to cyclists. John thinks that a bike car would be more attractive to cyclists than the current system because "cyclists would be ensured that there was space on the train for them and would not have to contend with others for room" (John). If such a system were implemented on BART, cyclists would be subjected to many of the same problems that Caltrain cyclists face. There is a finite amount of space for bikes, whether or not cyclists have a bike car.

Many of the problems that cyclists have with trains can be overcome through better car design. Daniel believes that the bikes should be hung in the train car by their front wheel from the ceiling, allowing for more bikes to fit into the car. He cites the Portland Oregon light rail as a good example of such a bike storage system. Daniel estimates that nearly twice as many bikes would be able to fit in the old style cars if this system of storing bikes were employed. Hanging the bikes would also eliminate the hassle of moving other peoples' bikes that are in the way of cyclists getting off of the train. He also posed the idea of having bike valets. A bike valet would handle the bikes and store them in the car adjacent to the riders. Daniel stated that he would be willing to pay an extra dollar or two for such a service. He feels that the current system works, but it is outdated and inadequate.

The current method of handling bikes on both Caltrain and BART may discourage commuters from choosing cycling as their method of traveling to and from the train stations. As a result, commuters look to other modes of transportation as an alternative. The majority of commuters do not bring a bike on to the train; rather, they choose to walk, drive or use another form of public transportation.

### Getting Bumped

Many cyclists talk about getting "bumped" as one of the largest shortcomings of taking the train. This variable can create stress and make the experience less satisfying. Being bumped refers to the

times that the rider was not able to board the train because there was not enough space for his/her bicycle. For Caltrain cyclists this means that there was not enough room in the bike car and for BART cyclists it means there were too many people on the train to bring the bike aboard. When a cyclist is bumped, he is forced to wait for the next train. My surveys indicate that cyclists on Caltrain get bumped three percent of the time whereas BART cyclists get bumped seven percent of the time.

On the whole, BART cyclists perceive getting bumped as just part of riding the train. One BART cyclist stated that “getting bumped is frustrating, but that’s just the way it is” (Mike). The other BART cyclists I interviewed expressed a similar view of the problem. If they are unable to board a train, cyclists only have to wait about 15 minutes for the next train to arrive. As with Caltrain, BART cyclists do not know if they will be bumped until the train arrives. By this time it is too late for cyclists to lock up their bikes and jump on the train. Therefore, if cyclists are traveling during commute hours, it is very risky to try to travel with a bike. BART attempts to limit the number of people that get bumped by simply prohibiting cyclists to board the trains at certain stations during commute hours. Even though it is against the rules, some cyclists still ride the trains during these hours.

My surveys found that BART cyclists are more likely to get bumped than Caltrain cyclists. Yet, Caltrain cyclist interviewees were more adamant about their right to space in the trains than were BART cyclist interviewees. BART cyclists did not seem perturbed by the fact that they were bumped; they took it for granted as a common occurrence (Laura). Caltrain cyclists voiced the experience of getting bumped as an injustice that requires attention. Caltrain cyclists may be more vocal about getting bumped because Caltrain does not run as frequently as BART. Caltrain cyclists may have to wait for an hour for the next train.

On Caltrain, one of cyclists’ largest concerns is the possibility of being bumped. For Daniel, a Caltrain cyclist, reliability is the largest problem in integrating cycling with taking the train. He claims that 90% of the time he gets “bumped.” Daniel and many other cyclists will not leave their bikes behind

because they are concerned about vandalism. When Daniel was bumped (and before the purchase of his locker at Palo Alto) he would wait for the next train because he needed his bike on the other side of the commute. Such inconveniences are a large deterrent to using a bike and taking it on Caltrain. He feels that the system is not reliable because he may not be able to board the train with his bike when he needs to. While Daniel is confident that the train will arrive on time, he feels that the risk of being bumped is too great. There is too much uncertainty in the system, resulting in many potential passengers driving to their destinations. Daniel even states that if there is too much risk he would rather take a car. He needs a “guarantee” that he will be able to get to where he is going in a reasonable time. As a result, Daniel has recently rented a bike locker at the Palo Alto station to store his bike in. This gives Daniel the ability to easily board the Caltrain and avoid the risk of getting bumped.

