AUTONOMOUS TRANSIT SYSTEMS IN PRACTICE: AN EXPLORATION IN DOOR-TO-DOOR TRANSIT IN NORTH SAN JOSE

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Abstract

Although Personal Rapid Transit (PRT) and autonomous vehicle technologies have presented viable transportation solutions for many years already, the public investment in these technologies is still quite minimal. Two key factors prohibiting his transition process and cost and public perception. Using San Jose, CA as a case study, I will be investigating possible transition factors in the planned re-zoning and development. The results from my research can subsequently be applied to other areas around the country interested in investing in a new autonomous transit system, to serve as examples that will push forward national adoption.
Acknowledgements

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Chapter 1

Introduction

On the dusty route for the 2005 DARPA Grand Challenge, through the dry Mojave desert, the world saw the concept of automated cars on our roads as an immediate possibility. As the retro-fitted self-driving cars navigated the 131.6 mile course, it became clear that fully automated vehicles were no longer a concept of the distant future, but rather a tangible reality that would soon come to local roads near you (Defense Advanced Research Projects Agency, 2005).

The introduction of and transition to Personal Rapid Transit (PRT) and autonomous vehicle technology has been slow thus far. Before the emergence of the Google Car on the evening news, self-driving cars and "smart" transit to most of the general public, were akin to something out of The Jetsons. American society is completely unprepared with the driverless cars on the road tomorrow. As reflected in the slow and sometimes hostile legislature development process for autonomous vehicles, smart vehicles face the challenge of not only refining the technological developments, but also of distrust by the general public. Those quickest have been driven by necessity, as Google’s range of testing expands into their territories. The Google Car is a "cool" experiment, but transition to these vehicles becoming a dominant figure on our roadways is filled with concerns of safety and liability, despite proven driving
records. As with the introduction of the first motorized cars and later, airplanes, the introduction of autonomous vehicles requires not only technology refinement, but also an official mass debut to society.

For many cities of America, the increase in urban sprawl over the past few decades have created a headache of increased traffic congestion, environmental pollution, and decreased productivity. Cities like Washington DC have grown rapidly in population in a short period of time, yet see most of their growth in the suburbs and the emerging “edge cities” (Stoel, 1999). Mass transit is often scarce or poorly developed in suburbs with low ridership in these suburbs. The resulting reliance on the personal car has caused traffic congestion to surge on roadways in and out of cities. The shift in land use as cities expand combined with the increase in fuel consumption as length of travel increases have serious implications on the growing negative environmental impact. As Fallah et al. (2011) found in their analysis, urban sprawl correlates directly with a decrease in average worker productivity.

This thesis aims to examines the unique opportunity in North San Jose: The already started re-development serve as a potential launch pad for developing and implementing a viable transition system that will demonstrate the potential of introduce autonomous short-distance transit systems. Plagued with the challenge of a low jobs to employed population ratio, San Jose suffers from increasingly problematic congested traffic patterns in and out of the city to neighboring technology centers. In a study of incorporating Urban Village development goals with an autonomous second leg transit system, this paper will analyze transit demand and supply, projected forward in line with San Jose’s 2040 Envision plan. The proposed plan will focus on 1) travel demand an an Urban Village environment 2) demand responsiveness to maximize efficiency and efficacy 3)shared ridership potential and 4) development funding options and opportunities. In writing this thesis, I want to answer a key question for the viability and the role of autonomous transit systems in revitalizing the urban
centers of our cities. The goal is to develop a sustainable and viable solution that will promote the introduction of and transition to autonomous transit in San Jose. From the San Jose example, this paper will conclude with a discussion on replicability in other areas of interest.
Chapter 2

Motivation

The development and propagation of cars has been, for a long time, symbolic of the American dream. With the increased accessibility of cars, however, average rider to vehicle rates have gone down. In California, US Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics (2012) estimates show that in 2012, 73.25% of those commuting to work drive alone. In contrast, only 11.10% carpool, and a mere 5.16% travel via public transit. Yet despite these high rates of single person ridership, California ranks 8th out of 50 states and Washington D.C., in lowest single person ridership commuter rates. As a result of the low shared ridership in vehicles on the road, and low usage of mass transit, commuters in California face long drives to and from work, each and every single day. The potential increase in productivity and economic output if a portion of this time on the road were diverted is tremendous.

As a result of urban sprawl, many cities have grown in size while maintaining low population density. The resulting transportation needs, increased by the distances between locations, have contributed to the traffic problems seen today. In Silicon Valley, San Jose faces a unique situation of net exportation of labor, meaning that the city loses on potential economic production while suffering traffic problems as its
residents commute to nearby cities such as San Francisco. This scenario discourages potential residents from moving to the city, and in turn, causes the local economy to stagnate and decline. Traffic each day, as a whole, moves away from, rather than towards the city.

For cities like San Jose, this is a unique time of opportunity for them to redefine and revitalize themselves. Despite the urban sprawl problems that many cities in the US face as a result of the mass move to the suburbs, more and more Americans are moving back to the cities. United States Census Bureau (2012) reported that urban populations, increasing at 12.1%, were growing faster than the national average of 9.7% in the same period. The aversion to long commuting hours can be seen in Edenvale, CA’s success in attracting industry by leveraging it’s reverse commute position (Keit, 2014). This means that the trip to Edenvale is generally reverse traffic trends during rush hour, and travelers can therefore avoid the morning and evening rush hour traffic.

Public transportation has traditionally been point of division between socioeconomic levels. Buses are often unpopular due to their generally increased circuity, slow speed, and perceived inconsistency. Traditionally, those who could afford vehicles moved out into the suburbs, while those who depended on public transportation stayed closer to the collapsing city centers. Combined, these two factors have created a social stigma against buses as being of lower class. Light and heavy rail are viewed more favorably, but the advantages of convenience and speed have allowed cars to thrive as the prime choice transportation.

For the younger generation that’s driving this move back to the urban centers, convenience is a top priority. Interest in driving has decreased in the under-30 population, as shown by a steady decrease in licensing over the course of the past thirty years (Delbosc and Currie, 2013). Furthermore, those who do have a license on average, drive less. For the young professional, a walkable city with an effective and
efficient public transit system are an attractive alternative to the suburbs of baby boomers. As Adamson et al. (2004) found, the choice of household location depends not only on economic opportunities, but also other amenities, including cultural diversity, access to entertainment and services, etc. Cities with few amenities and smaller in size may experience a brain drain as young professionals, particularly couples, seek areas that provide both amenities and colocation opportunities (Costa and Kahn, 2000).

