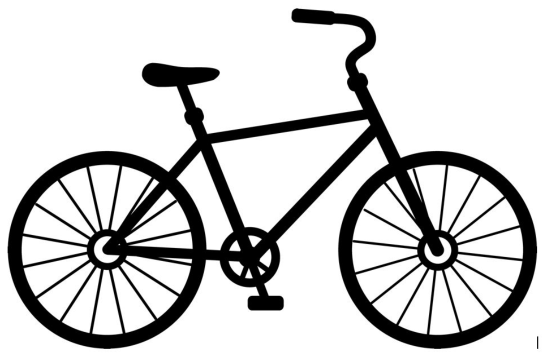
Advanced Bikeways for Enhancing Cross-Regional Mobility in the Mid-Peninsula



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1. EXECUTIVE SUMMARY

Due to major economic and population growth in the Mid-Peninsula, communities are struggling with increased traffic congestion despite increases in some public transit use. Joint Venture Silicon Valley (JVSV) has facilitated the Manager's Mobility Partnership (MMP) working group -- a coalition of Redwood City, Menlo Park, Stanford, Mountain View, and Palo Alto -- whose interests include creating an interconnected regional bike network. JVSV and the MMP engaged the Senior Practicum to develop proposals for advanced cross-regional bikeways. This report proposes two alternatives for a North-South (N-S) central corridor bikeway that promotes cross-community integration and increased bike mode share.

In order to propose worthwhile bikeway designs for regional integration, it was imperative to first understand the demographics, commuter data, and priority destination hubs of each community. Our research showed that significant numbers of people are commuting both across community borders and within potential biking distance. We also identified the N-S central corridor of the Mid-Peninsula as a prime location for an advanced bike path. The N-S central corridor is defined by the Redwood City-Mountain View axis and within one mile on either side of the Caltrain track. This axis is optimal, as it runs through the communities' downtown areas, is accessible to people who live both to the East and West, and connects to major employment centers. Additionally, there are no existing bike routes explicitly designed for connecting these communities, thus creating an optimal opportunity for cross-regional integration.

The route selection and design was informed by our understanding of cycling demographic. We learned that cyclists can be divided into four categories: Strong and Fearless, Enthused and Confident, No Way No How and Interested but Concerned. The greatest proportion of cyclists are considered to be Interested but Concerned, so increasing bike mode-share would come mostly from this category. We found that safety concerns are the major barrier that prevent the Interested but Concerned category from choosing biking as a mode of transportation, so creating cyclist safety became a main priority in our bikeway designs.

The next phase of our research entailed understanding different bike lane design alternatives in order to explore infrastructure possibilities, as well as the needs of the communities. We identified five bike lane classifications, Class I through IV and the bike boulevard. Class I bicycle facilities are off-road paths and trails. Class II facilities designate an on-road bicycle lane demarcated by painted lines. Class III has no specified lanes, only general signage designating a bike route. Class IV bike facilities are protected bike lanes that are separated from the vehicle travel lane by a physical barrier. Finally, bicycle boulevards are streets that prioritize bicycle transportation through a number of traffic-calming strategies to ensure the ease and safety of cyclists.

We then looked into bicycle infrastructure and policy in places such as Scandinavia, an area of the world with high bike mode-share, and U.S. cities like Portland. We also reviewed the research literature, and many studies determined that separated bikeways, such as Classes I and IV, increase bike mode-share more than other classifications. In addition, we researched the most current designs and guidelines available in resources such as NACTO (the National Association of City Transportation Officials) *Urban Bikeway Design Guide* and the Federal Highway Administration (FHWA) *Separated Bike Lane Planning and Design Guide*. We reviewed the recommended guidelines from the Rails with Trails Conservancy that provides resources for construction bike paths along active rail lines like Caltrain.

We determined that in order for a route to stimulate a significant increase in bike mode-share, it should include the following five properties:

- ❖ **Perception of Safety:** How safe riders think they will be on the road. It is achieved through protected bike lanes, protection in intersections, and generous space.
- ❖ **Directness:** Our goal is to give commuters the luxury to ride their bicycles to their places of work on the most direct route, which is defined for the remainder of the paper as a function of distance, simplicity and time.
- ❖ **Advances in Overall Bike Network:** Advances in the overall bike network would include an increase in (1) the overall mileage of bikeways and (2) the connectivity of these bikeways across the Mid-Peninsula.
- ❖ **Proximity to Trip Attractors and Generators:** The proximity to trip attractors and generators captures how close the route runs to places where people typically originate and terminate trips.
- ❖ **Ability to Accommodate E-Bikes:** Due to their growing prevalence it is important for us to evaluate whether future bike infrastructure developments can accommodate e-bikes.

The subsequent phase of our research included determining current N-S route options. To establish a benchmark for any new proposed bikeways, we studied an existing 12.26 mile linked set of streets from Redwood City to Mountain View that is being considered for designation as a inter-city route. The route includes a combination of Class II, III, a bike boulevard, and streets with no bike infrastructure, and primarily utilizes secondary roads to avoid high stress intersections. However, the route has some limitations, including the complexity, lack of signage, number of intersections, and perceived lack of safety. With this, we gained a greater understanding of the existing cross-regional infrastructure, which propelled us to endeavor to design our own.

Our first proposed bikeway location is El Camino Real. It is a major thoroughfare spanning the MMP communities with access to shops, services, transit, schools, and employment. The route is very direct and fast. Additionally, bicyclists are already on El Camino, although the site has high collision and fatality rates. Advanced bike infrastructure can be implemented to significantly improve actual and perceived safety, and increase bike usage.

Using NACTO and FHWA design principles, we present two bikeway design alternatives for enhancing bike travel on El Camino Real:

The first alternative is side-running one-way bike lanes on each side of the roadway., protected from motor vehicle traffic by raised curbs. Essentially, these lanes would replace the current parking lane along El Camino Real. Intersections, driveways, and bus services present potential challenges while navigating this bike design. Additional features can be included to mitigate the challenges. For instance, implementing specific turn arrows or bike lights and creating lateral shift intersections are two options for intersections. A potential solution for driveways is including raised or enlarged barriers to create wider, slower turns for motor vehicles. Lastly, an island platform transit stop or central-running bus services can be implemented in order for the side-running lane to work in conjunction with bus services.

The second alternative for El Camino Real is a two-way central bikeway protected from motor vehicle traffic by raised curbs. The bikes lanes would be created in place of the existing median.The advantage of this alternative is that parking lanes do not have to be eliminated. Entering and exiting this bikeway could present a challenge; however solutions are available to ensure safety for the cyclists. One solution is to include signage indicating that cyclists must walk their bikes between the sidewalks and the bikeway via the crosswalk. A more difficult challenge of the central bikeway is managing left-turns for cyclists and drivers in order to avoid collisions. Installing stoplights with distinct signals for cyclists and drivers turning left could provide clarity. Signage could be installed informing travelers that cyclists have the right-of-way to turn left before motor vehicles. Another intersection treatment is to paint the bike lanes green in the intersections and to implement bicycle turn queue boxes in order to increase visibility of cyclists.

The second proposed location for a bikeway is primarily along the Caltrain corridor. Active train tracks with bikeways running alongside are known as "rails-with-trails." The Rails to Trails Conservancy has identified 161 Rails-With-Trails in 41 states. A route alongside the Caltrain provides many benefits due to its location and its separation from automobiles. The proposed Caltrain bike route is mostly a Class I bikeway, with some Class IV portions, limiting contact with motorized traffic.

There are three main safety design modifications that we recommend, operating under the assumption that high speed rail will be implemented on the Caltrain corridor by 2029. We propose a setback distance, the distance between the paved edge of an RWT and the centerline of the closest active railroad track, of 20 feet. e propose a solid barrier rather than a simple fence in order to protect pedestrians and bicyclists alike from high speed rail sound, vibrations and wind. The last component would be to create grade separation for major cross-streets so they go under the Caltrain and Caltrain bike path. For minor cross streets a stop sign or light would control the intersection.

There are also challenges for a Caltrain bike path from the limited available right of way in certain places. In some spots we reduce the setback distance from 20 feet to 17 feet. Another solution is to have the path switch from one side of the railway tracks to the other using a bike underpass/tunnel a total of five times. In some segments, such as to get around a Caltrain station, we switch to a two-way Class IV bike lane on an immediately adjoining road. Caltrain currently opposes giving up any right of way for bike paths. Where rails with trails have been achieved, the railroad have often been reluctant, and Caltrain did grant an easement several years ago for the Embarcadero Bike Path.

We estimate the construction cost of the El Camino Real bikeway to be $18,040,000. The individual inputs to the route along El Camino include 11.6 miles of a Class IV bikeway, concrete barriers that separate the cycle tracks from motorized vehicles, 85 regular intersections with marking improvements, and 25 protected intersections.

It is useful to break down our construction cost estimate for the Caltrain route into three components. The first includes everything but the soundwall and under-crossings for major streets, and totals an estimated $37 million. The second component is the soundwall, at an estimated $17 million, and the third is the eight undercrossings where major cross streets will go under the Caltrain/bike path grade, at a total of $216 million (~27 million each). The total for all three is $270 million. However, the second and third cost components may need to be incurred whether or not a Caltrain bike path is constructed; the soundwall to protect current uses directly adjoining Caltrain from high speed rail impacts and the under-crossings for major streets to deal with traffic interruptions from increased train frequency. Taking away these two major components, the cost of the Caltrain bike route drops to around $37 million.

The final section of our report ranks each alternative in terms of potential impact on bike mode share and cost. Our assessment of how each alternative will impact bike mode-share is qualitative as opposed to quantitative, and relative as opposed to absolute. We use the extent to which each alternative successfully addresses the five desirable properties of bikeways to assign a relative ranking on the bike mode-share impact. The El Camino Real route outranks the base case route on four of the desirable properties and ties on one (e-bikes). The Caltrain route outranks the base case route on four of the desirable properties and ranks lower on one (e-bikes). Both of these routes have the potential to increase bike mode share more than the existing route as represented in the base case. We assign a higher impact on mode share rating to the El Camino Real route than the Caltrain route. While Caltrain slightly surpasses ECR in terms of perception of safety, it does not add as much in connecting major attractors and generators and is less suitable for e-bikes, a potential significant source of future growth.

In our overall ranking of the route alternatives, we consider cost together with impact on mode share. Even at the lowest estimate for the incremental cost of the Caltrain route, its costs is still twice as much as the El Camino Real route. In addition to the El Camino Route being cheaper, we have rated it has having a higher potential impact on bike mode share. So clearly El Camino should be assigned a higher overall rating than Caltrain. We believe that the potential for increased bike share mode also justifies a higher rating for the El Camino route relative to the base case, even considering the former's $18 million cost, and for the Caltrain route relative to the base case, if we consider only the $37 million cost. If the incremental cost of the Caltrain route were $270 million, it would require more analysis for justify ranking it over the base case.

We suggest that the MMP examine the effects of these bikeways on their impact on equity in the surroundings communities. We also suggest that other eastern and western routes be examined since people interested in cycling as a method of commuting are looking for convenience, meaning they are not willing to go significantly out of their way to use a bike lane. Finally, the political feasibility of the routes and designs needs to be analyzed.

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Table of Contents

3. Introduction

Of the 85,000 new residents who arrived in the Bay Area in 2014, 40,000 settled on the peninsula.[1] The rate of population growth at this time was around 1%, higher than that of both the state of California and the country. Economic expansion in the Mid-Peninsula drives population growth. Tech companies like Facebook, Google, and LinkedIn already employ tens of thousands of people yet they are constantly expanding, adding new jobs and attracting more people to settle in Silicon Valley. Population and job growth rates are projected to remain near 1% at least until 2025.[2]

Though economic expansion has its benefits, it is critical to remain cognizant of the problems it creates as well. In addition to growth in jobs and tax revenues for local governments, the Mid-Peninsula's economic boom has caused an unprecedented surge in housing prices, fueled gentrification, and exacerbated income inequality. Further, Mid-Peninsula communities are struggling with increased traffic congestion despite increases in public transit use[3]. Problems associated with traffic congestion include collisions, injuries, and fatalities; wasted fuel while vehicles idle; late delivery charges; and losses in productivity hours.

One simple yet high-potential solution to addressing these transportation challenges is a greater reliance on the bike. The flat topography and moderate climate of the Mid-Peninsula region are ideal conditions to allow for cycling as a major mode of transport. In addition to reducing the number of motor vehicles on congested roadways, increasing bike mode-share can be beneficial for environmental, community, and individual health.

This report proposes two potential route alternatives, and three design alternatives, for a north-south central corridor bikeway to promote cross-community integration among Redwood City, Menlo Park, Palo Alto, Stanford, and Mountain View -- five communities working collectively on transportation challenges as the Manager's Mobility Partnership. To begin, we provide general background, detail our methodology, and present key findings of our initial research. Next, we outline the desirable route and infrastructure properties that an effective cross-regional bikeway should incorporate. Then, we describe an existing north-south route as a base case to which we compare our alternatives. Following the base case is a detailed discussion of our proposals for

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[1] Levy, Steve. "The Four E's--Population Growth in the Peninsula and Region." Palo Alto Online. July 18, 2015. http://www.paloaltoonline.com/blogs/p/2015/07/18/the-four-es--population-growth-in-the-peninsula-and-region
[2] "The Four E's"
[3] "The Four E's"

two potential, alternative north-south cross regional bikeway routes. We then evaluate these alternatives relative to the base case using the criteria of potential impact on commuter bike mode-share and construction cost, and make recommendations. We conclude by discussing the limitations of our analysis and potential directions for further study.

4. Client and Project Scope

Joint Venture Silicon Valley (JVSV) brings together leaders in business, government, academia, labor and the nonprofit sector to tackle problems within the region. Joint Venture Silicon Valley helped facilitate the formation of the Manager's Mobility Partnership (MMP). This collaborative effort includes the city Manager's of Menlo Park, Mountain View, Palo Alto, Redwood City, and the senior associate vice president (emeritus) of Stanford University. These representatives “have agreed to work jointly to address the transportation and mobility challenges facing the region in the wake of population growth and economic expansion” (MMP Guiding Principles).

One of the solution areas of focus for the MMP is “Enhancing our bicycle lanes and associated infrastructure, with a goal of creating an interconnected regional network by addressing gaps at city boundaries, safety concerns, and the impediments caused by railroad tracks, freeways and major roadways.”

The JVSC and MMP initially asked our team to analyze the potential for cross-region Class I and Class IV bikeways and prioritize them relative to other biking and transportation initiatives. At our initial meeting with the JVSC and MMP representatives, the scope of our work was refined to focus on developing proposals for cross-region bikeways that would significantly increase bike mode-share in the Mid-Peninsula. This refinement was based on the amount of work that would be needed to develop and evaluate possible routes in the ten weeks available for our team practicum project. Our project would be a first step in a process of creating an ideal bike network for the Mid-Peninsula. Future research and planning should be considered regarding other transportation initiatives to further increase bike mode-share and develop comfortable, efficient travel throughout the area.

5. Methodology and Research Stage Findings

Given our policy question and the parameters of our scope, we began our work by conducting research in four key areas: existing conditions within the MMP communities, priorities for route selection, cyclist segmentation, and infrastructure design principles.

5.1 Existing Conditions within the MMP Communities

Though the MMP communities span only thirteen miles, their local contexts vary greatly in regards to city layout, per capita income, and bike lane agendas. In order to propose worthwhile bikeway designs for regional integration, it was imperative to first understand the demographics, commuter data, and priority destination hubs of each community. These findings are summarized in Appendix 11.6. Through a review of the existing and proposed bike networks within each community, we identified high-priority and high-potential corridors for a cross-regional bikeway. Using the Longitudinal Employer-Household Dynamics from the Census Bureau and the accompanying “On the Map” visualization tool, we studied general housing and employment concentrations in the region. After identifying four major employment concentrations in North Mountain View, South West Palo Alto, North Stanford, and Central Redwood City, we mapped where the employees who work in these areas live (these maps can be found in Appendix 11.2). This analysis shows that significant numbers of people are commuting both across and within community borders, and within potential biking distance.