Some Caltrain cyclists do not have as many issues with getting bumped. Allen is not concerned about the limited bike space on trains because he never gets bumped. Since Allen boards the train at the terminal stations, he has a low probability of getting bumped. He has seen passengers get bumped at other stations, but in 2009 Caltrain added a second bike car to some of the trains. Since then, Allen has found that “getting bumped has not been an issue.” Caltrain only equips some of the trains with two bike cars, making it difficult for cyclists to predict the total bike capacity of a train. Even with this uncertainty, Allen is happy with the current setup of the train system.

Daniel explained that there is only a high risk of being bumped on certain commutes. On northbound trips into the city, Daniel claims that it is nearly impossible to get one’s bike on the express trains during rush hour. However, on morning southbound trips it is much easier for him to board the trains with his bike. When he boards at 4<sup>th</sup> and King Street Station, the terminal station in San Francisco, there is little risk of getting bumped because it is the first station. As the train travels further from its point of origin, the probability of getting bumped increases.

Peter used to get bumped constantly when he commuted south from San Francisco after work. Now he travels to and from San Jose, so he does not get bumped as frequently. When he rode the train from San Francisco, he would have to time the trains. Peter figured out that the trains that left between five and six pm were especially busy. This increased the probability that he would get bumped; consequently Peter would try to get on other trains. This came at a great cost to Peter because he would have to schedule his entire day around the train he was trying to catch. However, as of late, Peter has had better luck with getting on the trains. Kurt, another Caltrain cyclist, has been bumped before, but he does not find it to be a major problem. He commutes along a lower ridership corridor, so he does not face as much competition for bike stowing. Kurt only gets bumped about one percent of the time. Kurt also pointed out that it is particularly difficult for cyclists to board at the Palo Alto station. This is due to the high volume of cyclists who board at the Palo Alto station. To mitigate the problem, Kurt recommended buying two bikes and leaving them at the stations. If it were truly impossible to bring your bike aboard the train, cyclists could just store a bike on each side of the commute.

Caltrain has been receptive to Kurt's and other cyclists' needs. Trains comprised of the new style car used not to have enough space for cyclists. However, according to Kurt, Caltrain has done a better job of providing space for cyclists by adding an additional bike car on the baby bullet trains. Despite Caltrain's efforts, Kurt still believes that cyclists are not provided with enough space. He would like to see more bike cars on every train. Kurt acknowledged that Caltrain has equipped some of its bullet trains with two bike cars; however, he feels that there is a major flaw in the way that Caltrain provides the additional bike cars. Kurt states that, "the main problem is that we [cyclists] don't know when there is going to be one or two [bike cars]." He estimates that trains running between 5pm and 7pm have a 20 percent chance of having a second bike car. Kurt feels that Caltrain does not do an adequate job of displaying which cars have two bike cars.

## The Expectations of Cyclists

Cyclists have an entirely different experience on the train in comparison to non-cyclists. Their experiences differ because cyclists have a certain etiquette that they are supposed to ascribe to. There is also inter-system variation because both systems handle cyclists differently. This creates an interesting comparison because both cyclists on BART and Caltrain report similar negative experiences, but the causes of these experiences differ.

Most “good” cyclists ascribe to proper bike etiquette. Some of the etiquette overlaps with other riders habits. For example, passengers will get off of the train before boarding passengers may enter the car. However, there are also certain rules of etiquette that cyclists must follow. Cyclists are obliged to allow other passengers to board the train before they themselves board. This means that all cyclists getting on the train must wait for all other passengers to get off and on the train before they can board.

On BART, Cyclists are the last ones to enter the car and are often relegated to standing in the aisle. Cyclists will frequently stand by the doors of the trains, where the aisle is the widest. Since the cyclists are standing in front of the doors where the aisle is the widest, at every stop, they must exit the train so that other passengers can exit. If a BART cyclist is fortunate enough to get a seat by the door, he is responsible for balancing the bike for the duration of the trip. Since the aisles are not wide enough to accommodate a commuter and a bike at the same time, cyclists have to rearrange their bikes every time a person enters or exits the train.