Autonomous vehicles, as a method of public transportation, bring both the speed and efficiency that would attract both residents and businesses. By offering door-to-door mobility that complements the longer distance travel of light rail and the short trips on foot or bike. Targeting last-leg travel, autonomous vehicles create an on-the-ground solution to the distance between rail stops. The efficiency and speed mean that such a system would be both "sexy" for the young professionals and price accessible to the general population, as a result of cost reduction in removing inefficient labor patterns.

Baum (2009) has shown that car ownership is not only directly correlated with owners’ job security and income levels, but also a facilitator for socioeconomic mobility. For the owner, car ownership brings both increased mobility as well as connectivity to the surrounding community. Rather than being dependent on ownership, however, these benefits stem from the accessibility to quick transportation that comes with car ownership. In an urban context, autonomous transit systems can provide the same mobility with the increased efficiency in usage of the vehicle. The burden of purchasing and maintaining the vehicle would be shared amongst all users, making the system a more accessible to those in lower socioeconomic brackets, who would experience the most increase in marginal benefit.

San Jose’s exploration in urban villages and developing mixed use zones that combine urban living with close proximity to the industrial centers of the city makes it
a prime case study for analyzing the potential and possibly implementing an effective automated transit system. With it’s focus on infrastructure development and sustainability, the City is in a position to be a harbinger of change in the way it address transportation. By focusing on increasing intra-city traffic, San Jose attract companies and industry investment from firms that are interested in maximizing the efficiency and quality-of-life of their employees. The combination in growth of industry and local businesses to support the increasing population can redefine San Jose’s identity as a major player in Silicon Valley.
Chapter 3

Autonomous Vehicle Development and Challenges Today

3.1 Personal Rapid Transit

Personal Rapid Transit, or PRT, is the most common form of autonomous transit implemented in practice today. Comprised of independently acting vehicles driving on guideways, PRT operates on-demand. Riders can call a car and choose an arrival destination accessible via the system. PRT improves the challenge of customization that mass transit often faces today. The on-demand nature of PRT systems increases the efficiency of each trip, eliminating unnecessary miles traveled. This reduces the time it might take for a rider to get from point A to point B. Systems have been developed and implemented in Morgantown (WV) and Londons Heathrow Airport, and have shown great success. However, the initial investment required to build such systems, due to their large infrastructure requirements, have slowed the adoption of such systems. PRT’s reliance on guideways limits its accessibility, both from a development perspective and also a usage perspective, in the decision of station locations.
3.2 Driver Assistance Technologies

Driver assistance technologies have recently been introduced to the top lines of commercial luxury vehicles as tools that aid in reducing accidents due to driver error. The focus of these driver assistance technologies lies in three key areas: lane keeping, car following, and obstacle crash avoidance. A type of back-up system, driver assistance technologies currently focus on small direction changes and braking to increase crash avoidance, but generally do not autonomously drive and control vehicles.

Through the use of sensors and cameras, the systems can detect the lanes on the road as well as the objects around the car. This means that vehicles equipped with these systems can help drivers to avoid some of the behaviors that result from distracted driving, including lane meandering and tail gating, as well as improve defensive driving measures by detecting obstacles in the road.

Although these technologies can be tremendously effective in theory, in practice, the consumer available product has yet to be refined to such a state. Strong limitations include speed of the vehicle, height of the obstruction, and weather conditions, each which can limit the systems ability to detect and act.

The two most prominent figures in this area are Mercedes Benz and Volvo, both of whom offer these systems in their higher price segmented vehicles. Some of the systems rolled out imply a much higher potential in the R&D labs. For instance, Mercedes Benzs Magic Body Control feature alludes to a very high level of sophistication in the ability of the cameras and sensors to measure small changes in the terrain, and very quickly adjust. However, systems of this high level have yet to be seen in safety-oriented systems, perhaps due to questions of liability.
3.3 Fully Automated Personal Vehicles: The Google Car

The Google Car is one of the hottest topics in conversation today. Google has been able to create and develop a fully autonomous vehicle that has demonstrated incredible safety and navigation ability on roads. Brought out of Google[x], the Google Car has rapidly shortened the timeline for fully autonomous vehicles, creating an in-this-lifetime for autonomous vehicles.

Having logged over 500,000 miles as of early 2013, the fleet of Google Cars show a remarkable ability to identify and adapt to both road characteristics and others on the road (Muller, 2013). Challenges however, still exist. As with any computer automated system, the Google Car is vulnerable to irregular conditions, or corner cases. Weather conditions that obstruct camera view can create difficulties, as can special road situations including human override of traffic controls. The current dependency on a map database means that newly constructed roads present a challenge. Although responses to regular driving are remarkably well refined, processes such as entering and exiting the freeway still require development.

3.4 Autonomous Transit: CityMobil2

The CityMobil2 project has demonstrated the feasibility of an autonomous transit system. A collaborative project co-funded by the EU’s Seventh Framework Programme, CityMobil2 seeks to remove the barriers to implementing autonomous road transport systems. The project focuses on the three areas of legal framework, implementation process, and economic effects that are still questions that impede the transition to autonomous transit systems.

In collaboration with researchers, CityMobil2 developed autonomous vehicles and
will demonstrate autonomous transit in five different host sites for six months. With the goal of complementing existing public transportation networks by targeting areas with low or dispersed demand, CityMobil2 seeks to introduce the feasibility of autonomous transit systems in Europe and through demonstration, introduce the general public to fully automated vehicles. Public demonstrations have shown that the vehicles developed are capable of handling various traffic and road arrangements, with cases categorized by origin and destination types (city, country, etc.) (cit).

CityMobil2 has shown both the possibility of autonomous transit systems as well as the importance of demonstration to the process to actually implementing these systems. This thesis seeks to outline a parallel opportunity in North San Jose, and subsequently, other interested localities, that will serve as demonstration of the capability and feasibility of autonomous transit systems.
Chapter 4

The San Jose Picture

4.1 San Jose: Redevelopment and Envision 2040

In recent years, San Jose has faced the increasing problem of a housing to job ratio imbalance, a reason that some locals cite as the cause for San Jose being overlooked in many development opportunities (Keit, 2014). As the only major city in America that acts as a net exporter of workers in its region, San Jose faces challenges in growing both economically and culturally (City of San Jose, 2011). Although San Jose has two large technology focused industry centers within city limits, it is home to very few headquarters, instead often chosen for satellite offices (Keit, 2014).