5.2 Route Selection

Based on our community research, we developed recommendations that focus on best practices for optimizing bike transportation within the central corridor. With information from the “On The Map” technology, which tracks population along with commute information, we were able to locate data on employment hubs and where those employees live. From the mapping technology, we noticed that the majority of commuters from each city, travel through the center of the Mid-Peninsula. Additionally, data from the US Census and the Longitudinal Employer-Household Dynamics show how far people travel for work. The Census estimates that roughly 20% of commuters (amount varies between each MMP city) commute for less than 20 minutes one way each day (Appendix 11.1). The Longitudinal Employer-Household Dynamics program estimates that over 30% of commuters in each MMP community, excluding Stanford, live within 10 miles of their employment (Appendix 11.2). This data confirms that great opportunity exists to increase bike mode-share through creating a north-south central bikeway route for commuters in the Mid-Peninsula traveling a short distance. Acknowledging this opportunity, our recommendations focus on designs for the central route.

The central corridor is the priority location for building a safe, efficient bikeway because we believe it to be effective in advancing cross-community integration. We believe it will promote bike travel between adjacent communities as an alternative to the congested roadways. What we are calling the north-south central corridor refers to the Redwood City-Mountain View axis through the middle of the region, one mile on either side of the Caltrain route. Although three north-south bike routes -- one each in the center, east, and west -- would be ideal for encouraging people to divert from driving to biking, the central corridor is the focus of this report because this axis

- (1) runs through the communities' downtown areas;
- (2) is essentially equally accessible to people who live in the East and West,
- (3) touches on major employment centers,
- (4) it crosses community borders, thus creating an opportunity for cross-regional integration.

From our research we determined that the five MMP communities are progressing steadily in building routes within their individual borders that travel east and west, and a central north-south bikeway will be able to connect to these routes and address connectivity gaps.

5.3 Cyclist Segmentation

Our route selection was also informed by cycling demographics. We learned from the Portland Office of Transportation that the general population can be divided into four main categories based on their cycling frequency as a function of confidence level.[4]

The first type of cyclists are "The Strong and Fearless." According to the report, this small percentage of the population will ride regardless of the roadway conditions. The conditions can vary from the traffic level, to speed limit, to weather. This class of bikers are confident riding in any environment and riding is a strong part of their identity. Because this population doesn't need any more incentive to ride, an enhanced bikeway system wouldn't encourage more of these individuals to commute via bicycle.

The second type of cyclists are "The Enthused and the Confident." This group is a larger percentage of bikers who are comfortable sharing the roadways with automotive traffic, but prefer to bike on their own facilities. These cyclists appreciate bike lanes and bicycle boulevards, and they are more likely to use bicycles as their

[4]Geller, Roger. "Four Types of Cyclists". Portland Office of Transportation. https://www.portlandoregon.gov/transportation/article/264746

regular commuting mode if the required infrastructure exists. This population would greatly benefit from a protected super bikeway.

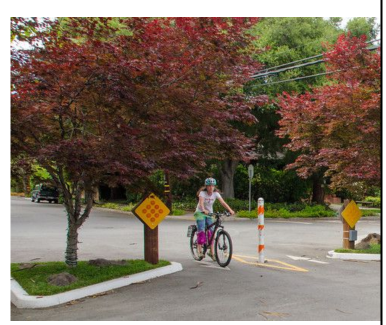
The third type, and largest percentage of bikers, are “The Interested but Concerned.” These riders understand the efficiency of biking, enjoy biking and would like to bike more, but they are afraid of the potential dangers that accompany sharing the road with motor vehicles and biking in inclement weather. Our goal is to encourage this group of riders to use bicycles by increasing safety and providing access to bikeways that provide direct access to their place of employment and to schools. The more opportunities this group has for safe bicycle use, the more likely they are to get out of their cars and onto their bikes. The greatest potential increase in bike mode-share lies with this group of commuters.

The fourth type of bicyclists are the “No Way No How” population. Unfortunately, this group is not interested in bicycling for a myriad of reasons and therefore were not considered in the creation of these bikeway proposals. Regardless of bikeway improvements, this population is highly unlikely to change their transportation habits.

5.4 Infrastructure Design Alternatives

Before we discuss some of the many studies on the effect of bike infrastructure on bike mode-share, it is imperative first to understand the different types of bike paths. Table 1 below discusses the primary classifications of bikeway infrastructure alternatives that we considered. These different classifications are important when thinking about cyclists’ perception of safety and infrastructure costs.

Table 1. Bikeway Infrastructure Definitions[5] (Bike Silicon Valley)

Class I Bikeway:	"Class I bicycle facilities are off-road paths and trails. Often, this takes the form of multiuse trails. The defining aspect is that they are not on streets shared with vehicles, but separate places for bikes and other recreational uses."	
Class II Bikeway:	"Class II facilities designates an on-road bicycle lane. Width and other characteristics can vary."	
Class III Bikeway:	"This label applies to bicycle routes, which are preferred routes for people on bikes as compared to other alternatives. These are shared facilities with vehicles and other road users. They are often marked by signs appointing them as such and often include sharrows."	
Class IV Bikeway:	"A protected bike lane is one that is physically separated from the vehicle travel lane by more than the white stripe. This can entail grade separation, flexible bollards or permanent barriers. California State Assembly Bill 1193 created this new class of bikeway facilities in 2014. Protected bike lanes provide the most protection and comfort for people on bikes and do the most to encourage a broad range of users."	
Bicycle Boulevard:	"Bicycle boulevards are streets that are designed to prioritize bicycle transportation. This is achieved through a number of traffic-calming strategies. They are typically low-traffic, residential streets with low motorized traffic speeds. Bicycle boulevards are usually signed and facilitate bike travel. The first bicycle boulevard in the nation was in Palo Alto: Bryant Street."	

[5] Bike Silicon Valley. *Bikeway Design*. https://bikesiliconvalley.org/bikeway-design/

5.5 Literature Discussion

Our goal is to offer the MMP creative, feasible, and impactful bikeway possibilities. To do so, we reviewed the considerable research conducted in the last decade of both national and international cases on what aspects of the bike network encourage or discourage biking as a transportation choice. Our infrastructure design principles in the following section are informed by said research and we used these findings in forming our proposals.

First we looked to international success stories as a possible model for our own prototypes. Pucher and Buehler (2009) study the transformation of bike travel in Dutch, Danish, and German cities. Before 1975, bike mode-share hung around the same small percentages as exist currently in the Mid-Peninsula. At the time of this paper, these European cities had experienced bike mode-shares upwards of 45%.[6] To cause this dramatic upswing, Dutch, Danish and German cities championed extensive systems of separate cycling facilities, intersection modifications and priority traffic signals, coordination with public transport, bike parking, traffic calming, traffic education and training, as well as traffic laws. Our plan looks to emulate similar improvements to the Mid-Peninsula in hopes of realizing a comparable bike mode-share increase. (See Appendix 11.3 for the complete list of actions made by Dutch, Danish, and German cities to increase bike mode-share).

Our infrastructure design principles are also informed by considerable research conducted in the last decade and a half on what aspects of the bike network encourage or discourage biking as a transportation choice. Separated bikeways (including Class I and Class IV cycle tracks) are beneficial because they have been shown to increase mode-share. The Federal Highway Administration's (FHWA) Separated Bike Lane Planning and Design Guide references many studies that make a strong case for separated bike lanes. Goodno et al. (2013) found that separated bikeways in the D.C. area caused an increase of 200% in bike mode-share once installed. In addition a 2006 before and after study from Jensen et. al. found “an 18 to 20 percent increase in cycle/moped traffic on streets where separated bike lanes were installed.”[7] This may be due to the fact that cyclists have a greater perception of safety on separated bikeways.

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[6] Pucher and Beuhler. “Making Cycling Irresistible: Lessons from the Netherlands, Denmark and Germany”. Transit Reviews, Vol. 28, No. 4, 495-528, July 2008. Aiding the pull of policies which made cycling more attractive was the push of actions to make driving less attractive including tax policy, gas taxes, and limiting road capacity and parking. Urban density also played a role.

[7] Schneider and Hunter. “Separated Bike Lanes Planning and Design Guide Literature Review.” 2013

The FHWA literature also references a paper by Monsere et. al. that "conducted a survey of separated bike lane users on Broadway Ave in Portland, OR, and found that 71 percent of the cyclists surveyed felt that the separated bike lane made bicycling safer and easier."[8]

Buehler and Dill also explore factors that encourage cycling as a mode of transport in their 2016 paper Bikeway Networks: *A Review of Effects on Cycling.* While separated paths or lanes are preferred over directly mingling with cars, they cite that in the absence of such facilities "When riding on roadways with motorized traffic, cyclists seem to prefer traffic-calmed residential, neighborhood streets, lower car traffic volumes, slower car traffic speeds, and roadways without car parking." In addition, they offer solutions for busier intersections such as a signal when motorized traffic volumes are high. They also articulate how "A handful of studies indicate that cyclists value bicycle-specific traffic control devices at intersections, such as bike boxes, bike traffic signals, and bicycle signal activation."[9]

The above research shaped the outlook of our proposal process as we then understood exactly what qualities of a bike route have been deemed successful in both domestic and international case studies and how riders perceived differences in bike infrastructure. This research was vital to our objective of proposing the optimal bike route for the Mid-Peninsula.

6. Desirable Route and Infrastructure Properties

Through our research, we determined that in order for a route to stimulate a significant increase in bike mode-share, it should include the following properties.

6.1 Perception of Safety

The perception of safety is so important because this is what will actually entice riders on the edge, "The Interested but Concerned," to get out of their cars and onto their bicycles. If potential cyclists perceive the route to be safe, then they will be more likely to begin biking. This is separate from the actual safety of the environment, but rather how safe riders think they will be on the road. Perceived safety is accomplished through protected bike lanes, protection in intersections, and generous space to ride

[8] "Separated Bike Lanes Planning and Design Guide Literature Review." Federal Highway Administration. May 2015.
[9] Buehler and Dill. "Bikeway Networks: A Review of Effects on Cycling." 2016

comfortably in any weather or traffic condition. Good plans embody a strong perception of safety.

6.2 Directness

Directness is the combination of distance, simplicity, and time. Distance represents how far a rider will have to travel on the route to reach their desired destination. Simplicity refers to how easily the rider can navigate the route in regards to turns or intersections. A more complex route would be less direct and, thus, less desirable. Lastly, time is a measure of how long it takes for the rider to travel along the route to their destination. All three are necessary because different routes would be considered more direct in one of these attributes, and less on others. Rather than looking at directness with just one of these qualities, it is important to judge a route's directness based on how well it accomplishes improvements in each of the three characteristics. Our goal is to give commuters the luxury to ride their bicycles to their places of work on the most direct route, which is defined for the remainder of the paper as a function of distance, simplicity, and time.

6.3 Advances in Overall Bike Network

Distinct from bike mode-share, advances in the overall bike network would include an increase in (1) the overall mileage of bikeways and (2) the connectivity of these bikeways across the Mid-Peninsula.

6.4 Proximity to Trip Attractors and Generators

The proximity to trip attractors and generators captures how close the route runs to places where people typically originate and terminate trips. Examples of trip attractors are priority destinations like workplaces, schools, and shopping centers. Examples of trip generators are starting points, like residences, and transit services, like Caltrain. A bike lane is proximitous if it is easy for people to begin using from trip generators or trip attractors.

6.5 Ability to Accommodate E-Bikes

Electric bikes (e-bikes) are increasing in popularity. A recent study by Elliot Fishman and Christopher Cherry summarizes how “Electric bicycles (e-bikes) represent one of the fastest growing segments of the transport market. Over 31 million e-bikes were sold in 2012."[10] Due to their growing prevalence it is important for us to evaluate whether future bike infrastructure developments can accommodate them.

7. Base Case: A Current North-South Route

There is currently no officially designated preferred route for traveling north-south by bike from Mountain View to Redwood City. The base case for bike network improvements in the MMP communities is the Mid-Peninsula Bicycle Route (See Appendix 11.4). Local transportation planners designated this route as a possible network from Mountain View to Redwood City with signage, though it has been neither officially proclaimed nor publicized. This section details the route and describes its limitations.

7.1 Mid-Peninsula Bicycle Route

Chris Corrao, senior transportation planner of Palo Alto, provided us with his proposed linked route. Stretching from Redwood City to Mountain View, the Mid-Peninsula Bicycle Route spans 12.26 miles of linked routes northeast of El Camino Real (Table 2 and Figure 1). The route primarily uses secondary roads with a variety of bike route classifications. One large advantage of the base case is that it avoids many high stress intersections. Because it avoids these high stress intersections, this route can be seen as safest to children and families. Our group had the opportunity to see the base case and were impressed with the amount of creativity used to connect so many secondary roads. Bridges, bike boulevards, and street paint signals all increased accessibility and safety for riders to access the Mid-Peninsula on bike.

[10] Fishman and Cherry. "E-bikes in the mainstream, reviewing a Decade of Research". 2016

Table 2. Mid-Peninsula Bicycle Route (Chris Corrao)

Mid-Peninsula Bicycle Route (distance: 12.26 mi)	
Regions (6)	**Roads Utilized** (20)
Redwood city	Main Street and Middlefield
Fair Oaks	Middlefield
Atherton	Encinal and Laurel
Menlo Park	Willow Road and Willow Place
Palo Alto	Palo Alto Ave, Bryant Street Bike Boulevard, Redwood Circle/Carlson Court, and Duncan
Mountain View	Creekside, Nelson, Mackay, Nita, Whitney, Laura, Fay, Montecito, Steirlin, and Central

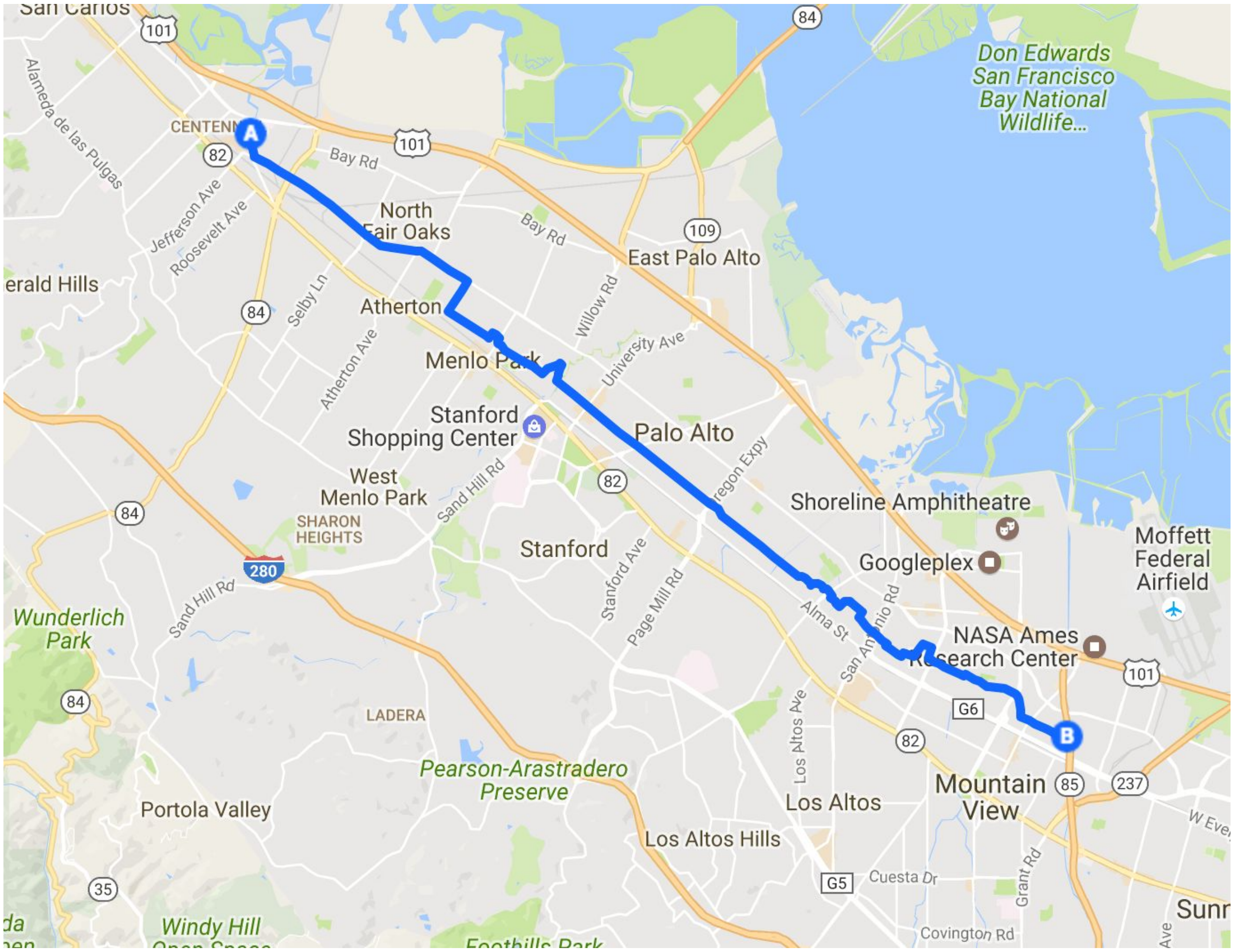

Figure 1. Google Map illustrating the highlighted base case, an example of a current north-south route

7.2 Limitations

While the base case is a promising initial bike route plan, many issues with complexity and serious safety concerns render this plan sub-optimal. In regards to complexity, a rider must pass through 131 intersections and make 19 turns to cover all 12.26 miles of the route. Even though many of these intersections are not high-stress with heavy car traffic, a rider still must encounter cars at these intersections as well as navigate the complex route. The amount of turns and intersections combined does not champion directness, which we defined earlier as a combination of distance, simplicity and time of travel. One remedy to a complex route is clear signage. Yet, clear signage both to notify cars of bike presence and to help bikers navigate the route does not exist throughout the route. The complexity resulting from large amounts of intersections and turns in addition to the lack of signage renders route navigation on the base case very difficult and could deter first-time riders.