On Caltrain the bikes are stacked against the interior walls of a designated rail car. Often, especially during commute hours, the bikes may be stacked next to each other. The stack can be up to five bikes deep, which can cause problems for cyclists when they get off the train. To minimize problems, all bikes are tagged with the station that the cyclist is traveling to. This enables cyclists to order their bikes by the stations that they will be departing at. Bikes that will be departing at distant stations are deep in the stack and close to the wall; whereas, bikes with closer destinations will be closer to the aisle.

When a cyclist enters the bike car, he must find a stack of bikes that either has bikes tagged with stations that are further away than the station he is departing at or rearrange the bikes in a stack so that his bike does not block any cyclists departing the train before him. For this system to work, all cyclists must know the order of the stations.

If a cyclist does not have his bike labeled, the entire system will break down. Cyclists will have to find out what is going on with the bikes that are not labeled. This often entails asking everyone in the bike car “who has the blue Trek?” The neophytes inadvertently cause problems, but also create a sense of community. The discussion about the blue Trek will break the deafening silence of the early morning commute. It gives cyclists an excuse to talk to one another. In both the interviews and surveys, cyclists discuss the importance of the community (Allen).

Typically, cyclists on Caltrain will leave their seats a station before their destination to get ready to depart. Cyclists are expected to be as quick as possible exiting the train. For example, if a cyclist is getting off of a south bound Caltrain in Palo Alto, he will go to his bike at the Menlo Park station to get ready to depart. For the few minutes between the Menlo Park and Palo Alto station, the cyclist will wait in the aisle while balancing his bike. This permits the cyclist to get off of the train as quickly as possible. There is social pressure from the conductors to act in such a manner. During hours of commute, conductors will stand in the bike car and “help” cyclists leave the train. This often implies watching cyclists carry their bikes up and down the steps and asking them to speed up.

### The Role of the Conductor

Unlike BART, Caltrain has conductors that oversee people boarding the train, thereby creating a sense of urgency. The conductors are under pressure to make sure that the train runs on time. Since cyclists are often the limiting factor in determining when the train can depart from the station, the conductors pass the pressure onto the cyclists. When cyclists leave and board the train, they are expected to be just as quick as other passengers.

The design of the train cars affects the relationship between cyclists and conductors. Cyclists are often the last people to board the train. This is not because cyclists tend to be late getting to the platform, but rather because cyclists have to move their bikes onto the train after other passengers get on and off. Cyclists also take longer than other passengers to board the train because they have to haul their bike onto the train. On Caltrain, only one cyclist and bike can move up the flight of stairs at a time. This is a bottle neck for cyclists, which can result in the entire train waiting for them. For the conductors, cyclists cause stress because they are often the last people to board the train. In addition, the design of the train cars that cyclists travel in can be difficult for conductors to manage. During peak commute hours, one conductor is stationed on each bike car to help cyclists arrange themselves in the car, get on the train, and get off the train. Conductors have a difficult time moving around inside of these cars because all of the cyclists' bikes are stowed there. However, some cyclists will stand and wait with their bikes in the aisle because their destination is approaching. Cyclists do this because it will allow them to get off of the train faster; however, the trade off is that it is very difficult to walk up and down the aisle of the car. This makes it very difficult for conductors to check tickets on the bike cars. Some of the conductors I spoke with commented on the additional energy they need to devote to cyclists. As such, many conductors do not get along with some of the cyclists. On roughly 5% of the surveys, cyclists commented on the way that the conductors treat them. Some cyclists even stated that the conductors treat them as second-class citizens.

During the data collection phase of this research, I experienced varying degrees of negativity from conductors towards cyclists. Robert was one of three Caltrain conductors who allowed me to distribute surveys on the train. When I asked him for permission the first time, I provided him with a five minute explanation of the research. Robert was excited that I was doing research on cyclists and stated, "I am the person who is both a conductor on Caltrain and a member of the bike coalition. The other conductors think that I am a traitor." This statement shows how the majority of Caltrain conductors view

cyclist advocacy groups as the enemy. However, Robert happily expresses his allegiance to both groups and believes that they are not mutually exclusive. His coworkers on the other hand believe that cyclist advocacy groups could potentially harm Caltrain. Robert sympathized with my research, and allowed me to distribute surveys. The majority of other conductors did not allow me to distribute surveys on the trains because they did not want the data to be published.