4.1.1 Redevelopment

San Jose, like many cities up and down the state of California, formed its redevelopment agency before the turn of the century with the goal of revitalizing the city and addressing, on a large scale, problems faced by its residents. In California’s Silicon Valley, San Jose sought to define itself and become an urban center attractive to the technology giants of the area whilst surrounded by San Francisco, Palo Alto, and others.
Redevelopment in San Jose targeted three main goals. The first was to develop the downtown area, through major investments in infrastructure and public sites that would return traffic back through the increasingly deserted city center, as a result of urban sprawl. The second was to build stronger communities within the city, through raising the urban population density, promoting walkability, and revitalizing public spaces and storefronts. Finally, the city sought to increase it’s presence in the Silicon Valley technology sector by providing tax incentives and large equipment capital subsidy (Keit, 2014).

In February, 2012, the State of California officially dissolved all redevelopment agencies, in part due to state funding conflicts (San Jose Redevelopment Agency, 2012). Projects that were already in place continued, but scheduled projects are currently being unwound. In response, the city of San Jose developed it’s Envision 2040 plan.

4.1.2 Envision 2040

San Jose’s Envision 2040 plan outlines the city’s plans to redefine the San Jose metropolitan area, and attract industry and residents by increasing quality of life, promoting mobility through improved transportation, and re-evaluating land use to create an environmentally friendly and sustainable city. As a highly cosmopolitan city with a high educated population, at 35% of the workforce possessing a 4-year university degree compared to the national average 27%, San Jose is well situated to develop itself as a urban center attractive to young professionals.

The focus is to revive San Jose as an influential innovation center in Silicon Valley, with an emphasis on green development. With the target goal of 1.3 jobs/1 employed resident in the city, San Jose seeks to reduce low-efficiency highway traffic out of the city, and instead, promote high efficiency intra-city travel and support inter-city travel with light and heavy rail development (City of San Jose, 2011).
4.2 Urban Villages and the Goal of Walkability

The Urban Villages concept has been key aspect of San Jose’s development and re-imaging. Envision 2040 uses the concept to create a set of policy framework with the goal of creating walkable and biking friendly communities within the greater sphere of the San Jose metropolitan area. The Urban Village concept emphasizes mixed use land zoning, to allow residents to live, work, eat, and play all in an accessible region.

The Urban Villages are classified into four categories: Regional Transit Urban Villages, San Jose Transit Urban Villages, Commercial Center Urban Villages, and Neighborhood Urban Villages. For the purpose of this thesis, the San Jose Transit Urban Villages and Neighborhood Urban Villages were explored more in depth. The first emphasize high-density job and housing growth along light rail facilities. The second focus on mixed use zoning, with an integration of neighborhood businesses with housing, the goal being that residents living in these areas will have access to attractive urban amenities within walking distance.

4.3 North San Jose: The Innovation Triangle

The North San Jose area originally grew out of the San Jose Redevelopment Agency’s agenda to increase business and industry in the Industrial Project Areas. In doing so, the city aimed to both directly increase high-level skilled jobs as well as indirectly promote the local economy by increasing the demand for local businesses.

The northern Industrial Project Area, first known as the Innovation Triangle, and today referred to as North San Jose, is defined by the surrounding I-880, Highway 101, and (not shown) Highway 237 to the north. With strong access from both highway and light rail line, the area is home today to offices of numerous companies in the Silicon Valley.

Currently, there is little housing development in the area, partially due to land
zoning. Such is the case, that a negative feedback cycle has arisen that there exists a shortage in supporting urban amenities and businesses, resulting in little incentive for housing development. This means that the area has traditionally been an in-and-out area, where employees arrive during the day for work, and leave after working hours.

The new *North San Jose Area Development Policy* makes it clear that planning is under way to change this dynamic. Over the course of the next 10+ years, the policy sets a goal for creating 80,000 new jobs in the North San Jose area, and the development of 32,000 new housing units, with 6,400 being affordable units (City of San Jose, 2010). In a similar vein, the Envision San Jose 2040 plan targets 97,000 new
jobs and the same number of housing units by 2040 in North San Jose, development progressing in line with the bigger San Jose revitalization process.

With its existing infrastructure of light rail, the North San Jose area is well situated for a second-leg oriented autonomous transit system. As evident from 4.2, most of the core area of development is encompassed within 2000 feet of the light rail station. A autonomous transit system would be influential in connecting residents to the existing light rail system, and following, the greater San Jose area, as well as promoting interconnectivity between regions within the North San Jose district.

4.4 Green San Jose

For San Jose, sustainability and reduction of and transition of energy consumption to green options has been a high priority. In 2007, the city council passed and began the implementation of its 12 year plan towards greening San Jose. Part of the focus of the plan is to increase green-oriented job development as well as green-transportation.

It has been shown in other areas that TOD has significant job-creation potential (Angelides et al., 2014). The development of an autonomous transit system would promote shared ridership, reduce commute travel, and promote higher density development, which in turn, promotes walkability. The combined efficiency and effectiveness of an autonomous transit system falls well in line with San Jose’s Green goals, and would create jobs both directly and indirectly.
Figure 4.2: North San Jose Neighborhoods Plan with 2000 Feet Light Rail Station Zone Overlay

Source: City of San Jose
Chapter 5

Population Generation: Morphing to 2040

5.1 Introduction

Part of the challenge faced in planning for and eventually implementing new transportation infrastructure arises from the changes in population make-up and demand from the beginning of planning to the final implementation stage. With the City of San Jose pursuing an aggressive strategy of growth and development, the challenge becomes to model the changes in transit dynamic that will arise as the industry and residency changes.

This next section will outline the methodology used to project population, business, and school changes in the North San Jose district, using guidelines from the Envision 2040 plan as well as directives from the North San Jose planning committee. This model creates a synthetic estimate of a potential layout of North San Jose under the guidelines established, in order to estimate transit demand around the district.
5.2 Employee and Patronage Estimation

The main uses of transportation come from traveling to-and-from work and home and the patronage of businesses. This model assumes that travel to non-businesses (i.e., no employees) is negligible and will not significantly affect transportation patterns.