Along with complexity, portions of the route lack optimal bike infrastructure and do not create a strong perception of safety. While a large portion of the route is the Bryant Street Bike Boulevard which privileges cyclists over motorists, the other two-thirds of the route are Classes II and III bike lanes, forcing riders to share the road with cars and put themselves in compromising positions with drivers. Additionally, even with bike infrastructure such as clear bike lanes, signage, and intersection bike boxes, there is always a risk of collision any time bikes are not separated from cars. As explained in the section on cyclist segmentation, safety is one of the most important features of a new bikeway in order to encourage those riders who are on the verge of commuting via bike. The base case is creative in connecting current bike infrastructure, but struggles to present a simple and safe bike route for riders.

8. Two Potential Routes

Transitioning from detailing our key research findings, this section of the report discusses our proposals for advanced bikeways on El Camino Real and Caltrain. We provide the motivation for choosing each route, our design principles, major challenges to each design, and potential modes of overcoming these challenges.

8.1 El Camino Real

As a major thoroughfare spanning the MMP communities, El Camino Real (ECR) is an ideal route for a central bikeway corridor (Figure 2). Also, one of the goals of the Grand Boulevard Initiative is to transform ECR into a Complete Street.[11] This highway is a direct and fast north-south route with access to shops, services, transit, schools, and employment.[12] The fact is that cyclists are already on ECR -- for example, bicycle counts range from 50 to 400 at different segments in Palo Alto and Mountain View during peak hours[13] -- because of its directness and connection to several destination

[11] "Safety on El Camino" Presentation. Grand Boulevard Initiative Task Force. SVBC. December 2015.
[12] "Bikes on El Camino Real" Presentation. Grand Boulevard Initiative Task Force. VTA. March 2014.
[13] "Bikes on El Camino Real"

hubs[14]; therefore, it is the responsibility of local governments to make this road safer for them.[15]

Because of the high activity and high driving speeds along this corridor, it is also a site of high collisions and subsequent injuries and deaths. ECR is only 1% of streets in San Mateo County, but 13.8% of cyclist collisions occurred on or within fifty feet of the road between 2009 and 2013. Likewise, ECR is only 0.5% of streets in Santa Clara County, yet 6% of cyclist collisions occurred within the same area.[16] These dangers demand that city and county planners target this street for redesign in order to reduce unsafe driving speeds and to increase accessibility and safety for other modes of transport, namely biking. Further, ECR's large roadway space holds great potential for reallocation of lane purposes.

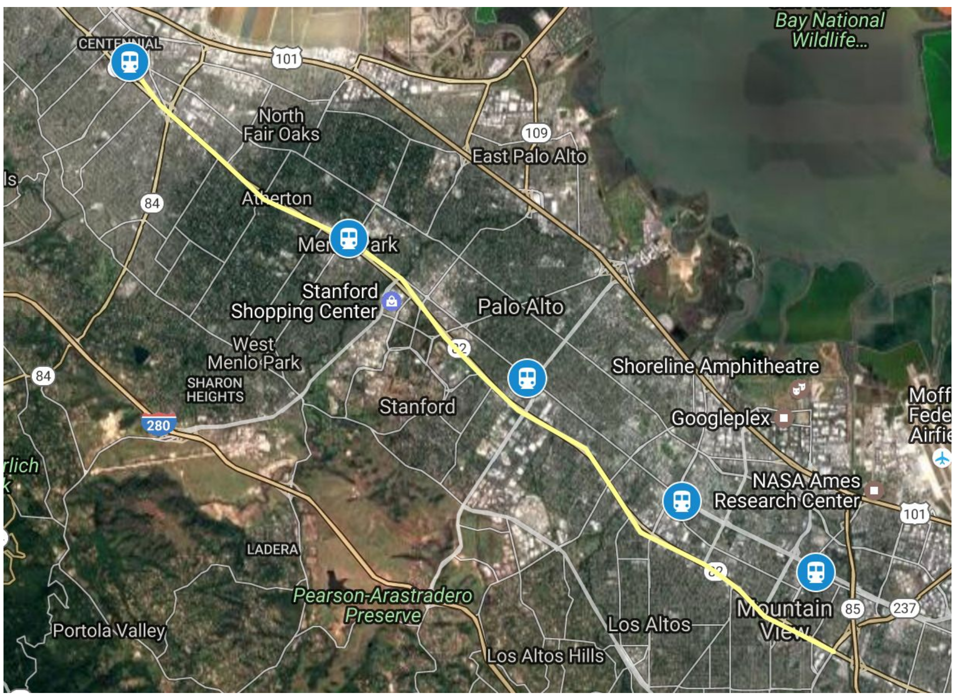

Figure 2. Google Satellite Image of the Mid-Peninsula with ECR route highlighted in yellow

[14] "Safety on El Camino"
[15] It is important to note that El Camino Real is under the jurisdiction of the State of California as a state highway, so collaborating and negotiating with the State will be a major consideration if the MMP chooses to pursue bikeways on El Camino Real.
[16] "Safety on El Camino"

8.1.1. Physical Specifications and Constraints

The ECR curb-to-curb width varies from 84 to 120 feet.[17] The Santa Clara County segment of El Camino Real has a constant width of 104 feet. This segment consists of three 12-foot motor vehicle lanes and one 8-foot parking space on each side of the street. The sides of the street are divided by a 16-foot median that reduces in width to provide space for motor vehicle left turn lanes. To represent the Santa Clara County segment of El Camino Real and other segments of comparable width and configuration, we have chosen to prototype a 104-foot wide segment. In addition in order to accommodate other segments with narrower widths, we have chosen to also prototype an 84-foot wide segment. This represents a block on El Camino Real such as Roble Avenue to Ravenswood Avenue in Menlo Park. Slightly larger street segments can be adjusted to fit this prototype by widening the motor vehicle through-lanes or cycle track, depending on what provides a better perception of safety in the given segment. A visual description of this El Camino Real segment is provided below in Figure 3.

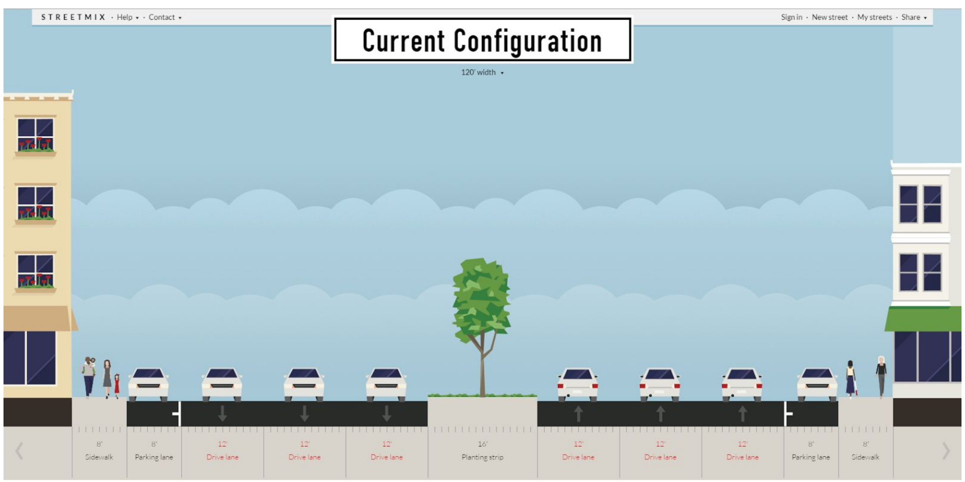

Figure 3: Santa Clara County ECR Configuration
(A. Burger and L. Ledbetter, personal communication, November 14, 2016)

8.1.2. Key Safety Design Features

In order to target a wide range of cyclists, we have chosen to adapt a Class IV bikeway onto El Camino Real. The high traffic volumes and high speeds increase the perception of danger for cyclists, so including a protective barrier along the bikeway will allow cyclists to feel safer and create a comfortable experience. Because the United States lacks general requirements regarding Class IV bikeways, or cycle tracks, our

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[17] “El Camino Real Corridor Study.” City of Menlo Park. July 2015.

bikeway designs rely on recommendations from the National Association of City Transport Officials (NACTO) Urban Bikeway Design Guide. NACTO uses the Netherlands' requirements to model recommendations for cycle tracks in the United States. The recommended minimum cycle track width for a one-way protected cycle track is 5 feet, but 7 feet is desired in areas with high volumes of cyclists or uphill sections to allow for cyclists to pass each other. Also, 7-foot lanes potentially provide adequate space for e-bikes and bikes with tail wagons. A two-way cycle track allows for bi-directional bicycle travel on a designated portion of the street with protective barriers on the outer portions of the track. The NACTO Urban Bike Design Guide recommends that a two-way cycle track be 12 feet wide, with a minimum acceptable width of 8 feet. In addition, to classify as a Class IV bikeway, the cycle track must be protected by a physical barrier that is, at minimum, 3 feet wide. If a painted buffer is chosen as the method of protection, the cycle track must also be protected by a physical barrier such as tubular markings or planters. A raised curb or median can serve as the physical barrier between the cycle track and motor vehicle traffic.

8.1.3. Design Alternatives

Based on ECR's biking needs and physical constraints, we recommend two bikeway design alternatives: (1) side-running one-way bike lanes on each side of ECR and (2) a two-way bikeway in the center of ECR. We present descriptions and visuals of these designs, their benefits, the challenges they create, potential solutions to overcome these challenges, and detail options. Further, we discuss Bus Rapid Transit and accessibility implications of these designs.

8.1.3a. Alternative 1: Side-Running One-Way Bike Lanes

This alternative is known as a One-Way Protected Cycle Track by the NACTO Urban Bikeway Design Guide. The track consists of a single-direction lane that dedicates space for cyclists with a protective barrier from motor vehicle traffic. The implementation of the one-way track system on El Camino Real will involve the removal of parking spaces. This road space will be converted into two one-way protected cycle tracks, one on each side of the roadway. The Santa Clara County 104-foot segment of ECR currently has 8-foot wide parking spaces, which will provide ample space for an 8-foot wide cycle track (Figure 4a). In addition, the current lane widths for two through-lanes will be reduced from 12 feet to 11 feet, with the inner most lane at 10 feet wide. This will provide an extra space on each side, to create a 4-foot wide barrier for each one-way cycle track. The 84-foot segment of ECR will be configured to include the one-way protected cycle track (Figure 4b). The parking or outside through-lane will be converted into a 7-foot cycle track with a 4-foot barrier. The innermost through-lane will be reduced to 11 feet. However, in our 84-foot model, there is enough road width for a 12-foot through-lane. It is recommended that the 12-foot lane be nearest the cycle track, thus allowing more space between motor vehicles and bikes and contributing to cyclists' sense of safety.

Figure 4a. Prototype for 104-foot wide segment

Figure 4b. Prototype for 84-foot wide segment

According to NACTO, one-way protected cycle tracks have shown a 28% lower injury rate than a track on a comparable street without dedicated bike infrastructure. The safety features of a one-way protected cycle track encourages more bicycle use along the given road. It has been found that over twice as many cyclists use cycle tracks, or Class IV bikeways, compared to streets without bicycle facilities. These types of tracks can be strategically built along dangerous and busy streets to allow a wider variety of cyclists to feel comfortable biking to their destination. Typically, one-way protected cycle tracks are constructed along streets with high bicycle volumes and high motor vehicle volumes and speed, thus making it a practical alternative for El Camino Real.[18]

The one-way protected cycle track can be adapted from the current design to the suggested configurations with minimal amounts of infrastructure change. The conversion of the parking spaces provide the needed road space to allow for a protected lane. The amount of infrastructure development that will be needed is dependent on the method of protection that is used. For instance, painted lines with tubular markers require less construction than a raised median or curb, although investment in raised medians and curbs demonstrates a commitment to a long-term vision of super bikeways in a way that tubular markers and other moveable barriers do not.

The major challenges of integrating side-running, one-way protected cycle tracks are the interactions that still must occur with motor vehicle traffic at intersections, driveways, and bus stops. These interactions create potential dangers and perceived dangers but there are many features that can be included in the design to mitigate conflicts with motor vehicles. Intersection features include both maintaining bicycle and motor vehicle separation and shifting bicycles across motor vehicle turn lanes. The Federal Highway Administration provides detailed recommendations for these turning movements.[19] Two of these options are provided: signalization and lateral shifts.

(1) Signalization treatments maintain separation between bicycles and motor vehicle traffic through the intersection. The furthest right through-lane is designated for a right turn only, or right turn and through-lane, and maintains the protective barrier of the bike lane. A specific bicycle signal light and a right turn signal are required to determine right-of-way. A visual example of this intersection is shown below in Figure 5.

[18] "Urban Bikeway Design Guide, Second Edition."
[19] "Separated Bike Lane Planning and Design Guide"

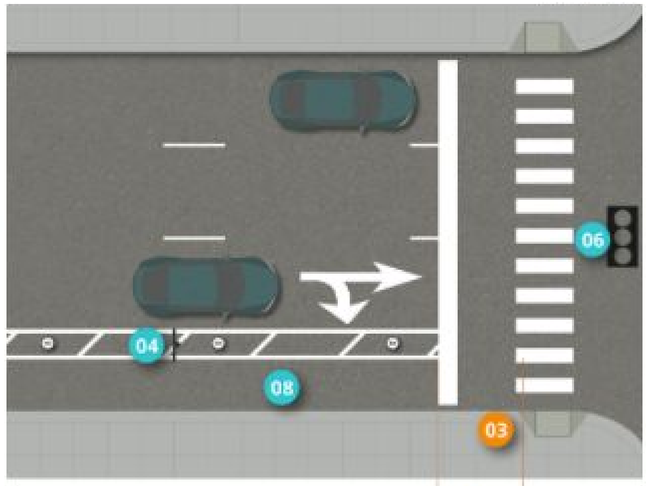


Figure 5. Signalization Treatment
(“Separated Bike Lane Planning and Design Guide,” FHWA)

In addition, protected intersections are an option to increase protection for cyclists at intersections. This feature includes a protective barrier island as an extension to the “Bend Out” design. The bike lane veers to the right to make room for an enlargement of the barrier, the barrier then breaks to provide room for a pedestrian crosswalk. An extra island barrier is situated to protect the cyclist at the corner of the intersection. This option was provided in the Menlo Park El Camino Real Corridor Study, and the image is shown below (Figure 6). Alta’s report on the “Evolution of the Protected Intersection” provides an example of the use of signals to allow right-of-way for cyclists in each direction (Figure 7).