Other Caltrain conductors were much more cautious about providing me with permission to distribute surveys. They feared that I had an agenda that was not favorable for Caltrain. One Caltrain conductor, named Jim, verified that I was not a part of the San Francisco Bike Coalition by asking me a host of questions. I was subjected to roughly ten minutes of questioning before he allowed me to pass out the surveys. Jim told me that the only reason he permitted me to collect data was because he felt that I was not a threat to Caltrain. However, even after the conversation, he kept a very close eye on me.

Beyond people's experiences in and around the train, other factors discourage commuters from using a bike. Many roads in the Bay Area were only designed for cars, making cycling on those streets dangerous. Not all work places provide bike parking and few provide showers for cyclists. The weather also has a large effect on cycling. Few people are willing to bike in the rain or on cold days, restricting their modal choices. Uncertainties, such as the weather and danger posed by motors, undoubtedly contribute to some of the negative experiences that cyclists have. Even though the problems surrounding the combination of cycling with riding the train fall within the larger systemic problem, making it easier to commute this way will increase the number of people who choose to commute sustainably.

The design of the bike cars, getting bumped, additional expectations of cyclists, and the ways conductors treat cyclists all contribute to the lower levels of comfort, lower levels of satisfaction and higher levels of stress that cyclists report. The experiences of cyclists discourage non-cyclists from

commuting with a bike. By mitigating these negative aspects of integrating cycling with riding the train, it is likely that more people will choose to commute sustainably.

Despite all of the negatives that go along with cycling, cyclists find their commutes more pleasurable than non-cyclists, indicating that they are deriving utility from their commute. Through the interviews, cyclists discuss how biking is much more enjoyable than commuting any other way. Kurt, a Caltrain cyclist, discussed how cycling keeps him in shape and gives him the freedom to travel in ways that other modes of transportation cannot provide. Allan, another cyclist, echoed Kurt's sentiments, and added that cycling reminds him of his youth. For Allen, riding a bike makes him feel young and energetic. Beyond just these two interviews, many of the other cyclists I spoke with hold these same notions. For these cyclists, the hardships they encounter on a daily basis are not enough to dissuade them from cycling.

#### **IV. Conclusion**

One of the most efficient ways to move people into and around cities is via a combination of trains and bikes. Multimodal commutes require a large amount of investment, but the social rewards of such commutes are worthwhile. Some of the most relevant benefits include reducing pollution levels, decreasing congestion, and minimizing the need for parking lots. To design more livable cities, large investments will have to be made to create larger and faster rail services and to design bike friendly environments.

My findings show that cyclists experience vastly different levels of satisfaction with the BART and Caltrain in comparison to non-cyclists, showing that cyclists have additional needs that can be met by designing the train systems to be more accessible to cyclists. Some cyclists attribute their additional levels of stress and lower levels of satisfaction to "mean" conductors and poor design. The current design of the stations and trains is not conducive to traveling with a bike. For example, cyclists would benefit from more accessible train cars. This includes cars with either fewer steps or a bike ramp in place

of steps. Bike cars that are specifically designed for cyclists to quickly move their bikes on and off the trains would also facilitate commuting with a bike. These cars could be designed with wider doors and bike stalls to promote quick boarding and departing with minimal amounts of stress. If Caltrain and BART are able to reduce the negative experiences that cyclists endure, they will likely have higher ridership levels with more cyclists.

My analysis also shows that Commuters' Perceptions are the most influential in determining the likelihood that they are also cyclists. Surprisingly, commuters' demographics and commute facts do not adequately differentiate the two populations. The only variables to emerge as significant from these two categories are Gender and Distance. However, the Gender parameter can be explained by women's high sensitivity to the negative aspects of cycling and the Distance variable is inconsistent because it is always positively correlated with the likelihood of being a cyclist. My findings indicate that the parameters within the Commuters' Perception category are the most adequate explanatory agents.

The interviews echoed the majority of the sentiments that were present in the surveys. Most subjects were motivated to travel because of environmental reasons and a general dislike of cars. Of the people interviewed, nearly all voiced concern about the state of the environment. Cyclists' standpoints on the environment prompted them to think about commuting sustainably and to give up their cars. However, this parameter is not significant in the regression results. People's dislike of the car was also very apparent in the interviews, showing that the automobile is a significant component of the equation.