5.2.1 Categorizing Businesses: The K-Means Method

In projecting an model of the North San Jose business make-up in 2040, we must first determine the types of businesses existing, and set growth models for each. To do so, we use the K-Means Method to categorize each business. Businesses are classified based on NAICS code, Patron-to-Employee Ratio, Number of Total Patrons, and Sales Volume. NAICS codes are used to classify businesses by industry, and further, more specifically, by use of raw materials, capital equipment, and labor. The latter three classification parameters were chosen to show business type and size, in relation to patronage.
The main goal of categorizing the businesses is to model stronger growth in urban amenity related businesses, such as small shops, restaurants, entertainment, etc. while maintaining even and steady growth in the remaining industries. These will support the population growth and promote the mixed use goal for the North San Jose District. From nai, we can see that "General Retail" falls, under NAICS Industry codes 44-45. "Leisure and Hospitality", which includes museums, spectator sports, and food services, is entered in 71-72. These two industries will be what we look for in our K-Means analysis.

The K-Means Method is a commonly used method to categorize the $n$ observations
into $k$ clusters. To explain the method, let us use a basic example of a two-dimensional data set, consisting of points on a plane. The process is a repeated two-step process. First, $k$ means, as in averages, akin to emission points or centroids, are randomly chosen. Each observation is classified by finding the nearest mean point. New mean locations are then calculated within each cluster, and the process is repeated until there is minimal change between each iteration.

The first step to using the K-Means clustering analysis is to determine the number of clusters that exist among the observations. Since the K-Means method takes in number of clusters as an input variable, we must find this before we can proceed with our categorization problem. Determining the number of clusters focuses on reducing the within groups sum of squares, without overfitting by inducing extra clusters. Underestimating the number of clusters can result in poorly fit categories, due to over-simplifying the problem and trying to fit multiple categories into one. Overestimating the number of clusters can result in an increase in noise generated from the analysis and will reduce the efficiency and effectiveness of analysis.

From 5.1, we can see that there are approximately 5 clusters, or 5 different types of businesses. From 2 to 4 clusters, we see that each additional cluster gives a relatively large and steady decrease within the groups. However, from 6 clusters onwards, the incremental decrease within groups sum of squares is minimal, and even increases slightly. The oscillation after 5 is an example of the overfitting than can occur with over-estimation of the number of clusters.
Figure 5.1: North San Jose Business Categorization: Clustering Analysis via NAICS, Patron-to-Employee Ratio, Patrons, and Sales Volume

<table>
<thead>
<tr>
<th>Cluster</th>
<th>NAICS</th>
<th>Patrons/Employee</th>
<th>Patrons</th>
<th>Sales</th>
<th>Latitude</th>
<th>Longitude</th>
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<tr>
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<td>20.93745693</td>
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<td>37.29025</td>
<td>-121.8996</td>
</tr>
</tbody>
</table>

Table 5.2: Cluster Means from K-Means Analysis of Employers
Using 5.1, we can see how the the industry codes match up to the projected NAICS codes from the K-Means analysis. Since NAICS codes only encompass a subset of integers from 1 to 100, some of the ”average” NAICS codes can be interpreted as a blend of those adjacent. Therefore, while it cluster 1 falls in the ”Trade, Transportation, and Utilities” industry label, cluster 3 is more likely to be made up of a combination ”Other Services” and ”Public Administration.”

The resulting Patrons numbers for each of the clusters, at a high level, reflect correlation between industries and patronage. Cluster 2, classified predominantly under ”Leisure and Hospitality,” is logically much higher than the other clusters.

5.2.2 Morphing to 2040: Generating the Employer and Patronage Outlook in North San Jose

In order to estimate the way through which the North San Jose District will develop, I used the Urban Village concept, as currently being deployed in other areas of the city, as a model for how the area should develop. The goal of attracting industry investment and an increase in local residency by the associated employed professionals can be well met through developing residential areas in-line with the Urban Village goals. By increasing mobility and urban amenity accessibility in the North San Jose District, the City of San Jose can attract companies and employees who wish to avoid wasting time on the home-to-work commute. The increase in urban population density in the area will decrease traffic congestion leaving and entering the city during rush hour for employees and increase company productivity.

The projections of the businesses in the North San Jose District are driven by the Envision 2040 and North San Jose Committee goals. With a target of 80,000-97,000 new jobs, San Jose seeks to sharply increase the productivity and economic output of the North San Jose district.

Some of the job growth will come from the addition of large industry, attracted by
the combination of urban amenities with close proximity between work and home. The other major portion of job growth will come from development in small businesses, that will cater to the anticipated population growth. With regards to the NAICs codes discussed, the two main areas of focus lie in general retail and leisure and hospitality, which from here on, will be referred to as "urban amenity businesses".

In this model, growth rates are approached as job growth rates, measured by employee numbers. Used in conjunction with land usage, the two are combined to estimate the expansion of businesses in the North San Jose District.

Another possible approach would have been to target patronage capacity, and use the projected population growth as the guideline for new businesses. This approach was passed in favor of the first due to uncertainty about estimates of the resident to urban amenity ratio.

Envision 2040 guidelines outline maximum FAR limits at 10 for development in Urban Villages. FAR refers to "floor area ratio." This is calculated by dividing total square feet of a building by the total lot size that it sits on. A higher FAR indicates higher density development, while a lower FAR designation both restricts the number of stories a building can be built as well as the density of land usage.

Using the FAR limits as an estimate for household to business proportion, I estimated that there would be approximately 4 households per urban amenity. This estimate was made by examining both areas designated for Urban Village development in San Jose as well as Princeton, as an example of a walkable community.

Using these guidelines, I generated a potential representation of the North San Jose business and patronage profile. For each category, statistics and characteristics were pulled, uniformly, from the array of existing businesses. Urban amenity oriented businesses were generated first, using the FAR numbers as a guideline for quantity. Locations of the businesses were generated by drawing from census blocks that contained households, proportional to the number of households contained in each block.
Some manual processing was done after the generation to make sure that there wasn’t an overflow of businesses in one single area.

After the urban amenity oriented businesses were generated, the other categories were generated with even job growth. The remaining number of jobs were divvied up based on initial job count. Businesses were generated uniformly by sampling with replacement, from the pool of businesses in the same category. Locations were then assigned, at the census block level, from the pool of existing census block assignments in that category, as FIPS numbers. Finally, the FIPS numbers were converted to census block centroid latitude and longitudes.