Figure 6. Protected Right Turn Intersection
(“El Camino Real Corridor Study,” City of Menlo Park)

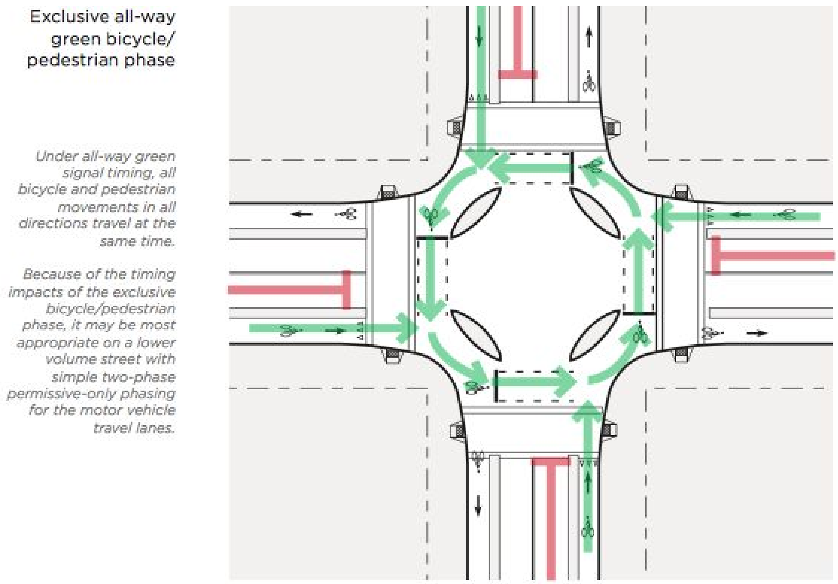


Figure 7. Protect Right Turn with Signalization
("Evolution of Protected Intersection," Alta)

(2) Lateral shift intersection treatments require the crossing of bike lanes and right turn lanes. Cyclists are shifted to the left of motor vehicle right turn lanes and the protective barrier is momentarily eliminated for this crossing. An image is provided below. In addition, this image shows the option to include a "bike box" in front of stopped traffic. This allows bikers to move first when a signal light changes to increase the visibility of the cyclists to motor vehicles. Bike boxes also provide an opportunity for cyclist left turns (Figure 8).

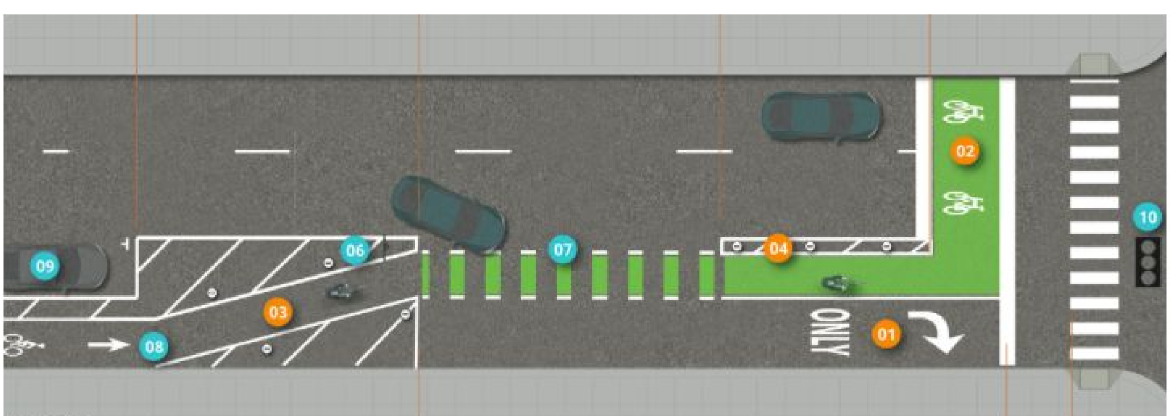


Figure 8. Lateral Shift Intersection
("Separated Bike Lane Planning and Design Guide," FHWA)

Side-running bus services also pose a problem for one-way protected cycle tracks. The bus would be no longer able to access the side of the road without crossing over the bike lane. One solution to this challenge is to construct an island platform, or bus bulb, as a transit stop, which would divert the bike lane around the island, away from the street. A visualization from the FHWA is pictured below (Figure 9). This solution requires extra space, as the bike lane would be rerouted through part of the sidewalk. Also, bus riders would need to cross over the bike lane to get from the island transit stop to the sidewalk. Signage and painted lines on the road could alert both the cyclists and the bus users of the crossing.

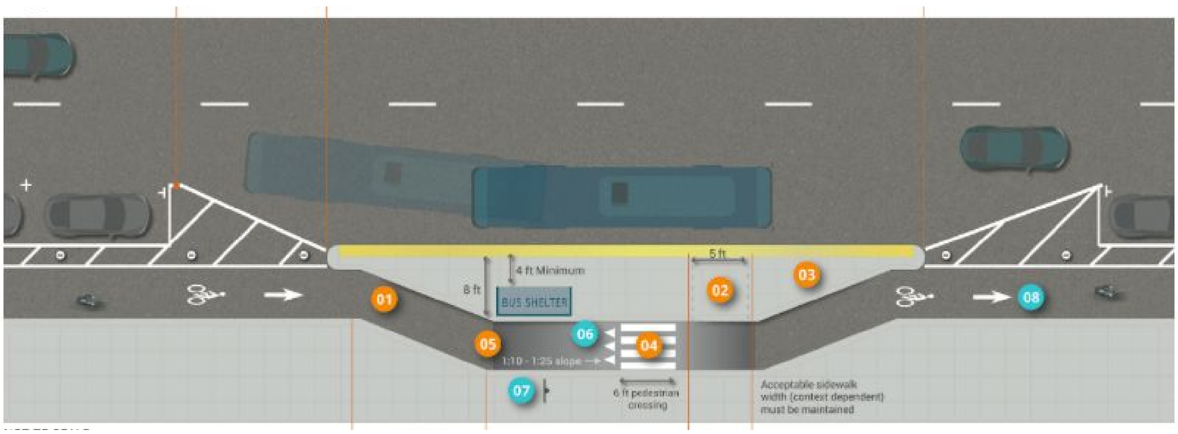


Figure 9. Island Platform Transit Stop
("Separated Bike Lane Planning and Design Guide," FHWA)

Another solution to side-running bus services is to adjust for central-running bus services, in which the bus operates and stops along the median division between the sides of the road. The VTA has proposed this alternative in the El Camino Real Bus Rapid Transit Project in conjunction with side-running bike lanes.[20] The 104-foot wide segments and other wider sections of ECR, central-running bus services will still allow space for two through-lanes for motor vehicle traffic. Shown below is a StreetMix prototype of a center-running bus service for an 84-foot wide segment of ECR (Figure 10).

[20] "BRT Street Configuration Options". Valley Authority Transportation Authority. Website.

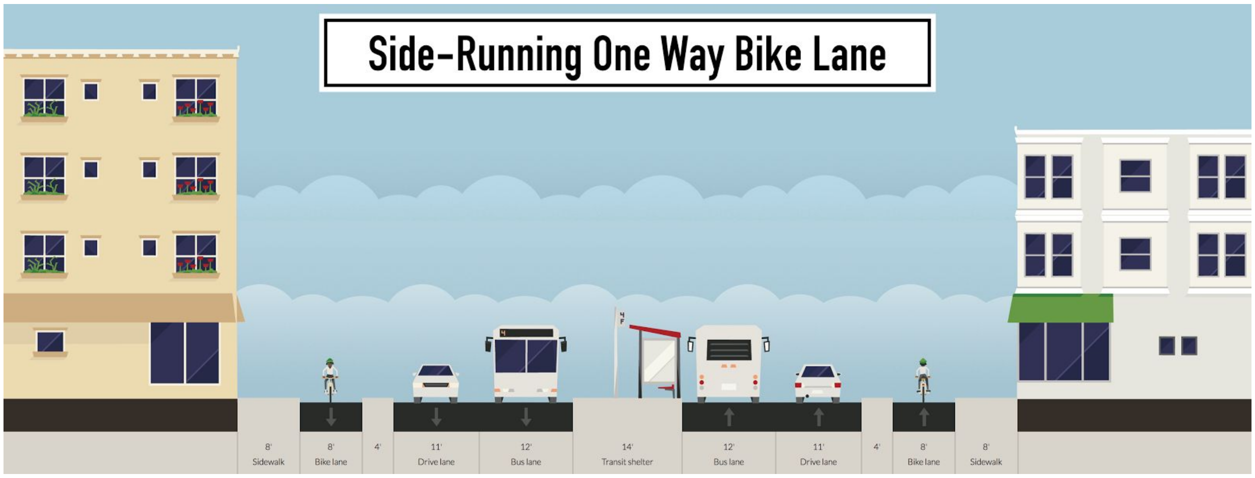


Figure 10. Central Running Bus Service, 84 ft Prototype

Another challenge of side-running bike lanes are the crossing of driveways along the roadway. Cars entering and exiting driveways of residential areas or parking lots are required to cross over the bike lane to get to the motor vehicle lane. This creates an added danger, as visibility is often low due to landscaping or other obstructions. Ideally, during the construction stages of the bikeway, driveways would be consolidated to reduce the amount of vehicle crossings. For the remaining driveways, there are some design options to mitigate the dangers and increase cyclist safety. For instance, a raised barrier can be included or enlarged on either side of the gap in protective barrier. This directs the turning vehicles to a wider and slower turn. Signage and road paint should also be included throughout these crossings to ensure that both the vehicles and the cyclists are informed of the driveway intersection. These design options are shown below in the Federal Highway Administration's example (Figure 11).

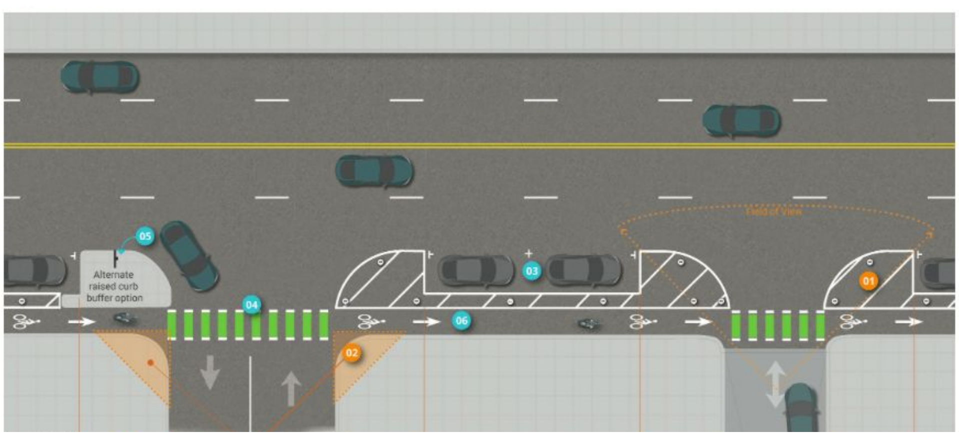
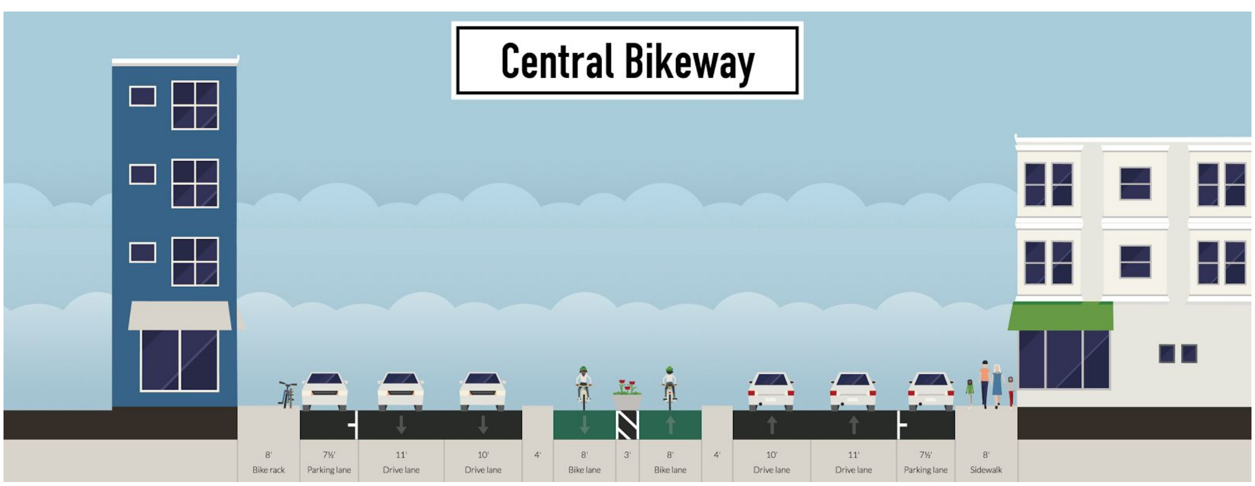


Figure 11. Driveway Design Option
("Separated Bike Lane Planning and Design Guide," FHWA)

The final challenge of this alternative was the decision to eliminate the parking spaces along the entire length of ECR. According to the Menlo Park El Camino Real Corridor Study, just shy of 35% of parking spaces were occupied during peak hours of the weekday.[21] Due to the relatively low percentage of occupancy, eliminating parking spaces would have less of an effect on the users of El Camino Real than eliminating a motor vehicle lane. In this case, other parking spaces would need to be accessible to the drivers on ECR, especially in segments near storefronts, to ensure that businesses are not significantly affected by the loss of parking spaces directly in front of their store. Parking-protected bike lanes are also an option for certain segments of ECR. These lanes would be beneficial in areas with multiple storefronts and few alternative parking spaces. Adding parking protected lanes would reduce one driving lane and would require signage to inform drivers, pedestrians, and cyclists of the change of protective barrier and pedestrian crossing. The configuration of parking protected lanes is recommended to have a 3-foot buffer separating the parking spaces from the bike lanes, as parking-protected lanes create potential dangerous exchanges with parked car doors and pedestrians going to and from parked cars.[22]

8.1.3b. Alternative 2: Two-Way Central Bikeway

Alternative 2 is a two-way Class IV bikeway running along the center of El Camino Real that is protected from motor vehicle traffic by raised curbs on both sides. The raised curbs must be a minimum of 3 feet wide, but we have designed for 4-foot wide barriers. Cyclists traveling in opposite directions are protected from head-on collisions by the central median (Figures 12 and 13).



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[21] Nagaya, Nikki. "El Camino Real Corridor Study". City of Menlo Park.
[22] "Urban Bikeway Design Guide, Second Edition". National Association of Transportation Officials. August 2013.