The research and analysis that I conduct in this paper have some limitations. A disproportionate number of the surveys were distributed on Fridays, leading to a possible sample bias. In addition, the sample size is not particularly large, which could skew results. Outliers could be reducing the significance of some of the variables in the regression. There were also some discrepancies between the survey and interview findings. In the interviews, about half of the subjects shared their concerns about the costs of owning a car. However, in the surveys the subjects did not feel that saving money was a motivating

factor. The average subject was only slightly motivated by Money to take the train and ride his/ her bike. This variable was only given an average score of three on the importance scale. Hopefully, as the research continues, these types of discrepancies will be eliminated. To understand the true effects that money has on peoples' decisions to commute via bike and train, more research and a greater sample size is required.

Future researchers may also want to build on this research in other ways because there are still some questions left unanswered. My findings in this paper prompt new and equally pressing questions. Why are commuter cyclists primarily male? I find that female commuters are more sensitive to the negative aspects of cycling, which may lead them to choose other modes for commutes. However, to empirically demonstrate this claim, more research needs to be conducted. Additionally, why is there a huge income gap between cyclists and non-cyclists? Why do Caltrain cyclists have higher incomes than Caltrain non-cyclists, whereas BART cyclists have lower incomes than BART non-cyclists? These findings, presented in the summary statistics, show how the four populations differ, but do not explain the causes of these differences.

A commuter's modal choice primarily depends on his/her perception of cycling and the train system. There is a discrepancy between cyclists' feelings and non-cyclists' perceptions. My results suggest that people can be encouraged to commute sustainably by making cycling easier and by presenting new information to non-cyclists. If non-cyclists perceive cycling to be easier, whether or not it actually is, they will be more likely to bike. Across all three regressions, the most statistically significant variable is people's perception of how difficult it is to cycle. Even though cycling is more difficult than taking another mode of transportation, non-cyclists perceive cycling to be much more difficult than cyclists find it to be. If non-cyclists are shown that cycling is easier than they perceive it to be, it is likely that more people will begin to commute via bicycle.

The push toward sustainable commutes will likely come from a grassroots organization that engages communities through outreach programs. This outreach may come in the form of distribution of bicycle trail maps, cost-calculators that compare the prices of cycling and train-riding to driving, and information on the health benefits of cycling. More specifically, it would be most helpful to take into account the variables that survey respondents listed as most influential in their decision not to cycle. These include weather, time/distance, and stress/hassle. For example, my data shows that non-cyclists actually have longer commute times than do cyclists. Although this additional commute duration can be partially attributed to larger distances that non-cyclists travel, the data show that if non-cyclists were to cycle to the train station, their total travel time would only be marginally increased. Non-cyclists simply need to be made aware that cycling is a plausible alternative to other modes of commuting.

**Appendix A**

Cyclist Pilot Survey

Caltrain Pilot Survey  
Stanford University  
April 24, 2010

**Pilot Survey**

What is your gender?  Male  Female

What is your age? \_\_\_\_\_

Do you have a valid driver's license?  Yes  No

What is your annual income? \$ \_\_\_\_\_

Where are you coming from today? Please state the address/ intersection.

\_\_\_\_\_

What station are you boarding at? \_\_\_\_\_

How far away is your starting point from the station? \_\_\_\_\_ miles

What forms of transportation did you use to get from your starting point to the train station today?

\_\_\_\_\_

What station are you getting off at today?

\_\_\_\_\_

Where are you going? Please state the address/ intersection.

\_\_\_\_\_

How far away is your end point from the station? \_\_\_\_\_ miles

What forms of transportation are you using to get from the train station to the destination?

\_\_\_\_\_

How frequently do you make this trip? Circle one.

Every Day      3-4 Times Per Week      1-2 Times Per Week      Twice a Month      Once a Month or Less

How often does your commute include cycling?

Every Day      3-4 Times Per Week      1-2 Times Per Week      Twice a Month      Once a Month or Less

What is the purpose of your trip? \_\_\_\_\_

What is your main reason for traveling via bike? \_\_\_\_\_

Why do you travel via train? \_\_\_\_\_

Is traveling with a bike easy? Circle a number.

Easy    1    2    3    4    5    Difficult

What percentage of the time are you unable to board a train with your bicycle because there is not enough room?