### 5.3 Population Estimation

#### 5.3.1 Population Statistics

<table>
<thead>
<tr>
<th>Code</th>
<th>Bracket</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$0 - $9,999</td>
</tr>
<tr>
<td>2</td>
<td>$10,000 - $24,999</td>
</tr>
<tr>
<td>3</td>
<td>$25,000 - $34,999</td>
</tr>
<tr>
<td>4</td>
<td>$35,000 - $49,999</td>
</tr>
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<td>$65,000 - $74,999</td>
</tr>
<tr>
<td>7</td>
<td>$75,000 - $99,999</td>
</tr>
<tr>
<td>8</td>
<td>$100,000+</td>
</tr>
</tbody>
</table>

Table 5.3: Income Brackets
5.3.2 Morphing to 2040: Projecting Households and Residents in the North San Jose District

Running a K-Means analysis again, this time for households, we find 4 household clusters, from which we can generate new households. To do this, census blocks containing at least a single household were subsetted out of the larger census data, and analyzed for household positioning patterns.

Figure 5.2: North San Jose Household Areas: Clustering Analysis via Latitude and Longitude
Table 5.4: Cluster Means from K-Means Analysis of Households

The analysis of the results showed four main clusters of households, which is in-line with our expectations. As can be seen when comparing 5.3 with 5.4, most of the census blocks in the designated planned housing areas already have households. A close examination revealed a few blocks missing.

To project to 2040, a small land increase of up-to 20% of each cluster was allowed.
This was in response to the few missing census blocks and counterbalanced some of the high household density blocks. This was calculated by finding the closest census blocks without households to each cluster center. Out of the 189 census blocks modeled in the North San Jose District, 70 blocks started with households. Approximately 8 distinct census blocks were added, with some clusters overlapping in their choice of nearest unfilled census blocks. These census blocks were then all started with 5 households, with household characteristics and distributions drawn from the census blocks directly adjacent. Initial population was calculated by multiplying totally household number with the average resident to household ratio.

With these initial numbers calculated, the household and population projections for 2040 based on the 32,000 new housing units targeted. Each census block was allocated a number of new housing units based on the number of units it started with in 2010 (excluding those that had been initialized to 5 in the 20% landmass addition), in proportion to the total number of housing units of 40,000. Then,
population numbers were re-calculated, based on the initial resident to household ratio, and rounded to the nearest integer.

Generation starts from the household level. Households in each census block are generated one-by-one. Using the population statistics from the 2010 census, the householder and any additional residents are created. Each person is assigned a FIPS number, household number, gender, age bracket, and income bracket. Then, uniformly distributing across the range, a specific age and income are generated.

5.4 Schools

To adjust for the increase in mixed-use development in the North San Jose District, City of San Jose (2008) discusses the new school development, and re-districting that will be required by 2040.

Students in the Santa Clara Unified District will be re-zoned to the new school proposed. For the purposes of this model, the school is designated as K-12, due to there not being a set location for the new elementary school(s) that could be built, depending on capacity in the other Santa Clara schools.

A small portion of the North San Jose District is zoned into the Orchard School district, which serves elementary and middle school only. Travel to the highschool currently assigned to the Orchard Elementary school doesn’t lie along light rail routes. For the purposes of modeling the predominantly intra-district travel dynamic that is the target of the North San Jose development, this model assumes that all travel in and out of the district occurs solely at light rail stations. Therefore, in this model, the small portion of highschool students in the Orchard School district are zoned to the new school to be developed in the Santa Clara Unified District.

Based on map examination and comparison, the new school was determined to be approximately situated at (37.405671, -121.936149).
School attendance is set to be 100% for all children between the ages of 5 and 15. For children between 16 and 19, attendance is estimated at 80%, from the 2000 SF3 Sample Data.

With regards to higher education, Santa Clara University is situated just outside of the North San Jose District zone. However, accessibility is poor due to no direct light rail access and the positioning of Mineta San Jose International Airport in-between the district and the University. Combined with the small number of residents between the ages of 18 and 22, with regards to the model, it is assumed that a negligible number of students from the district attend the university. Therefore, higher education travel patterns are omitted from the model.

5.5 Data Retrieval

5.5.1 Census and Population Statistics

Population statistics were pulled from the 2010 Census as well as 2012 ACS 1-Year estimates, both through the census’ Fact Finder portal. Data read in was manually re-formatted to reflect

\[ P(Criteria|PreviousLevel) \]  \hspace{1cm} (5.1)

For example, in the case of household statistics, columns represent \( P(\text{householder} = \text{female}|\text{householder}) \) and \( P(\text{householdhasspouse}|\text{househousehold} = \text{family}) \).

5.5.2 Employer and Patronage Statistics

Data for the employers in the San Jose, and subsequently North San Jose were drawn from the InfoGroup 2012 database, and accessed from the data repository for the ORF 467: Transportation Systems Planning & Analysis class. Data for San Jose was
subsetted from the data for the entire United States, and the North San Jose data, specifically, was subsetted by matching census tracts.

Employee to patronage ratios for businesses in New Jersey were determined and refined by Professor Kornhauser, Jake Gao ’13, and previous ORF 467 classes through a combination of research and intuition. Ratios subsequently, for the entire United States, were inferred using the New Jersey base, by Judy Sun ’14, through location and NAICS code matching.

In order to examine the employer and patronage dynamics in the North San Jose District, businesses were linked with the census block that they were contained in. The employer data came with a latitude and longitude location for each business. However, further processing was required due the census blocks being identified only by centroid location (latitude, longitude), and FIPS number.

In order to locate each business, FIPS numbers were located for each by parsing for the census block that contained each latitude and longitude combination. Each census block is assigned a unique FIPS code, that is a 15-character code. The code is the concatenation of fields consisting of the 2-character state FIPS code, the 3-character county FIPS code, the 6-character census tract code, and the 4-character tabulation block code. Using the API from the Federal Communications Commission, FIPS codes were obtained for the census block each business is located within.

Information about employment hours by industry was obtained from the 2007-2011 American Time Use Survey. Data was matched to employers via NAICS industry number assignment.
Chapter 6

Trip Generation Methodology

6.1 Hiring Employees

A major portion of trips each day are taken between home and work. For this model, employer and employee matching is carried out based on income vs salary match, travel distance, and industry affinity.

Data for this portion is pulled from the 2011 American Community Survey 1-Year estimates. In this case, working individuals are residents between the ages of 16 and 65, who are not in school. Those above 65 are labeled as retired, and those in school are full-time students. In this model, we will assume a close to 100% employment rate, of those of working age. This assumption will bias our data slightly, with a higher ratio of home-to-work trips in comparison to trips made to urban amenities.