Figure 12. Prototype for 84-foot wide segment

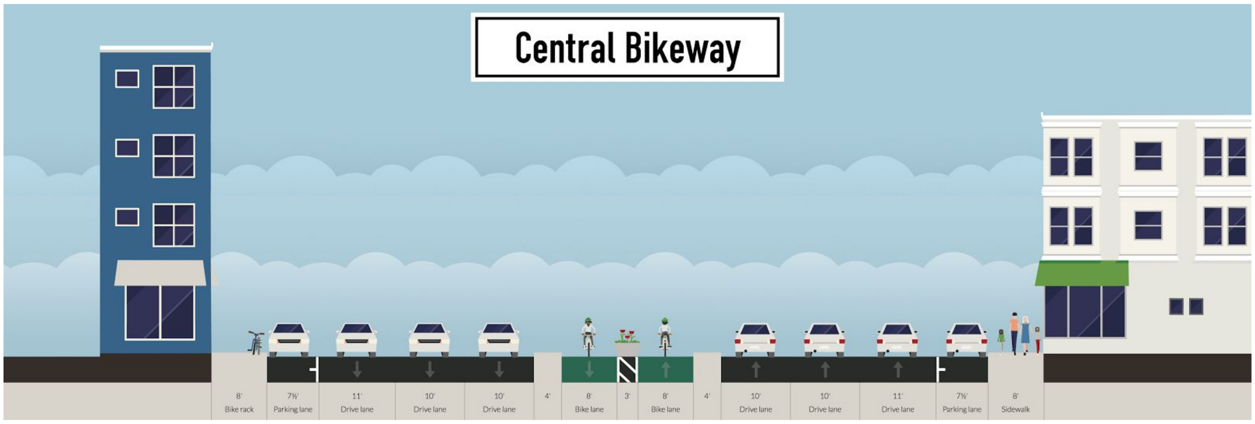

Figure 13. Prototype for 104-foot wide segment

In comparison to the side-running bike lanes, a central bikeway on El Camino Real does not interfere with street parking or driveways. For these reasons, local business owners may be more supportive of this design. Nor does it interfere with side-running bus services. The outermost through-lanes are wider in order to accommodate buses. Further, this design does not implement a raised curb between the driving lanes and the sidewalk, thus avoiding the creation of an obstacle for emergency responders.

In the 104-foot wide prototype, there remain three through-lanes for motor vehicles in each direction simply because there is enough roadway space to accommodate them. There is, of course, the option to reduce the number of through-lanes from three to two in each direction in these wider segments of ECR as well. In so doing, the MMP can demonstrate the same commitment to cyclist safety and belonging on the road through (1) expanding the width of the bike lanes or (2) constructing facilities for other modes of transport in support of Grand Boulevard Initiative's goal to transform ECR into a Complete Street (e.g. Bus Rapid Transit or pedestrian facilities). To avoid carving the bike lanes out of the existing median with recently planted trees, the bike lanes could potentially replace an existing through-lane on either side of the median. Alternatively, if the bike lanes are carved out of the existing median, efforts should be taken to decorate the new, narrower median with shrubbery and flowers because green space is a priority for the city-scape.

The widths of the medians and raised curb protections can be reduced (to a minimum of 3 feet) at points along ECR in order to accommodate left-turn lanes and other intersection variations. The median dividing the two-way cycle track can be removed altogether at points to provide more space; however, this is not advised because it will reduce cyclists' sense of safety due to fears of head-on bike collisions with cyclists who are trying to pass.

A bikeway running down the center of a busy thoroughfare like El Camino Real begs the question: how will cyclists get on and off this bikeway? One potential solution to this challenge would be to implement signage indicating that cyclists must walk their bikes between the sidewalks and the bikeway via the crosswalk when pedestrians have the right-of-way. This solution may be simple enough for those cyclists wishing to enter the cycle track; however, for those wishing to exit, it can potentially create the problem of cyclists queuing in the bike lane while waiting for the ECR light to turn red and the cross street light to turn green. To remedy this, the bike lane must be either (1) wide enough to allow for passing along the left or (2) include a "bike box" to create a space for queuing.

A more difficult challenge is how to manage left turns for cyclists and drivers in order to avoid collisions. The cyclist faces the double threat of bike-car collisions with left-turning cars and bike-bike collisions with traffic from the oncoming bike lane. Solutions to this challenge require sophisticated intersection designs. At low-traffic intersections, signage can be installed informing travelers that cyclists have the right-of-way to turn left before motor vehicles. It should be understood with cyclists, as it is with drivers, that one cannot turn left at an intersection with no light until there is adequate room before the next oncoming car or bike. At high-traffic intersections, one potential solution is to install stoplights with distinct signals for cyclists and drivers turning left. According to the Federal Highway Administration (FHWA), separate signal phases are necessary for the bike lanes and for motor vehicle lanes turning left in order to best prevent collisions.

Another intersection treatment that FHWA recommends to increase visibility of cyclists is to paint the bike lanes green in the intersections and to implement bicycle turn queue boxes (143). A prototype of this treatment is shown in Figure 14 below:

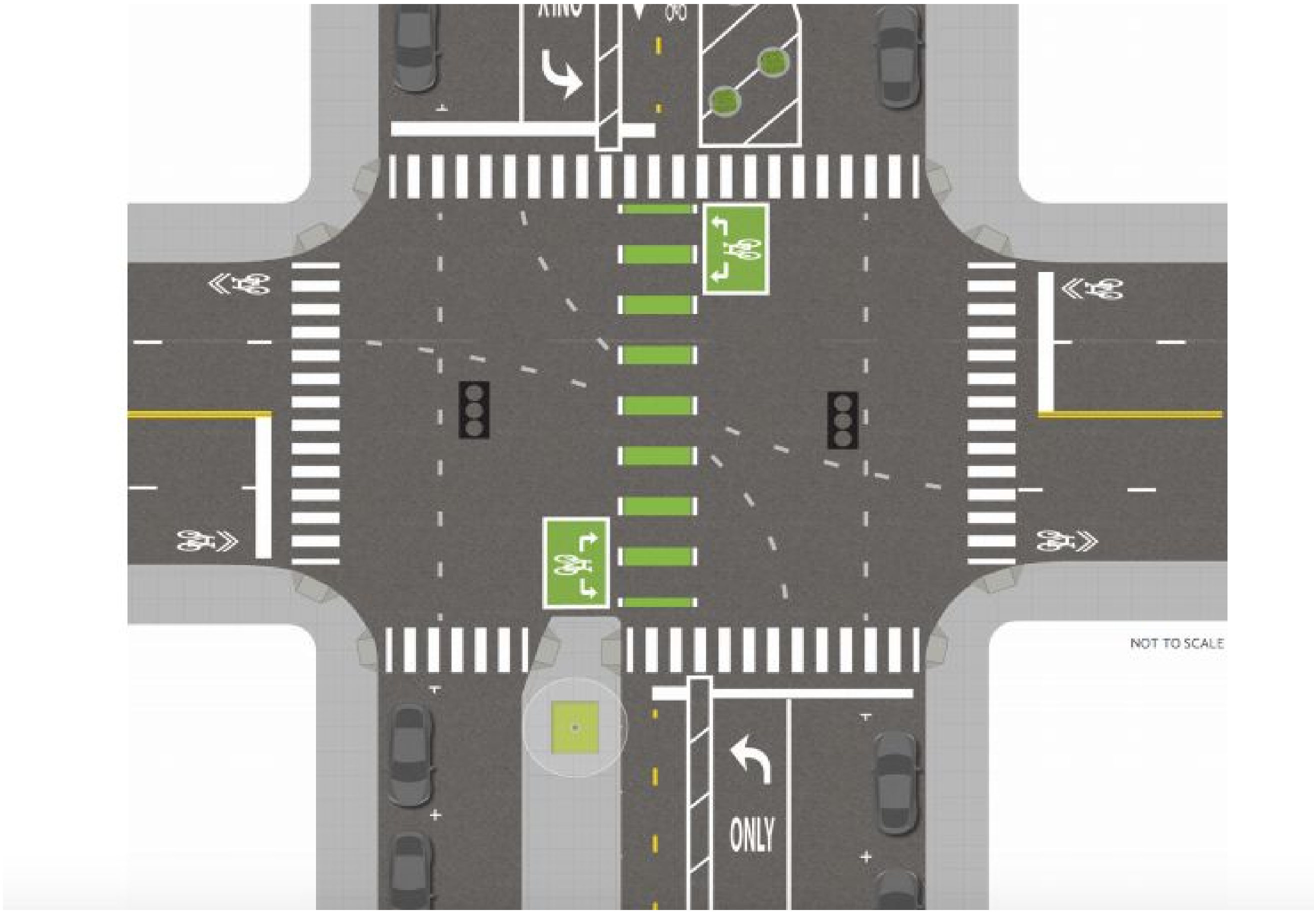

Figure 14. Intersection Treatments for Increased Cyclist Visibility (“Separated Bike Lane Planning and Design Guide,” FHWA)

8.1.4 Further Considerations

In addition to benefits and challenges, we considered detail options and accessibility concerns of these design alternatives.

8.1.4a. Detail Options

Physical barriers improve perceived comfort and safety for the cyclist. The eliminated risk and fear of collisions with vehicles increases cyclist perception of safety from traffic. There are numerous methods of protection available in designing a Class IV cycle track. Common protection techniques include tubular markings, bollards, raised medians, and planters. Each method provides a different level of comfort for the cyclist.

While the physical barrier allows the cyclist to feel safe, it is also proven to decrease cyclist injuries. The protective method can vary throughout the length of a cycle track in order to adjust to changes in road infrastructure and safety needs. Cost, durability, traffic speeds, aesthetics, emergency services, and maintenance should all be considered to find the appropriate method of protection for a given segment of the cycle track. For instance, high volumes of motor vehicle traffic might require a taller and more durable barrier in order to ensure that a cyclist feels safe. Downtown areas, where motor vehicle traffic is slower, the aesthetics of the barrier might be considered more important because cyclists don't perceive these areas to be as dangerous and city-goers are more pleased with the aesthetics of a planter.[23]

The bike lanes on ECR can be road-colored or painted green to increase visibility. Some residents may think the green lanes are an eyesore. However, increased visibility of cyclists is imperative for cyclists' sense of safety. We recommend that these bike lanes be painted green in commercial areas with high volumes of traffic, and left road-colored in residential areas.

8.1.4b. Bus Rapid Transit Implications

Based on an interview response with a member of Silicon Valley Bike Coalition, considerations of Bus Rapid Transit (BRT) lanes are not relevant at this time because few cities in Santa Clara County supported it in a recent vote. However, if support for BRT changes, the creation of either of these bikeway designs will not preclude its addition to El Camino Real.

The construction of BRT lanes is feasible with either of the two design alternatives; only the placement of the BRT lane would vary. With Alternative 1, the BRT lanes can inhabit the center of the road, and with Alternative 2, the BRT lanes can inhabit the outer lanes. With Alternative 2, the BRT lanes could also replace parking lanes, which is a policy decision for city and county officials to ponder.

8.1.4c. Accessibility

There are different bikes available for differently-abled people that can be used on these bike lanes. Through a conversation with a member of Silicon Valley Bike Coalition, we learned that bike lanes are typically not thought of as being designed for wheelchairs. Individuals using wheelchairs are considered pedestrians, so sidewalks must be ADA accessible. These bikeway designs focus on the curb-to-curb space (i.e.,

[23] "Separated Bike Lane Planning and Design Guide"

the road). Although sidewalks are outside of the scope of this project, it is critical that redesigns of El Camino Real (and other streets in the MMP communities) ensure that all sidewalks are ADA accessible.

8.1.4d. Current Case Studies

Protected bike lanes are becoming increasingly popular throughout the United States. Most current protected bike lanes span anywhere from a few blocks to two miles. The PeopleForBikes coalition has published three annual reports, starting in 2013, highlighting America's 10 Best New Bike Lanes for each year.[24] This source can be referenced for general bike lane success stories in numerous US cities.

In 2010, Washington, DC installed a buffered, but not protected, central running bike lane on Pennsylvania Avenue NW. In the first two years, the peak hour cyclist volume was increased by 250 percent, as cyclists found the bike lane to be safer, easier, and a useful connection. The bikeway includes various signage along the route, signaling cyclists to use crosswalks as the method of getting on and off the bike lane. The major concern of the Pennsylvania Ave. median bikeway was the lack of protective barrier, which raised many safety concerns due to motorists making illegal U-turns. Physical protective barriers have been proposed for improvements to the facility.[25]

A one-way protected bike lane, spanning over a mile, is soon to be completed on Roosevelt Way NE in Seattle, WA. The project was implemented in conjunction with bus services, which included consolidating transit stops and constructing island bus bulbs. The redesign of the street also included elimination of parking spaces. After its completion, this project will be a useful reference for integrating side-running bike lanes with side-running bus services.[26]

Salt Lake City, UT reconfigured six blocks of Broadway street to include a protected bike lane facility. The reconfiguration included a 30 percent reduction in parking spaces along the road and a protected right turn intersection, resembling Figure 6. After the installation, the businesses along the route actually saw an 8.8% increase in sales, with the majority of businesses in support of the new bike facility. While bike traffic increased by 30 percent, the main reason for the sales increase is assumed to be

[24] Michael Andersen. "America's 10 Best New Bike Lanes Of 2015." PeopleForBikes. 17 Dec. 2015. Web. 11 Dec 2016.
[25] "Evaluation of Innovative Bicycle Facilities in Washington, DC." District Department of Transportation.
[26] "Key Project Elements." Seattle Department of Transportation. Jan 2016.

caused by a higher quality of experience and a “more pleasant place to linger.”[27] For more information regarding the economic effects on businesses, refer to Streets Blog NYC’s article, “How to Measure the Economic Effect of Livable Streets.”[28]

These cases studies are useful references for understanding and justifying protected bike lanes along El Camino Real. While current bike infrastructure in the United States does not represent the 12-mile length of El Camino Real, our alternatives could bring about a breakthrough in cross-regional bike facilities across the country.

8.2 Caltrain

A bike route along the Caltrain offers a promising alternative in order to enhance regional connectivity among the MMP communities. Active train tracks with bikeways running alongside are known as “rails-with-trails.” The Rails to Trails Conservancy has helped to develop 161 rails-with-trails (RWTs) in 41 states and also has gained international traction. Hundreds of miles also span Western Australia, Canada, and Europe.[29] (Appendix 11.8).

A route alongside the Caltrain provides many benefits due to its location and its separation from automobiles. The proposed Caltrain bike route is mostly a Class I bikeway and has some Class IV portions which allows it to have limited contact with automobiles, thus making it safer. The Class I bikeway adds specific advantages because it allows pedestrians and recreationalists access. The route runs through the communities’ downtown areas, which has a high density of businesses and is a major employment area (Appendix 11.4). Finally, the Caltrain bike route is good for giving potential train commuters easy access to the Caltrain, using their bikes for the “first mile” trip from home to station or “last mile” from station to workplace.

8.2.1. Key Safety Design Features

There are three main safety design modifications under which we recommend the MMP operate. Our main assumption is that the high speed rail will be implemented on the Caltrain corridor by 2029. On May 5, 2016 the Caltrain Board of Directors adopted an agreement that invests $211 million in the Caltrain modernization program.

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[27] Michael Andersen. “Salt Lake City Street Removes Parking, Adds Bike Lanes and Sales Go Up.” PeopleForBikes. 5 Oct 2015.
[28] Stephen Miller. “How to Measure the Economic Effect of Livable Streets.” Streets Blog NYC. 20 Dec. 2013.
[29] Kelly Pack and Dan Tomes. “America’s Rails-with-Trails.” 2013.

The first phase of the program is set for 2010. According to the program fact sheet “The Peninsula Corridor Electrification Project will provide for operation of up to 6 Caltrain trains per peak hour per direction (an increase from 5 currently) with operating speeds of up to 79 mph (same as today).” Although the trains will stay the same speed the additional benefits range from improved train performance to providing High-Speed Rail compatible Electrical Infrastructure.[30] The Environmental Impact Statement for the Caltrain electrification stated that it will not have any adverse impacts on existing bike paths, including the Embarcadero bike path running along the Caltrain in Palo Alto.