\_\_\_\_\_ %

To what extent do the following factors play a role in your decision to commute via bike and train? Circle a number.  
Please rate the following on a 1(not very influential) to 5 (highly influential) scale.

Money	1	2	3	4	5
Environment	1	2	3	4	5
Health	1	2	3	4	5
Avoiding Traffic	1	2	3	4	5
Pleasure	1	2	3	4	5
Other _____	1	2	3	4	5

How satisfied are you with the train system? Circle a number.

Very Discontent    1    2    3    4    5    Very Satisfied

What is the greatest problem with the train system?

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This is a pilot survey. Do you have any comments about ways to make it better?

---

## Appendix B

### Cyclist Survey



Stanford University  
Date:

#### Survey 2.2

What is your gender?  Male  Female

What is your age? \_\_\_\_\_

What is your occupation? \_\_\_\_\_

What is your highest level of education? Circle one.

Some High School      High School Graduate      Some College      College Graduate      Graduate School

Do you have a valid driver's license?  Yes  No

Do you have a car you could drive to your destination today?  Yes  No

What time did you board the train? \_\_\_\_\_

What station are you boarding at? \_\_\_\_\_

How far did you have to travel to get to the train station today? \_\_\_\_\_ miles

How long does this part of your trip take (from your starting point to the station)? \_\_\_\_\_ minutes

What form(s) of transportation did you use to get from your starting point to the train station today? \_\_\_\_\_

What station are you getting off at? \_\_\_\_\_

How far away is your end point from the station you are getting off at? \_\_\_\_\_ miles

How long does this part of your trip take (from your arrival station to your destination)? \_\_\_\_\_ minutes

What form(s) of transportation are you using to get from the train station to your destination? \_\_\_\_\_

How long does your total commute take (including riding the train, driving, cycling, walking, etc.)? \_\_\_\_\_ minutes

How frequently do you make this trip? Circle one.

5-7 Times Per Week      3-4 Times Per Week      1-2 Times Per Week      Twice a Month      Once a Month or Less

How often does your commute include cycling?

5-7 Times Per Week      3-4 Times Per Week      1-2 Times Per Week      Twice a Month      Once a Month or Less

What is the purpose of your trip? \_\_\_\_\_

Do you work while you are on the train?  Yes  No

Does your work provide you with an incentive to use the train?  Yes  No

Please Fill Out Reverse Side

If so, what is the incentive? \_\_\_\_\_

How long would it take you to drive from your starting point to your destination? \_\_\_\_\_ minutes

What percentage of the time are you unable to board a train with your bicycle because there is not enough room? \_\_\_\_\_%

Is traveling with a bike easy? Circle a number.

Easy 1 2 3 4 5 Difficult

How often is the train late to pick you up? \_\_\_\_\_%

How much do you earn annually? \$ \_\_\_\_\_

To what extent do the following factors play a role in your decision to commute via bike and train? Circle a number. Please rate the following on a 1(not very influential) to 5 (highly influential) scale.

Money	1	2	3	4	5
Environment	1	2	3	4	5
Health	1	2	3	4	5
Avoiding Traffic	1	2	3	4	5
Pleasure	1	2	3	4	5
Saving Time	1	2	3	4	5
Exercise	1	2	3	4	5
Convenience	1	2	3	4	5
Comfort	1	2	3	4	5
Dislike of the car	1	2	3	4	5
The ability to work on the train	1	2	3	4	5
Other _____	1	2	3	4	5

Of the above categories, which one is the most important for you? \_\_\_\_\_

How satisfied are you with the train system? Circle a number.

Very Discontent 1 2 3 4 5 Very Satisfied

How stressful is riding the train? Circle a number.

Relaxing 1 2 3 4 5 Stressful

Are you concerned about the way this rail service is funded? Circle a number.

Not Concerned 1 2 3 4 5 Very Concerned

What is the greatest problem with the train system?

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## Appendix C

### Non-cyclist Survey



Stanford University  
Date:

#### Survey 3.0

What is your gender?  Male  Female

What is your age? \_\_\_\_\_

What is your occupation? \_\_\_\_\_

What is your highest level of education? Circle one.