For each employer, a job listing is created for each of the openings the employer is pursuing to hire for. Wages paid for each position are based off of the Industry by Median Earnings in the Past 12 Months (2012 Inflation Adjust Dollars) data file. Assuming that the earnings are normally distributed, each opening is assigned a wage amount using the median earnings as the average, and the margin of error as the standard deviation. In this case, since we are assuming that the wages are
normally distributed, it is acceptable to use the median as the mean of the simulation
distribution, with the assumption that the sample through which the median was
arrived at was sufficiently large.

Simulating real-world socioeconomic conditions, employees are sorted so that
higher-paid employees get first choice. Employees pick, in order, their preferred po-
sition, based on wage match, location, and finally, weighted by industry preference.
Industry preference is first simulated using a uniform random variable, which decides
the industry the resident will choose. Then, amongst the positions available within
that industry (based on NAICS codes), the resident will choose the opening of best
fit. If no position is available, then the industry preference is re-chosen until there is
one available.

Openings are ranked based on their employee appeal index. Employee appeal is
based on two aspects: 1) wage match and 2) location proximity to home. Wage match
is calculated by:

\[
\text{wagematch} = \frac{|\text{employee income} - \text{employer wage}|}{\text{employee income} + \text{employer wage}}
\] (6.1)

In this case, we normalize with respect to the average of the employee’s and
employer’s compensation expectation. The best match is attained when the wage
match is 0.

Location proximity is calculated slightly differently. First, distances are calculated
based on the longitude and latitude of the employee’s household and the employment
location. This is done using the Haversine formula
\[ \Delta \text{longitude} = \text{longitude}_{\text{home}} - \text{longitude}_{\text{work}} \tag{6.2} \]

\[ \Delta \text{latitude} = \text{latitude}_{\text{home}} - \text{latitude}_{\text{work}} \tag{6.3} \]

\[ a = \sin(0.5 \times \Delta \text{longitude}) \tag{6.4} \]

\[ b = \sin(0.5 \times \Delta \text{latitude}) \tag{6.5} \]

\[ D = R \times \arcsin(\sqrt{a^2 + \cos(\text{latitude}_{\text{home}}) \times \cos(\text{latitude}_{\text{work}}) \times b^2}) \tag{6.6} \]

As generally used in the ORF 467 class, five minutes is assumed to be the maximum time a person is willing to wait for mass transit. At average walking pace of 3.1 miles per hour, the average person can cover just over a quarter of a mile in that time.

As is the case, let us define all trips within 0.5 miles in distance to be walking trips. Trips above 0.5 miles in distance can be addressed by the autonomous transit system. Given the maximum wait time, trips between 0.5 miles and 0.75 miles can be completed either by autonomous transit or walking. Thus, we make the assumption that although trips above 0.5 miles can be catered to by autonomous transit systems, it is only trips above 0.75 miles that are worth the fare of taking autonomous transit. Furthermore, trips that are longer are in fact preferred to trips that are just above the cut-off, due to the cost of taking public transit. Therefore, trips that are in-between preferable walking distance and preferable transit distance are actually less preferable, despite being marginally closer.

Let us denote \( d = \text{distance(home, work)} \) as the distance between the two locations.
This means that we have set the optimal driving distance at 2.5 miles. In this case, we are trying to maximize the proximity factor. The curve is set up so that the proximity factor is maximized when work is within walking distance of home, and then reaches a local maximum when work is a short drive from home. However, once we reach past 2.5 miles in distance, the distance begins to severely discount the opportunity. This is in line with the district’s desire to minimize travel away from the North San Jose area for work.

Working individuals are first categorized into an industry based on industry vs gender and median earnings. Employee appeal is then calculates as

\[
appeal = \frac{proximity\ factor}{wagematch}
\]  

In the rare case that wagematch is 0, and the calculation would result in an error, wagematch is artificially set to 0.001.

Both data files referenced in this section are located via the US Census Bureau’s FactFinder portal, by subsetting the three census tracts encompassing the North San Jose District area.
6.2 Going to School

As mentioned above, students who go to school will all be routed to the new local Santa Clara Unified District school for modeling purposes. In practice, some students would independent elementary schools, but due to uncertainty about location, this assumption has been made to streamline the modeling process.

Higher education attendance will not be modeled in the North San Jose district, due to the projected negligible attendance from the area.

6.3 Patronage

Similar to the employee modeling, patronage is modeled based on anticipated demand from the business side. For each patronage required, residents are sorted by a patronage factor

\[
\text{patronage}_{\text{employed residents}} = \frac{\text{business}_{\text{total patrons}}}{\text{circuity measure}}
\]  

\[
\text{patronage}_{\text{student}} = 0.3 \times \frac{\text{business}_{\text{total patrons}}}{\text{circuity measure}}
\]  

\[
\text{patronage}_{\text{retired}} = \frac{\text{business}_{\text{total patrons}}}{0.5 \times \text{circuity measure}}
\]

The circuity measure measures the degree to which the additional stop increases travel distance to the base home-to-work scenario.

\[
\text{circuity}_{\text{employed residents}} = \left( \frac{\text{additional distance to business}}{\text{distance from home - to - work}} \right)^2
\]

In the case that the extra stop is exactly along the way, and adds zero distance, then the additional distance parameter is automatically set to a base level of 0.001,
to account for the cost of stopping.

For both students and retired residents, the majority of patronage stops are expected to occur as travel from home. Therefore,

\[
circuitystudent = \left( \frac{additional\,distance\,to\,business}{average(distance\,home\,-\,to\,-\,work)_{census\,group}} \right)^2 (6.13) \\
circuityretired = \left( \frac{0.3 \times additional\,distance\,to\,business}{average(distance\,home\,-\,to\,-\,work)_{census\,group}} \right)^2 (6.14)
\]

Residents are sorted by their patronage factor, for each business, and assigned to a business for patronage based on the demand from each business. Residents are also excluded from their own working place, due to the nature of the circuity factor. Residents are capped at 5 at 7 patronage locations, after which they are excluded from the rankings.

### 6.4 Trip Time Assignment

#### 6.4.1 Work

Work arrival times are determined based on information from Bureau of Labor Statistics (2011), which details the percent of people working on their main jobs during each hour of the day. The data provides a base arrival time for employees. Arrival times are then generated for each employee using a normal distribution with standard deviation of 15 minutes. Corresponding departure times from home are calculated by first calculating distance traveled, and then to time traveled based on mode of transport (walking or autonomous car). We assume that the autonomous cars travel at an average of 35 mph, due to the local nature of the travel.