Phase two of the modernization project will indeed impact the speed of the trains. Specifically California’s statewide High Speed Rail service is planned for 2029 and will add onto the existing upgrades to the system. The San Francisco County Transportation Authority reports that “By 2029, the system will run from San Francisco to the Los Angeles basin in under three hours at speeds capable of over 200 miles per hour.”[31] However the component in the Peninsula would have train speeds only up to 120mph.

8.2.1a. Setback Distance

Due to the speed of the Caltrain and the close proximity it would have to the proposed bikeway, safety precautions are necessary to ensure the safety of both cyclists and pedestrians. Both groups are exposed to debris, noise, and vibrations from the HSR.[32] By definition, setback is “the distance between the paved edge of an RWT and the centerline of the closest active railroad track.”[33] However, “although RWTs currently are operating along train corridors of varying types, speeds, and frequencies, there simply is no consensus on an appropriate setback recommendation.”[34]

Our base point of reference is the Embarcadero Bike Path. The Embarcadero Bike Path was designed by HMH engineers and parallels the Caltrain railroad tracks from Churchill Avenue in Palo Alto to the south end of the Palo Alto Medical Foundation facility.[35] The google map measurement illustrates that the setback distance is consistently around 17 feet (Figure 15). While the existing Caltrain operates at a

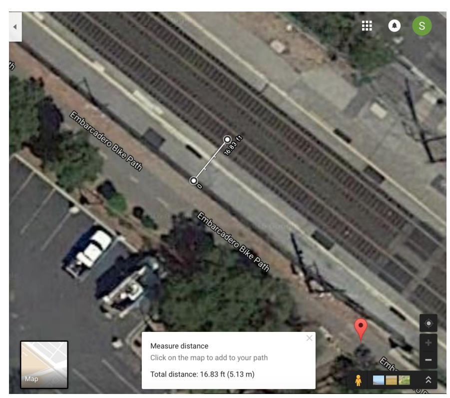

Figure 15. Embarcadero Bike Path Setback (Google Maps)

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[30] “Peninsula Corridor Electrification Fact Sheet.” Caltrain.com. 2015
[31] “ California High Speed Rail Project.” San Francisco County Transportation Authority.
[32] Trails and High Speed Rail: Are they Compatible? Mira Birk. 2003.
[33] Alta Planning and Design. “Rails with Trails Report: Lessons Learned.” 2002
[34] “Rails with Trails: Lessons Learned”
[35] HMH Engineers. “Embarcadero Pedestrian Bridge and Bike Path.” http://www.hmhca.com

maximum of 79 miles per hour (mph), we adjust our recommended setback distance in order to accommodate the high speed rail.

In order to accommodate the likely adoption of a high speed rail by the Caltrain, we plan to use a 20-foot setback as our model case. We base our standard on the Massachusetts Bay Transit Authority Commuter Rail and Amtrak since that is a high speed rail running in a dense community, similar to the one that will be running through the Mid-Peninsula. The Massachusetts Amtrak Train has a maximum speed of 145 mph, is setback at least 20 feet from the trail, and is separated by a concrete wall and a chain link fence.[36]

8.2.1b. Barrier Protection

For protection of cyclists, over 70 percent of existing trails next to railways utilize barriers such as fencing and vegetation as a means to separate cyclists and pedestrians from railroads.[37] Typical design options for a barrier to protect cyclists are (1) picket fence, (2) post and cable, (3) chain-link, (4) vinyl-coated chain link, (5) Israeli style steel fence, (6) wrought iron steel fence, and (7) solid concrete wall.[38] The Embarcadero Bike Path is separated from the Caltrain by a wrought iron steel fence. Our second main modification under the assumption of the HSR is that a solid barrier is much more desirable than a simple fence in order to protect pedestrians and bicyclists alike. Mia Birk, a principal from Alta Planning and Design, recommends that sound walls are key safety features in the case of bike paths adjacent to high speed trains.[39]

8.2.1c. Safe Intersection Crossings

The other main components that would ensure the safety of cyclists using a bikeway next to the Caltrain would be designing safe intersection crossings between automobiles on cross-streets and bikes on the bike path, as well as the Caltrain. The ideal method to deal with this issue would be to create grade separation between the cross-street and the Caltrain and Caltrain bike path. This would also allow for both cars on the cross-street and bikers on the path to continue without stoppages. The bike path segment of the street would continue on the same grade as the Caltrain, while motor vehicle traffic is on a street that goes under the Caltrain and bike path at these intersections. This would allow for easy on and off access for bikers through ramps to

[36] Alta Planning and Design. “Rails with Trails Report: Lessons Learned.” 2002
[37] “Rails with Trails: Lessons Learned”.
[38] “America’s Rails with Trails”
[39] Mira Birk. “Trails and High Speed Rail: Are they Compatible?” 2003.

and from the street, and would not require bikers to traverse a grade change, as they would if the bike path was sent over or under the cross street.

The alternative would be installing a stop sign or stoplight that would prevent cyclists and motor vehicles from colliding with each other. Because of the sizeable expense of grade separation, this is likely to be a cost-effective solution where the bike path (and Caltrain) crosses streets with only moderate traffic. We further illustrate these components in our additional design considerations.

8.3 Physical Specifications and Design Principles

For our prototype, we are focusing on the segment of the Caltrain that spans from the Redwood City area to the Mountain View station (specifically this is mile 25-38 along the Caltrain).[40]

The *Rails with Trails: Lessons Learned* report prepared by Alta Planning highlights that “no national standards or guidelines dictate RWT facility design. Guidance must be pieced together from standards related to shared-use paths, pedestrian facilities, railroad facilities, and/or roadway crossings of railroad rights-of-way.”[41] We used the Class I Bikeway Guidance from Chapter 1000.3 of the Bicycle Transportation Design in order to understand specifications for traveled way, bike path separation from a pedestrian walkway, clearance to obstructions, and bike paths adjacent to Streets and Highways. In addition, guidelines from the Rails with Trails Conservancy informs our setback distance (Appendix 11.8).

Figure 16 below displays our consolidated design principles that will ultimately accommodate the implementation of HSR. The two-way Class IV bike path will be 12 feet in width with an additional 2-foot shoulder separating the bike path from the wall. In addition, the setback distance is ideally 20 feet, but a minimum of 17 feet may be acceptable in the case of a highly protective wall.

[40] “Caltrain Right of Way Maps.” 2009.
http://caltrain-hsr.blogspot.com/2009/01/caltrain-right-of-way-maps.html
[41] “Rails-with-Trails: Lessons Learned”

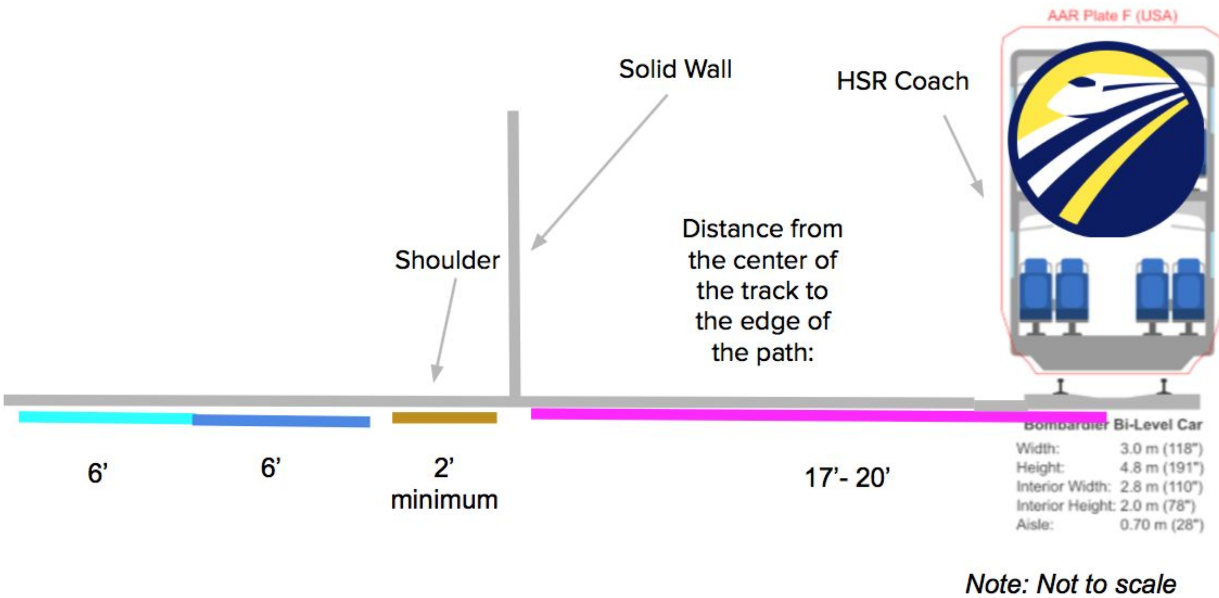


Figure 16. Consolidated HSR Design Principles

8.4 Dealing With Right of Way Constraints

There are three main solutions that we use in order to deal with Right of Way constraints. In some cases the area is too narrow and other times there is insufficient space due to the train station. Our first solution is that we vary the length of the setback distance from 17-20 feet, with 20 feet being optimal. Another solution is for the bike path to switch sides via a bike underpass a total of five times. The underpass is used in situations where one side does not have room for the bike path anymore and other side has enough space required for the bike path to continue. And our third solution is a two-way Class IV bike lane on an adjoining road. For example, the first 1.9 mile segment through Redwood City lacks space for a bikeway next to the Caltrain, so we propose implementing a bike path on El Camino Real. In addition we address the issue of lack of space at the segment beginning at California Avenue train station by recommending a two-way Class IV Bike path on Alma street until the bike path through San Francisquito Park.

8.5 Consolidated Prototype Design

Bringing together a variety of factors such as our design principles and right of way constraints, we generate a prototype of the ultimate route. We first categorized the segments by type in Table 4a. Next, we overlaid the segments onto a Google map using the same color coordination as displayed in Figure 17, and we further elaborate on our prototype in Table 4b.

Table 4a. Caltrain Route Prototype Classified by Route Type (Google Maps)

Route	Length	Class
El Camino Park	.5 miles	I (Existing)
Embarcadero Bike Path	.9 miles	I (Existing)
San Francisquito Park Bike Path	~.1 miles	I (Existing)
Western Class I Path	~ 2	I (Proposed)
Eastern Class I Path	~ 5 miles	I (Proposed)
Additional Class IV	~2.9 miles	IV (Proposed)
Grand Total	**~11.4 miles**	

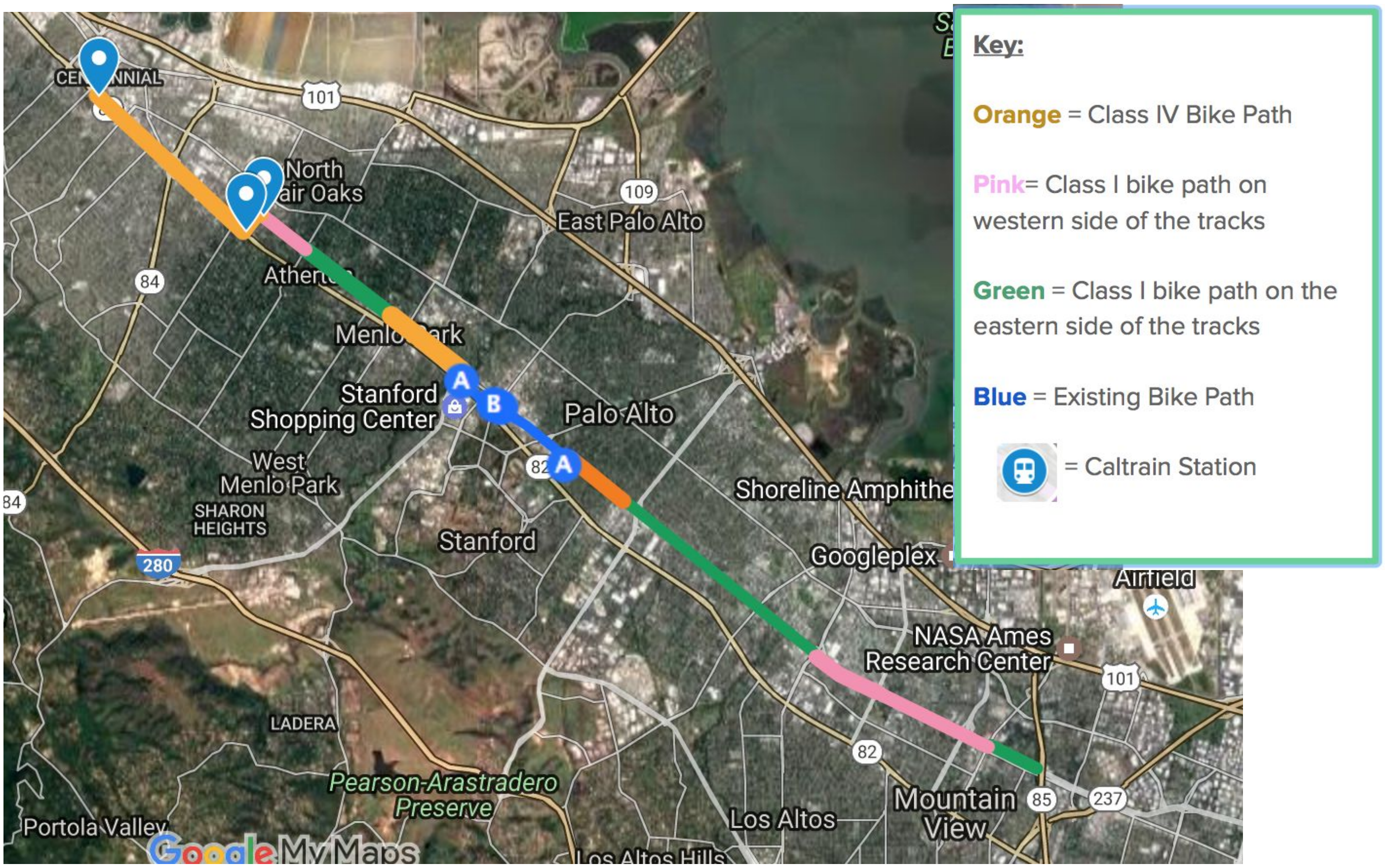


Figure 17. Color Coded Caltrain Route Prototype

Table 4b. Caltrain prototype details for the fourteen segments (Google Maps)

	Track side	Starting Location	Route	Ending Location
1	West	Intersection of Marshall Street and Broadway in Redwood City	El Camino Real	Intersection of Fifth Avenue And Glendale
2	West	Intersection of Fifth Avenue And Glendale	Along Caltrain	Fair Oaks Lane
3	East	Fair Oaks Lane	Along Caltrain	Oak Grove Avenue
4	East	Oak Grove Avenue connection to Alma Street	Two-way Class IV Bike Path on Alma Street	Alma Street and East Creek Drive
5	East	Alma Street and East Creek Drive	Bike route through San Francisquito Creek Bike path	Palo Alto Avenue
6	East	Palo Alto Avenue	Via Palo Alto Avenue	Bike Route in El Camino Park
7	East	Start of bike route in El Camino Park	Bike route in El Camino Park	End of Bike Route in El Camino Park
8	East	Bike Route in El Camino Park End	Palm Drive University Avenue	Embarcadero Bike Park Path Start
9	West	Embarcadero Bike Path Start	Embarcadero Bike Path	Churchill Avenue
10	East	Churchill Avenue	In between train tracks and Alma Street	California Avenue Train Station
11	East	California Avenue Train Station	In between train tracks and Alma Street	Intersection of Alma and San Antonio Avenue
12	West	Intersection of Alma and San Antonio Avenue	Along Caltrain	North Rengstorff Avenue
13	West	North Rengstorff Avenue	Along the Caltrain	Castro Street
14	West	Castro Street	Via the Southbound Central Expressway bike track	End at the intersection of the Southbound Central Expressway and the Steven’s Creek Trail

8.6 Further Considerations

The MMP will likely face opposition from the Caltrain when exploring this proposed solution. Melissa Jones, a senior planner at the Caltrain said, “Due to Caltrain’s safety, maintenance, and operating requirements, a recreational bike path along the Caltrain corridor on property owned by the Peninsula Corridor Joint Powers Board (JPB) is not feasible.” She cited the Caltrain’s Engineering Standards as a basis for her argument. Jones also referenced that outside of the Caltrain’s right-of-way, the “best practice” is that any use be placed at least 25 feet from the railroad for safety consideration if a physical barrier is not provided. Melissa Jones offers one perspective, but it is important to note that there is still room for redesign as evidenced by the research presented above. The Rails to Trails 2013 report highlights how 28% of RWT are adjacent to Class I Railroads (defined as having an annual operating revenue that exceeds $433 million based on 2011 dollars) and “Class I railroads continue to express formal opposition to the concept of trail development within or adjacent to their corridors.” The report further highlights how “numerous smaller private railroad companies and public rail authorities have reached agreements with trail Manager's on rail-with-trail development that have satisfactorily addressed any concerns about risk and liability.”[42] Caltrain did indeed give easement for the Embarcadero bike path, however it is revocable in order to preserve future options for Caltrains. As a result, any future proposed bike path in the Caltrain right-of-way would require additional conversations and negotiations regarding granting easement.