Some High School      High School Graduate      Some College      College Graduate      Graduate School

Do you have a valid driver's license?  Yes  No

Do you have a car you could drive to your destination today?  Yes  No

What time did you board the train? \_\_\_\_\_

What station did you boarding at? \_\_\_\_\_

How far did you have to travel to get to the train station today? \_\_\_\_\_ miles

How long does this part of your trip take (from your starting point to the station)? \_\_\_\_\_ minutes

What form(s) of transportation did you use to get from your starting point to the train station today? \_\_\_\_\_

What station are you getting off at? \_\_\_\_\_

How far away is your end point from the station you are getting off at? \_\_\_\_\_ miles

How long does this part of your trip take (from your arrival station to your destination)? \_\_\_\_\_ minutes

What form(s) of transportation are you using to get from the train station to your destination? \_\_\_\_\_

How long does your total commute take (including riding the train, driving, cycling, walking, etc.)? \_\_\_\_\_ minutes

How frequently do you make this trip? Circle one.

5-7 Times Per Week      3-4 Times Per Week      1-2 Times Per Week      Twice a Month      Once a Month or Less

What is the purpose of your trip? \_\_\_\_\_

Do you work while you are on the train?  Yes  No

Does your work provide you with an incentive to use the train?  Yes  No

If so, what is the incentive? \_\_\_\_\_

How long would it take you to drive from your starting point to your destination? \_\_\_\_\_ minutes

How often is the train late to pick you up? \_\_\_\_\_%

How satisfied are you with the train system? Circle a number.

Very Discontent    1    2    3    4    5    Very Satisfied

How stressful is riding the train? Circle a number.

Relaxing    1    2    3    4    5    Stressful

Please Fill Out Reverse Side

Are you concerned about the way this rail service is funded? Circle a number.

Not Concerned    1   2   3   4   5    Very Concerned

How much do you earn annually? \$\_\_\_\_\_

To what extent do the following factors play a role in your decision to commute via train? Circle a number. Please rate the following on a 1(not very influential) to 5 (highly influential) scale.

Money	1	2	3	4	5
Environment	1	2	3	4	5
Avoiding Traffic	1	2	3	4	5
Pleasure	1	2	3	4	5
Saving Time	1	2	3	4	5
Convenience	1	2	3	4	5
Comfort	1	2	3	4	5
Dislike of the car	1	2	3	4	5
The ability to work on the train	1	2	3	4	5
Other_____	1	2	3	4	5

Of the above categories, which one is the most important for you? \_\_\_\_\_

What is the greatest problem with the train system?

\_\_\_\_\_

Do you think traveling with a bike would be easy? Circle a number.

Easy    1   2   3   4   5    Difficult

To what extent do the following factors play a role in your decision to commute without a bike? Circle a number. Please rate the following on a 1(not very influential) to 5 (highly influential) scale.

Physical Effort	1	2	3	4	5
Appearance	1	2	3	4	5
Time/Distance	1	2	3	4	5
Stress/Hassle	1	2	3	4	5
Lack of Safety	1	2	3	4	5
Weather	1	2	3	4	5
Luggage	1	2	3	4	5
Bike Facilities (parking, etc)	1	2	3	4	5
Enjoy other mode of transit	1	2	3	4	5
Other_____	1	2	3	4	5