All employees work 8.5 hours per day, as a base model. Specific departure times are generated based on a normal distribution with mean set at anticipated departure
time, and standard deviation of 60 minutes.

6.4.2 School

School arrival is set based on the start of class, with arrival times for each student normally distributed with the mean set at 10 minutes before the start of class, and standard deviation of 8 minutes. This was intended so that tardy rates would be less than 20%. Departure times are calculated based on distance from school, and then mode of transportation.

The school day is set to run from 8AM to 3PM. Departure from school is again normally distributed, with mean 10 minutes after 3PM. Standard deviation is set at 90 minutes, to account for extracurricular activities. The departure times are artificially right skewed as all departure times are chosen to occur after 3PM. During departure time generation, simulation continues until simulated time, under the normal distribution, meets the required minimum.

6.4.3 Business Patronage

Business patronage arrival times are constrained between 6:00AM and 11:59PM. Patronage arrival times are generated based on time use information from Bureau of Labor Statistics (2011). The reasoning lies in that patronage ebb and flow should match employee ebb and flow. With the exception of lunch, to be discussed below, arrival times are simulated and re-generated so that all arrival times occur outside of school and work hours, accounting for transit time in-between. As with the work arrival times, patron arrival times are normally distributed with a standard deviation of 15 minutes.
6.4.4 Linking Trips

Using patronage arrival times as the indicator, whether or not residents travel home in-between is determined by intuition. Average patronage length is set at 2 hours, with a 1 hour standard deviation. Initial patronage duration is randomly generated, using the normal distribution, for each patronage destination. Patronage duration is constrained by the next arrival time for each resident. Therefore, duration is calculated as

\[
\text{departure} = \min(\text{arrival}_{\text{next, business}}, X \sim \mathcal{N}(2, 1))
\]  
\[
\text{duration} = \text{departure} - \text{arrival}
\]

If the projected duration time runs past the allotted segment before arrival at the next location, departure is calculated based on time required to travel from current location to next destination.

If the projected duration time is less than the time between tentative departure and arrival at next patronage, then it is possible for the resident to travel home. Travel home is only allowed if the transit time from patronage location 1/work to home to patronage location 2 is less than the time between projected departure from the first location and arrival at the second location.

If the length of time in-between is long enough, then whether or not the patron travels home vs. stays at current location until next trip is determined by the ratio

\[
\frac{\text{timein} - \text{between} \text{departure and arrival}}{\text{durationspentatcurrentlocation}}
\]

A uniform random variable is generated, between 0 and 1. If the random variable
is less the ratio calculated, the resident travels home and stays until time for next
departure. If the value is greater than or equal to the ratio calculated, the resident
stays at the current location and does not go home in between patronages. This ratio
favors residents staying longer at a location as compared to traveling continuously to-
and from- home. It essentially builds a cost structure for decision of whether or not
to return home.

If the current location is the final patronage location for the day, then the resident
immediate travels home after staying for the duration estimated.
Chapter 7

Results and Analysis

7.1 Population Growth and Development

For the North San Jose District, the potential increase in households and mixed use neighborhoods stand to significantly increase business, both physical and transaction, within the district.

The 2010 US Census showed 6,948 households, housing a mere 15,438 residents. The infrastructure of the city was such that housing density remained low and local businesses remained few. In census blocks zoned for housing, subsetting those with at least a single household unit, density was on average, 91 units per block. At a maximum of 10 FAR, each census block would house the equivalent of 9 households in 2-dimensional area.

The morphing process guided by both the Envision 2040 plan and the North San Jose development committee targeted a 366% growth in housing units. The result: 38,951 households residing in the North San Jose District, with a total of approximately 86,500 residents in total. Housing density will projected to rise tremendously, increasing the density of residential areas that, when combined with the addition of urban amenity oriented businesses, will dramatically improve the walkability of
neighborhoods in the district.

The new urban growth also dictates a change in business distribution. With the projected urban amenity growth rates, urban amenity related jobs account for more than half of the targeted 80,000 - 97,000 new jobs in the area. However, the industrial growth that is the underlying focus of the "Innovation Triangle," isn’t lost, but rather, re-distributed. In increasing residential development and mixed usage, the North San Jose District redefines itself as a locale enticing to employees of local industry for residency.

7.2 Mobility Implications

The focus of implementing an autonomous transit system in the North San Jose area is to take advantage of the planned increase in urban density and improve mobility while reducing the necessity of car-ownership. Autonomous transit provides quick on-demand service while eliminating the costs that traditional taxis and buses incur by running during low traffic times.

For the North San Jose district, preliminary trip analysis shows tremendous walkability. With the cut-off distance set at 0.75 miles, we see that approximately 30% of trips could be walking trips. On average, trips are 1.47 miles long, with non-walking trips averaging closer to 1.94 miles. This means that average autonomous transit trip times lie between 3 to 5 minutes, perhaps slightly more if traffic levels are high.

The implications for mobility are tremendous, in that regard. The main constraint on effectiveness of the autonomous transit system is the response time of the autonomous vehicles. With such short transit times, a comparatively large wait time would decrease the attractiveness of such systems.

Shared ridership is viable during peak transit hours. This is in large part due to the high density of both households and businesses. Initial analysis modeling transit
from census block to census block has shown that average shared ridership is around 2.5 - 4 people, depending on census tract, during daylight hours.

What this model has shown is that car ownership would be completely unnecessary for residents of the North San Jose area if a autonomous transit system could be effectively implemented. With ready access to downtown San Jose and the rest of Silicon Valley via light rails, travel outside of the North San Jose area can be effectively accommodated. However, as shown by the trip modeling within the North San Jose area, daily urban amenity access can be fully accommodated by the local businesses.

7.3 Environmental Impact

The potential reduction in energy footprint in the transit around the North San Jose district is tremendous. Estimates from the 2012 American Community Survey 1-Year Estimates for Workers 16 and Over show that over 76% of workers drive alone to work, everyday, in Santa Clara County. In contrast, a mere 3.5% took public transportation (excluding taxicabs). Furthermore, only 1.6% of people walked to work.