9. Evaluation

For our evaluation section, we examine the existing route designated as a base case and our two potential route alternatives for a north-south central corridor bikeway. First we compare the basic route characteristics of our alternatives, including e-bike feasibility on the routes. We then evaluate our proposals using two main criteria, impact on increasing bike mode-share and cost. Finally we conclude with a discussion of our evaluation before addressing our assumptions and limitations which include equity concerns and a discussion regarding cost-effectiveness.

Increasing bike mode-share is the proximate goal of improving cross-regional bike infrastructure. Bike mode-share is the proportion of all trips for which people use bikes compared to other modes of transportation. Current studies typically quantify commuter bike mode-share. In addition to decreasing car traffic, an increase in bike

[42] “America's Rails with Trails”

mode-share is sought after because biking can lead to health and environmental benefits. Successful super bikeways will encourage active transport. Biking is a low-physical-stress way for individuals of all ages to integrate exercise into their daily lives. Additionally, an increase in bike mode-share can result in lower gas emissions, thereby decreasing air pollution and avoiding environmental destruction. Overall, bikes are a healthy, environmentally-sustainable mode of transport.

Our assessment of how each alternative will impact bike mode-share is qualitative as opposed to quantitative, and relative as opposed to absolute. We use the extent to which each alternative successfully addresses the five desirable properties of bikeways to assign a relative ranking on the bike mode-share impact criterion.

While creating new cross-regional bike routes will produce a variety of benefits, we need to consider the costs of producing these benefits. In order to quantify the most direct costs, we have estimated the financial costs that would be incurred in constructing the proposed facilities.

We developed our cost estimates by translating the physical specifications for our our route infrastructure into the number of units of different components and multiplying these by units cost estimates. We use a variety of sources such as the Berkeley Bicycle Plan Public Draft 2016, *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public* By Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, Daniel A. Rodriguez, the Mountain View Bicycle Transportation Plan Update: Estimated Unit Costs, and *the Palo Alto Rail Corridor Study*. Our estimated costs do not include design costs.

In order to evaluate our proposals, we compare their route characteristics, their ability to accommodate e-bikes, their potential impact on increasing bike mode-share, their construction cost estimates, and finally our overall recommendation, weighing impact on bike mode-share against construction cost.

9.1 Comparing the Alternatives: Some Basic Route Characteristics

As background for our evaluation of the three alternatives, in Table 5 we provide data on basic route characteristics that relate to directness, perception of safety, and ability to accommodate e-bikes. The Base Case is 12.26 miles in length, has 19 turns, includes Class II and III bike paths, has 131 intersections, and accommodates all types of e-bikes. Next the route along el Camino is 11.6 miles in length, has zero turns, is composed of all Class IV bike paths, includes 110 intersections, and accommodates type 1, 2, and 3 e-bikes. Finally the route along the Caltrain corridor is 11.4 miles in length, has 5 turns, is composed of Class I and IV bike paths, has 37 intersections, and accommodates type 1 and 2 e-bikes on the Class I segment in addition to type 3 on the Class IV segments.

Table 5. Comparison of the Three Routes

		Route		
Desirable Attribute	**Route Feature**	**Base Case**	**El Camino Real**	**Caltrain**
Directness	**Distance** (mi)	12.26	11.6	11.4
	Number of Turns	19	0	5
Perception of Safety	**Bikeway Class**	II, III, bike boulevard, none	IV	I, IV
	Intersections	131	110 Protected intersections at major cross streets.Distinct signal phases for cyclists and drivers; Lateral shifts; Bike turn queue boxes; Bike lane painted green in intersection.	37 Grade separation at major intersections.Signals or stops signs at minor ones.
Ability to accommodate e-bikes	**Type of e-bikes acceptable on path**	Type 1, 2, 3, and Moped	Types 1, 2, and 3	Types 1 and 2 (and 3 on Class IV path)

9.2 E-Bike Considerations

Recent progressive legislation passed by Governor Jerry Brown in 2015 makes it much easier to integrate e-bikes into our proposed prototypes. Effective January 1, 2016 electric-assist bikes are permitted to ride on traditional bike paths. Type 3 e-bikes and Mopeds are not permitted on the Class I bikeway.[43] Types 1, 2, and 3 e-bikes are permitted on Class IV bike lanes (Table 6). (See Appendix 11.7 for additional information). In addition, the existing legislation only establishes the parameters within which localities can develop their own regulations. The initial news report highlighted that "The law does not prevent local authorities from further restricting e-bikes if necessary."[44]

Table 6. E-Bike Definitions

E-bike Type	Definition	State Law[45]	Bike Path Permitting E-bike Type	Necessary Additions to the Proposal
Type 1	Pedal assisted machines Max. speed of 20 mph	Allowed on off-street multi-use paths	Base Case, El Camino, Caltrain	Speed limit signage
Type 2	Throttle assisted machines Max. speed of 20 mph	Allowed on off-street multi-use paths	Base Case, El Camino, Caltrain	Speed limit signage
Type 3	Pedal assisted machines Maximum speed of 28mph	• Restricted to roads and bike facilities adjacent to roads (like on-street lanes) • Helmets are mandatory • No license plate required	Base Case and El Camino	Sign not permitting this e-bike type on the Class I bike paths along the Caltrain Route
Moped	Maximum speed ~ 31mph	• Requires driver's license, helmet, and licence plate.	Only Base Case	Sign not permitting this e-bike type on the

[43] Lindsey. "California Approves E-Bikes on Bike Paths". Bicycling.com. 2015
[44] Joe Lindsey. "California Approves E-bikes on Bike Paths". Bicycling.com. 2015.
[45] Logemann and Lommele. "New E-Bike Law Passes in California." Peopleforbikes.com 2015

				Caltrain Route or route on El Camino

9.3 Cost of the Two New Routes

Tables 7 and 8 includes details on our estimated construction cost for the routes along El Camino and the Caltrain corridor. The individual inputs to the route along El Camino include 11.6 miles of a Class IV bikeway, concrete barriers that separate the cycle tracks from motorized vehicles, 85 regular intersections with marking improvements, and 25 protected intersections. Our estimated grand total for this route is $18,040,000 (Table 7). The individual inputs for the route along the Caltrain corridor include 3 miles of the Class IV bikeway with the concrete separators, 3 protected intersections and 3 normal intersections. In addition our other inputs include 8 miles of Class I bike paths along the caltrain corridor. We also include five tunnels for when the track switches sides, improvements to 26 at grade intersections, eight intersections that cross under the railroad tracks, an overpass to Steven's Creek track to promote connectivity, and a barrier wall separation. Our estimated grand total for our second route is $269,037,560 (Table 8).

We also show the cost of the Caltrain route broken down into three components (Table 9). The first includes everything but the soundwall and under-crossings for major streets and totals an estimated $37 million. The second component is the soundwall, at an estimated $17 million, and the third is the eight undercrossings where major cross streets will go under the Caltrain/bike path grade, at a total of $216 million (~27 million each). The second and third cost components may need to be incurred whether or not a Caltrain bike path is constructed. Because the high speed rail will run very close to homes, businesses, parks and schools, a soundwall may be a necessary feature regardless of whether there is a bike path. In addition, the greater frequency of trains accompanying Caltrain electrification and high speed rail will likely so interrupt cross-street auto traffic flow that major cross streets will need to be routed. Taking away these two major components, the cost of the Caltrain bike route drops to around $37 million.

In Table 9 we see that even this lowest estimate for the incremental cost of the Caltrain route is much higher cost than that for the route along El Camino. One reason for the cost difference is the fact that the Class IV bike path with concrete separators ($200,000/mile for the path and $142,560/mile for the separators) is less expensive per mile than a Class I bike path ($775,000/mile), because building a bike path is essentially like building a new road. In addition the route along the Caltrain includes other features such as five $4 million tunnels for where the path switches track sides and a $3 million overpass connecting to another major path.

Table 7. Cost Analysis for the El Camino Route

Item	**Cost per Item**	**Number of Items or Length**	**Total**
Class IV Bikeway	$200,000/mile	11.6 miles	$2,320,000
Concrete barriers and Separators	$9/ square foot	11 miles * 5280 * 3 feet = 174240	$1,568,160* 2.5 = $3,920,400 (take average of alt. 1 & 2, thus 2.5)
Bicycle Crossing and Turning Improvements (Regular Intersection)	$10,000-$75,000/intersection ($60,000) (non protected part 1)	85* (60,000)	5,100,000
Bicycle Marking Improvements	$10,000-$25,000/intersection (20,000) (plus non protected part 2)	85* (20,000)	1,700,000
Protected Intersection	$100,000-$300,000/intersection midpoint	25* (200,000)	5,000,000
GRAND TOTAL			**$18,040,400**

Table 8. Cost Analysis for the Caltrain Route

Item	Cost per Item	# of Items or Length	Total
Bike Route through El Camino Park	No Cost	.5 miles	n/a
Embarcadero Bike Path	No Cost	.9 miles	n/a
Bike Route through San Francisquito Park	No Cost	.1 mile	n/a
Class IV Bike Path	$200,000/mile	2.9 miles	$580,000
Concrete separation of Class IV Bike Path	$9/square foot	3 miles * 5280 * $9	$142,560
Protected Intersections with Class IV bike path	$200,000)	3	$600,000
Normal Intersections with Class IV bike path	$60,000	3	$180,000
Western Class I Bike Path	$775,000/ mile	5	$3,875,000
Eastern Class I Bike Path	$775,000/ mile	3	$6,200,000
Overpass to Steven's Creek Trail	$3 million	1	$3,000,000
Track Side Switches (Tunnel)	4 million	5* 4 million	$20,000,000
Intersections where streets will cross under railway and path	$27 million per item	8* 27 million	$216,000,000
At grade intersection	$60,000	37-8-5 = 26	$1,440,000
Wall between rails and path (precast concrete)	$2 million per mile	8.5 miles	$17 million
GRAND TOTAL			**$269,017,560**

Table 9. Summarized Estimated Costs

Route	**El Camino Grand Total**	*Caltrain (Everything but soundwall and cross streets under Caltrain) +* +	*Caltrain Soundwall*	*Caltrain Cross Streets Under Caltrain*	**Caltrain Grand Total**
Est. Total	**~$18 million**	~37 million +	~$17 Million	+ ~216 million	**= ~$270 million**
Sources:	*Berkeley Bicycle Plan* Public Draft 2016, C*osts for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public* By Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, Daniel A. Rodriguez, *Mountain View Bicycle Transportation Plan Update* and *Palo Alto Rail Corridor Study*. (Appendix 11.5)				

9.4 Ranking the Alternative Routes

In this section we discuss our ranking of the alternative routes on our two main criteria--impact on mode share (including the individual sub-components) and construction cost--and on an overall criterion that considers both mode share impact and cost. Bike mode-share is positively affected through enhancing perception of safety, directness, advances in the overall bike network, proximity to trip attractors and generators, and the ability to accommodate e-bikes. These five qualities are described in the Desirable Route and Infrastructure Properties section. All rankings are relative to the base case, the existing north-south route. A ranking equivalent to the base case is indicated by a “0”, a superior ranking by one or more “+” symbols, and an inferior ranking by one or more “-” symbols. Table 10 shows all of our rankings.

In regards to directness, El Camino Real (ECR) receives a ranking of “++” because of its decreased distance relative to the base case and the complete lack of turns. Additionally, while a rider must make five turns on the Caltrain route v, it too receives a “++” rank, due to it’s shortened distance in relation to the base case as well as its relative simplicity to navigate. The third aspect of our directness definition, time, has two sides. First, Caltrain in theory would take less time because of the far fewer intersections a cyclist would potentially need to stop at. On the other hand, the presence of pedestrians and recreationists on the Caltrain path may reduce the speed that bikers can achieve compared to the ECR lanes.

The Caltrain route has the highest perception of safety, receiving a "++", as it is a separated route that does not come into contact with cars. Either route on ECR, central or side, receives "+" because despite being a protected bike lane, a rider must enter, exit, and continue on the path through intersections. As shown in the table above, there are 110 intersections along ECR and many of these are heavy traffic areas. While perception of safety decreases at these intersections, a majority of the commute will take place inside a protected bikeway, where perception of safety is very high, and we are proposing special intersection treatments for safety. The major cross streets that the Caltrain bike path will intersect with are proposed to be grade separated and the total number of intersections is lower. Both routes utilize separated Class I and Class IV bikeways, and thus both rank higher relative to the base case which has mixed bikeway classifications, a significant portion of which is streets with no bikeway designation, Class III (signs only) or unprotected Class II lanes on streets with significant traffic. The middle third of the base case, the Bryant bike boulevard, would by itself rank higher than the rest of the base case route.

Due to the many commercial and residential areas built off of ECR, as well as the highly populated areas of Stanford University and the Stanford Research Park, a bike route on this central corridor has greater proximity to attractors and generators than the base case and the Caltrain. It receives a "++" ranking on this sub-criterion. The Caltrain route does pass right next to all the Caltrains stations, and like ECR, it passes through all four downtowns. It receives a "+". The base case route passes through three of the four downtowns. (Reference Appendix 11.2 for an Employment and Housing Map).

Advances in the bike network refers to increases in total mileage of bikeways and in connectivity between existing bike routes. Both the ECR and the Caltrain routes add significant mileage and add network connections. However, these two routes only add a single north-south axis. We assign each of them a "+".

The base case route well accommodates e-bike transportation because it travels on secondary roads where there is adequate space for the higher speeds of e-bikes. We assign El Camino Real a rating of "0", equivalent to the base case, because it's 8' width allows for faster rider, including e-bikes, to pass slower ones safely. The Caltrain route, primarily a Class I bike path, is less suitable for -ebikes for two reasons. Most importantly, pedestrians and recreationists will be using this path and e-bikes in this restricted space may have more conflicts with them. Also, state law precludes one type of e-bike, type III, from being used on bike paths. Consequently Caltrain receives a "--" rating.

We now turn to our overall rating on impact on bike mode share, taking all five of the sub-components into consideration. The El Camino Real route outranks the base case route on four of the desirable properties and ties on one. The Caltrain route outranks the base case route on four of the desirable properties and ranks lower on one. Both of these routes have the potential to increase bike mode share more than the existing route as represented in the base case.   While Caltrain slightly surpasses ECR in terms of perception of safety, it does not add as much in connecting major attractors and generators and is less suitable for e-bikes, a potential significant source of future growth. Consequently we assign ECR a "++" rating and Caltrain a "+" rating.