Of the above categories, which one is the most important for you? \_\_\_\_\_

Do you own a bicycle?  Yes  No

## Work Cited

- Allen, personal communication, June 14, 2010.
- BART - Bay Area Rapid Transit. (2010). Retrieved from <<http://www.bart.gov>>
- Blickstein, S. & Hanson, S. (2001). Critical mass: forging a politics of sustainable mobility in the information age. *Transportation, 28*.
- Caltrain (2010). Retrieved from <<http://www.caltrain.com/>>
- Cervero, R. & Wu, K-L. (1997). Polycentrism, commuting, and residential location in the San Francisco Bay Area. *Environment and Planning, 29*.
- City of Palo Alto. (1999). Palo Alto Comprehensive Plan. Retrieved from <[http://www.cityofpaloalto.org/knowzone/city\\_projects/land\\_use/comprehensive\\_plan.asp](http://www.cityofpaloalto.org/knowzone/city_projects/land_use/comprehensive_plan.asp)>
- Daniel , personal communication, May 9, 2010.
- Espinosa, M. personal communication, May 12, 2010.
- Foushee, C. & Wier, M. (2009). SFGH Employee Travel Survey: Opportunities for Sustainable Transportation. *SFGH Travel Survey*.
- Hanson, R. & Young, G. (2008). Active Living and Biking: Tracing the Evolution of a Biking System in Arlington, Virginia. *Journal of Health Politics, Policy and Law, 33*.
- Hardin, G. (1968). The Tragedy of the Commons. *Science, 162*.
- Hill, R. C., William E. G. & Guay C. L. (2008). *Principles of Econometrics* (3<sup>rd</sup> ed.). Hoboken, New Jersey: John Wiley & Sons Inc.
- Jacobson, M. (2002). *Atmospheric Pollution: History, Science, and Regulation*. Cambridge, United Kingdom: Cambridge University Press.
- John, personal communication July 23, 2010.
- Kidder, J. L. (2008). Appropriating the City: Space, Theory, and Bike Messengers. *Theory and Sociology, 28*, (307-328). doi: 10.1007/s11186-008-9079-8
- Kitamura, R. Mokhtarian, P. & Laidet, L. (1997) A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. *Transportation, 24*.
- Korpi, M. (2006). Does Size of Local Labour Markets Affect Wage Inequality? A Rank-size Rule of Income Distribution. *Journal of Economic Geography, 8*.
- Kurt, personal communication. June 14, 2010.

- Laura, personal communication, July 22, 2010.
- Litman, T. (2010). *The Future Isn't What It Used To Be: Changing Trends And Their Implications For Transport Planning*, Victoria Transport Policy Institute.
- Martens, K. (2006). Promoting bike-and-ride: The Dutch experience. *Environmental Simulation Laboratory*.
- McFadden, D. (1974). The Measurement of Urban Travel Demand, *Journal of Public Economics*, 3.
- Mike, personal communication, July 23, 2010.
- Nankervis, M. (1999). The effect of weather and climate on bicycle commuting. *Transportation Research Part A* 33.
- Numan, P. & Kenworthy, J. (1998). *Sustainability and Cities: Overcoming Automobile Dependence*. Washington DC: Island Press.
- O'Sullivan, A. (2007). *Urban Economics* (6th ed). Chicago, IL: Irwin.
- Pan, H. Qing S. Ming, Z (2009). Influence of Urban Form on Travel Behaviour in Four Neighbourhoods of Shanghai, *Urban Studies Journal Limited*, 2009 46: 27. doi: 10.1177/0042098008099355
- Parody, T. (1977). Analysis of Predictive Qualities of Disaggregate Modal – Choice Models, *Transportation Research. Record No. 637*.
- Peter. personal communication, June 14, 2010.
- Pucher, J. & Buehler, R. (2009). Integrating Bicycling and Public Transport in North America. *Journal of Public Transportation*, 12, No. 3.
- Reynolds, J. J. (2005). Techniques of Research and Investigation Written Report Combining Bicycles and Public Transport. The University of Melbourne.
- Saelens, B. E. Sallis, J. F. & Frank, L. D. (2003). Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning. *Literatures Environment and Physical Activity*, 25.
- Schuit, J. (1999). Exercise Training and Heart Rate Variability in Older People. *Medicine & Science in Sports & Exercise*, 6.
- Shoup, D. (1997). The High Cost of Free Parking. *Journal of Planning Education and Research*, 17.
- Spindler, S. Bikes on Transit Ridership Statistics. Retrieved from <<http://www.bikemap.com/bikesontransit/statistics.php>>
- Timperio, A. Crawford, D. Telford, A. & Salmon, J. (2004). Perceptions About the Local Neighborhood and Walking and Cycling among children. *Preventive Medicine*, 38.

U.S. Environmental Protection Agency. (2002). *Asthma Research Strategy*. (EPA 600/R-01/061, 2002) Washington, DC: Office of Research and Development.

U.S. Environmental Protection Agency. (2010). *2010 U.S. Greenhouse Gas Inventory Report*. (EPA 430-R-11-005) Washington, DC: U.S. Office of Research and Development.

Voith, R. (1987). Commuter Rail Ridership: The Long and Short Haul. *Federal Reserve Bank of Philadelphia*.

Vuchic, V. (1999) *Transportation for Livable Cities*. New Brunswick, New Jersey: The Center for Urban Policy Research.