In contrast, the mobility and transit options in the North San Jose area, created by an environment of high density development with mixed use land use emphasis, can transfer the majority of trips from single car driver to shared vehicle or walking trips, without losing efficiency. In fact, the close development of the area means that people live close to where they work and close to where they eat and play. For a city that is suffering form the environmental as well as economic side effects of urban sprawl, San Jose could greatly benefit from the implementation of an effective urban autonomous transit system.

Although preliminary analysis in the context of an autonomous transit system to and from Mineta International Airport has been conducted (Paige, 2012), exploration in the context of urban centers and household oriented development zones has yet to
be explored fully. The initial modeling within this thesis shows a tremendous benefit to reducing carbon emission both from ridership inefficiency and high car ownership rates.
Chapter 8

Special Assessment Districts:
Funding New Development Projects

Funding infrastructure and transit development projects is an expensive endeavor, especially during a time in which the after-effects of the economic downturn are still being felt. The urban rail development of the 1970s in Washington DC, San Francisco, and Atlanta were funded entirely by the public sector. Each project required a huge commitment from the public sector, and resulted in continuing maintenance and funding problems (Fogarty et al., 2008).

The value of TODs lay not only in their macro-structure benefits, but also their effect on improving local communities. From a city’s point of view, TOD builds local infrastructure, improves pedestrian linkages, and increases property tax bases. For local communities, improved connectivity often signals higher density development, which can significantly increase foot fall for local businesses.

The concept of special assessment districts seeks to tap into the local benefits that come from public infrastructure development. As Mathur (2014) details, community
involvement in funding and developing transit can be quite substantial. Examples such as the Seattle Streetcar, funded more than half by local involvement, show the degree to which property owners recognize the value that TOD brings to their businesses and properties. The development of the New York Avenue Metro Station in Washington DC was able to raise $25 M in proposal of opening a new station in an area where property values had seen a vast decline with the exit of local businesses.

SADs can operate in many ways, although one of the more widely used ways involves charging property owners fees. These assessment are in proportion to the benefits that property owners would experience. Effective value capture is critical to the successful deployment of these SADs but has been proven to be possible (Neto et al., 2013).

As Smith and Gihring (2006) writes, although substantial research has been done with regards to property valuation in relation to proximity to stations, now is the time to test practical applications of value capture. In the context of the North San Jose district, the emphasis on mixed use and industry development position the area well for a public-private TOD oriented collaboration. TOD, through improving local mobility, can transform the area to become one of net import, becoming a center of both business and urban amenities for the surrounding area.
Chapter 9

Implications: Property Valuation and Traffic Pattern Changes

9.1 Property Valuation: Value Increases Related to Transit Oriented Development

Transit oriented development (TOD), has been shown in multiple case studies, to significantly increase property values. As Kay et al. (2014) discusses, TOD development and station proximity affects local property valuation not only through it’s local connectivity, but also more significantly, in it connectivity to large city centers. As demonstrated on the east coast with property near New York city, value was positively correlated with distance to and accessibility of stations. Similarly, Pan et al. (2014)’s comparison of transit in Houston vs Shanghai shows the growth potential that comes from increasing connectivity in urban areas.

Both ? and citetKay2014 emphasize that property valuation is directly related to proximity to rail stations. This means that property value is correlated with accessibility of rail stations. For rail development, as shown in 4.2, station close station proximity, within walking distance, is limited. Development of additional rail stations,
which would increase the area of property valuation rise, is expensive. In contrast, an autonomous transit system would require minimal infrastructure development, and would tackle the key issue of connectivity and accessibility to transit lines. By expanding developing on-the-ground transportation, cities could further leverage the benefit of the rail-lines in place. Combining convenience with accessibility, an autonomous transit system has much more potential than traditional bus systems to deliver a strong investment return and provide a highly used source of connectivity.

In the context of funding TOD development projects, such as the autonomous transit system that this thesis is proposing, the additional property valuation is a potential source of community engaged infrastructure development. More will be discussed below.

9.2 Traffic Pattern Changes

In the context of mixed-use development, it is possible for the North San Jose area to fully support its own population as well as serve as a business center for the surrounding area. Most importantly, mixed-use development can change the commute dynamic for the area, and focus employee residency within close proximity to work. This sort of change and move of professionals into the area would boost intra-district travel via local mass transit and local rodes rather than inter-city travel, bottlenecked on the area freeways.

Situated to the north of the city, North San Jose would also be able to take advantage of the reverse traffic trends if it can position itself as an industry center and attract new investments. Rather than traveling with traffic towards San Francisco, and therefore face congestion both directions, employees living in surrounding cities to the north and also working in the Innovation Triangle would be able to move in the direction opposite the crowd, and dramatically reduce transit time. The increase
in productivity, attractive to both employers and employees, would reinforce North San Jose’s development as an urban industry center.
Chapter 10

Conclusion

North San Jose development has been a key priority for the city in its goal to redefine the San Jose urban area in the context of Silicon Valley. Currently primarily an industrial zone, targets have been set to redevelop the area into a partial mixed-used community that would increase traffic and retention in the area. This thesis sought to analyze the potential impact of an autonomous transit system and project the regional development and traffic demands for the 2040 deadline.

The analysis and model developed have shown that the population and job creation targets for the North San Jose District, or "Innovation Triangle," position the area to become an urban center high levels of mobility amongst its residents. The efficiency and effectiveness of an autonomous transit system would promote ride-sharing, and could address all intra-district travel needs, thus removing the need for individual car ownership. From the analysis conducted, we can see that autonomous transit within the district can efficiently address travel demand while also significantly increasing shared ridership to reduce the district’s carbon emission footprint.

In developing along the lines of an urban village, with emphasis on urban amenities, the North San Jose district could attract an increase in investment from industry and also an influx in residents from the young urban professional population that de-
sires the access and convenience an urban environment can provide. In targeting corporate employers, the North San Jose district can develop itself as a vibrant district with a strong array of local businesses, attractive to not only its local residents but also those from surrounding communities. By increasing efficient connectivity within the district through autonomous transit development, the North San Jose area would see an increase in both foot traffic and local residency.

Further model development would focus on improving travel pattern estimation as well as traffic in and out of the district. The current analysis makes some simplifying assumptions to create a model of traffic patterns in the region, but is less robust in analyzing the potential traffic import the North San Jose district could develop from its surrounding neighbors. Trip refinement and patronage estimation can also be improved with a more accurate representation of the cost and benefits of patronage. Currently, costs are modeled with a simple analysis of circuity, but a more robust cost-benefit analysis would result in a more accurate model.
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