Finally, in our overall ranking of the route alternatives, we consider cost together with impact on mode share. Even at the lowest estimate for the incremental cost of the Caltrain route (component 1 in table 9), its costs is still twice as much as the El Camino Real route. In addition to the El Camino Route being cheaper, we have rated it has having a higher potential impact on bike mode share. So clearly El Camino should be assigned a higher overall rating than Caltrain. We believe that the potential for increased bike share mode also justifies a higher rating for the El Camino route relative to the base case, even considering the former's $18 million cost, and for the Caltrain route, if we consider only the $37 million cost. If the incremental cost of the Caltrain route were $270 million, it would require more analysis for justify ranking it over the base case. Based on these judgements, we assign the El Camino Real route an overall rating of "++" and the Caltrain route an overall rating of "+".

Table 10. Evaluation of Impact on Mode-Share, Cost, and Overall Rankings

	Impact on Mode-Share						Cost	Overall Evaluation
	Directness	Perception of Safety	Proximity to Attractors / Generators	Advances in Overall Bike Network	E-bikes	Overall Impact on Mode-Share		
Base Case: Current Route	0	0	0	0	0	0	0	0
ECR	++	+	++	+	0	++	--	++
Caltrain	++	++	+	+	--	+	---	+

9.5 Conclusions

Implementing either of our proposed route options--the El Camino Real protected bike lanes or the Caltrain bike path--would promote an increase in bike mode share in the MMP communities and leverage other future bike network improvements. Ultimately, the El Camino Real route should most effective in increasing bike mode share, as well costing less than the the Caltrain bike path. For these reasons, it has received the highest ranking in our report.

Table 11 below takes the material of Table 10 and presents another way to look at how the two proposed routes as well as the base case compare in terms of our desirable properties to increase commuter bike mode-share and cost. The left column individually displays all the qualities evaluated in this report, and the right column is the associated route which maximizes said quality. This chart is useful because some decision-makers or communities might prioritize different properties over others, and it is helpful for our clients to have a clearer understanding of what route creates certain outcomes.

Table 11. Priorities and Recommendations

If you prioritize...	We recommend...
Directness	ECR, Caltrain
Cyclists' Perception of Safety	Caltrain
Proximity to Trip Attractors and Generators	ECR
Advances in the Overall Bike Network	ECR, Caltrain
Overall impact on Mode-Share	ECR
Cost Savings	Base Case, ECR
Ability to Accommodate E-bikes	Base Case, ECR

9.6 Limitations

In addition to our key findings, we wish to highlight two of the limitations of our research.

9.6.1. Equity Concerns

Unfortunately, our research process mostly took for granted that the creation of these new bikeways would result in equitable outcomes in the Mid-Peninsula. However, we see now that an explicit commitment to equity must be foundational to proposals to increase bike mobility and to install new infrastructure.

Equity refers to resource allocation based on need, financial or otherwise. Aside from walking, biking is the lowest cost mode of transportation over an extended period of time and, for some, the bike may be the only affordable mode of transport. Silicon Valley Rising notes that for every new tech job, there are four non-tech jobs created, and "for many people, this means piecing together part-time minimum wage jobs - and a lot of times, people go between these jobs by bike because they can't afford other ways of getting around."[46] Knowing this, it is imperative to ensure an equitable allocation of bike facilities -- that is, ensuring that higher need areas enjoy easy access to them.

A true commitment to equity requires an examination of how the creation of new infrastructure leads to gentrification. Silicon Valley Bike Coalition (SVBC) reminds us that "even the most well-intentioned projects can potentially lead to unanticipated displacement or gentrification."[47] They emphasize community consultation -- e.g. interviews with residents, attendance at community meetings -- in order to understand the full needs of communities, include them in the entire policy process, and prevent these unintended consequences.

We recommend the creation of an equity index in order to address this limitation. For example, the Los Angeles Department of Transportation (LADOT) maintains an explicit commitment to equity by utilizing an equity index when planning street designs. This equity index includes items such as "access to resources, income level, previous attention and funding, land use and community character, and health variables such as childhood obesity and rate of respiratory disease."[48] In addition to income level, other items from LADOT's equity index and health variables relevant to the MMP communities should be included in an MMP equity index.

9.6.2. Cost-Effectiveness: Quantifying Mode Share Impact

Ideally, evaluating our alternatives would include a quantitative evaluation of cost-effectiveness. Cost-effectiveness is calculated by dividing the output (increase in bike mode-share) by the total cost of implementation. This would be done for each alternative to provide a comparative value of a dollar contributed toward each alternative. These ratios inform how much "bang for your buck" is provided by each alternative--or the effectiveness of each dollar spent in increasing mode-share. A quantitative cost-effectiveness ratio would aid the client in making an informed decision.

Our team was not able to make numerical estimates for the potential mode-share gain resulting from our specific alternatives, due to the lack of project time. Therefore, we were not able to calculate numerical cost-effectiveness ratios. We did consider, in a qualitative fashion, the relative ranking of the alternatives in potential impact on mode share together with their relative cost, in our overall rating of them.. Future analysis of these bikeway proposals should include a quantitative evaluation of possible

[46] "Sharing Our Notes: Two Conferences Address Equity"
[47] "Sharing Our Notes: Two Conferences Address Equity"
[48] "Sharing Our Notes: Two Conferences Address Equity"

mode-share impact. Such an evaluation would likely produce an estimated range of potential results as opposed to a single point estimate, and would be subject to uncertainty.[49] Nonetheless, this would create a more informed cost-effectiveness analysis to ensure financial efficiency and attainment of bike mode-share goals.

10. Recommendations for Further Study

10.1 West Side and East Side Routes

An interview with Stefan Heck, an urban mobility specialist in the Bay Area, gave insight into the bikeway needs across the Mid-Peninsula. Heck emphasized that people interested in cycling as a method of commuting are looking for convenience, meaning they are not willing to go significantly out of their way in order to use a bikeway. For this reason, Heck proposed the solution of providing three bike route options, one in each of the east, west, and central locations, to create a Mid-Peninsula master bikeway plan. While there is existing infrastructure in these areas, improvements to allow for a greater perception of safety, such as Class IV bikeways, would reach a wider variety of cyclists. This report focuses on connecting the central corridor because it has high volumes of traffic and large populations of commuters. To fully address cyclist mobility in the region, the western route option should also be studied as a possibility for commuter connectivity. This would allow for a more comprehensive and elaborate bike network throughout the entire region.

In addition to the western route, Heck encouraged local governments to complete the eastern route. According to Heck, two simple bridges over the San Francisquito creek will sufficiently connect East Palo Alto to Palo Alto, completing the extensive bike network already in place. Much of this system is a result of the Google Bike Vision Plan, and it stretches far along the Bay residential and commercial areas. There are still many improvements to be made on this eastern route but the first objective is to complete the two bridges. Further research can be done on how to increase directness to the network already in place and how to enhance the quality of bike lanes in order to create a greater perception of safety.

10.2 Political Feasibility

Per the client's request, this investigation refrained from considering political feasibility in order to allow us to focus on developing concrete proposals for new route

[49]Beuhler and Dill. "Bikeway Networks: A Review of Effects on Cycling." 2016.

options. Our task was to imagine what an ideal bikeway network could look like for the Mid-Peninsula and to describe why and how. Therefore, in future work on this project, it will be necessary to research the political feasibility of the proposed bikeway routes and designs. This will involve an understanding of support and opposition for the proposals, options for mitigating adverse impacts to increase support, and strategies for leveraging support in order to create the political will necessary for implementation. Major items of potential community concern (and concerned groups) to research include removal of street parking on El Camino Real (local businesses and shoppers), construction alongside El Camino Real or the Caltrain (homeowners, Caltrain administrators, businesses, parks), and sensitivity to neighborhood change (community residents).

We also may be able to mitigate conflict through solutions identified in feasibility studies. For example, when building these bikeways, there might be disruption of the streets or trails during construction.[50] However, Burlingame has been able to implement construction with limited disruption.

[50] "Next Phase of Bike Path Rehabilitation Breaks Ground."

11. Appendices

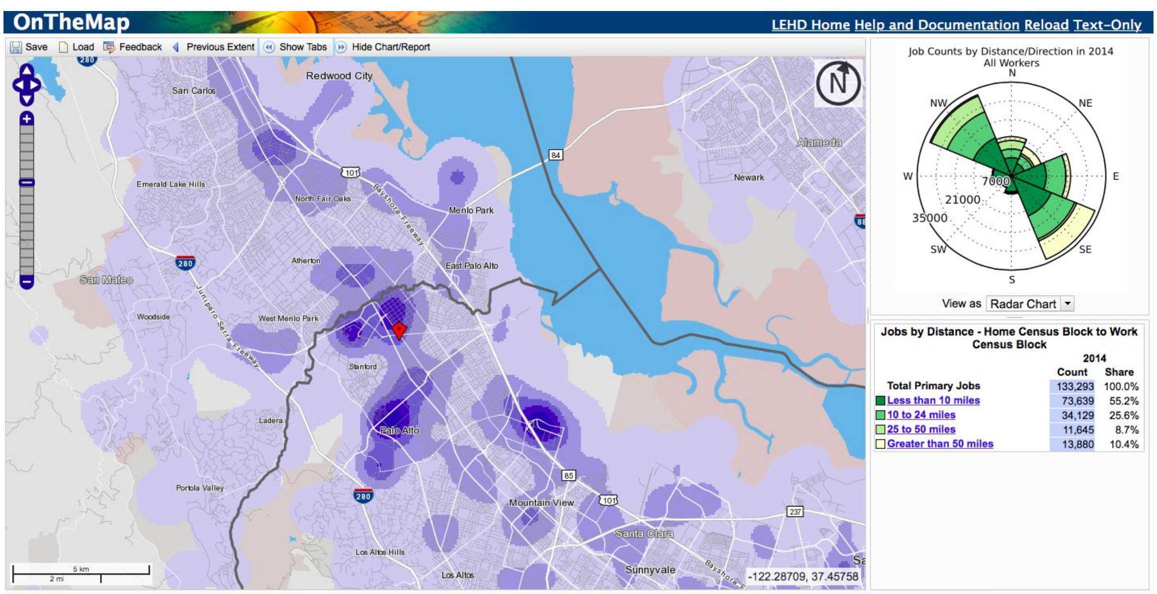
Appendix 11.1: Census Mid-Peninsula Commute Data[51]

City	Commuters	Bike Total	Bike Male	Bike Female	Drive Alone	Travel Time	<10 Mins	10-14 Mins	14-19 Mins
Menlo Park	15,722	7.70%	9.80%	5.20%	69.50%	32.90%	13.30%	14.10%	19.10%
Redwood City	42,147	1.90%	3.10%	0.50%	73.50%	50%	17%	14.50%	18.50%
Mountain View	40,375	5.60%	6.90%	3.70%	71.50%	49.50%	10.70%	15.40%	23.40%
Palo Alto	31,113	9%	10.90%	6.60%	64.90%	47%	11.60%	16.50%	18.90%
Stanford CDP	5,430	46%	51%	40%	19%	82.90%	34.90%	27.30%	20.70%

Appendix 11.2: Employment and Housing Mapping

A. Employment

Where do people within the radius work?

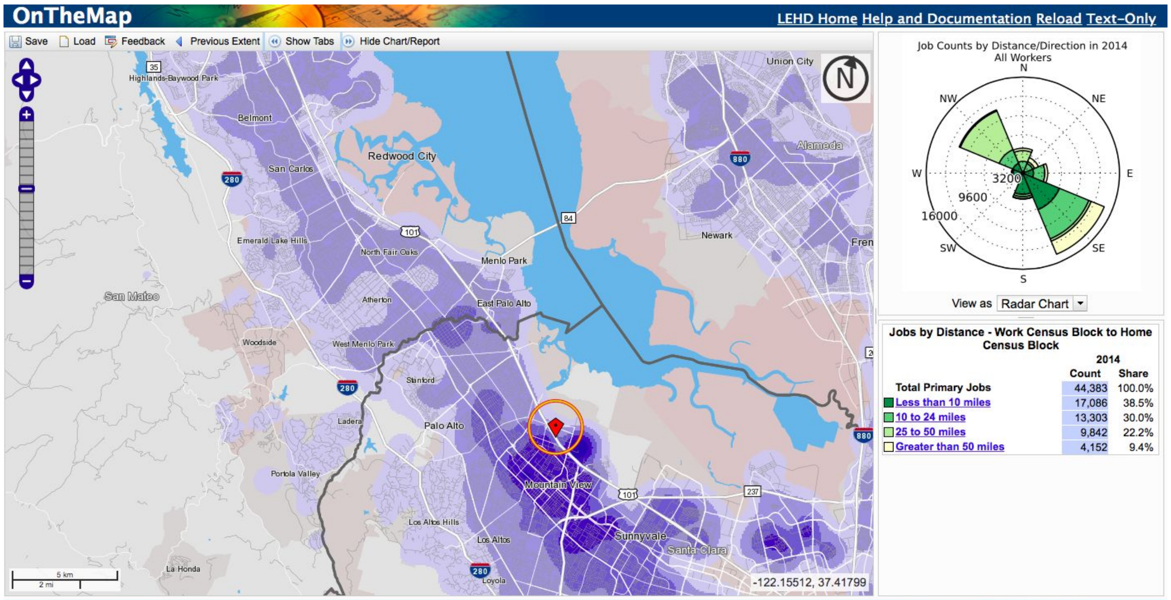


[51] US Census. Fact Finder 2015. http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_14_5YR_S0801&prodType=table

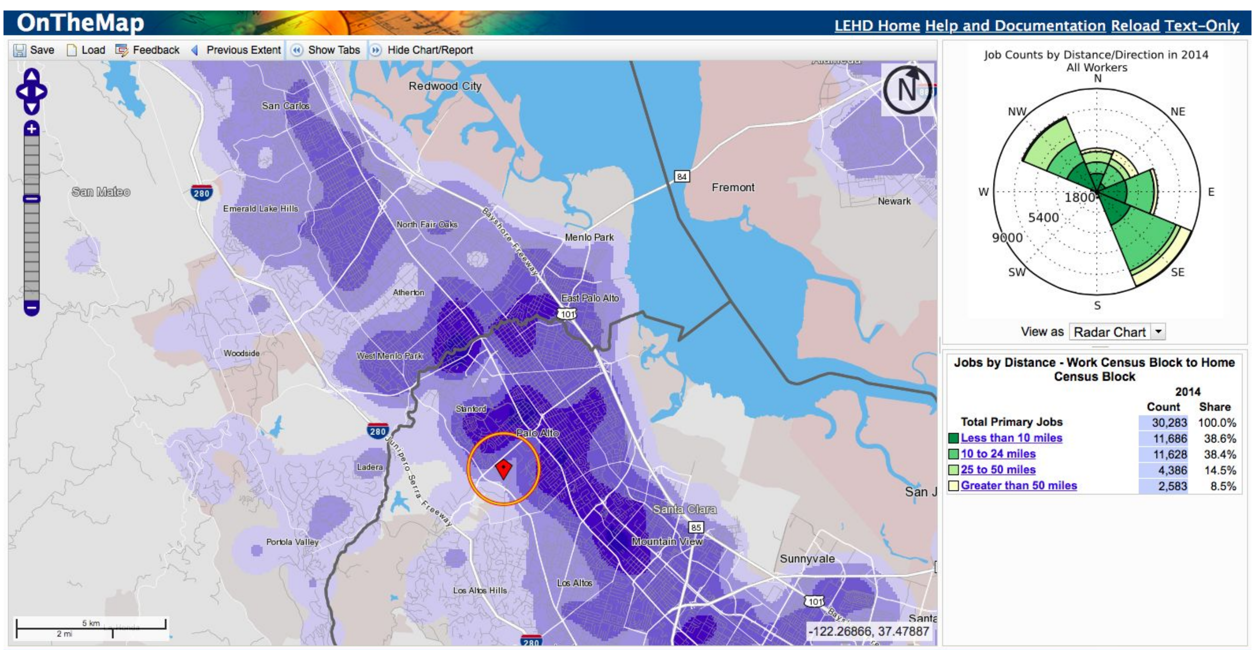
B. Employee Housing

Where do employees from this location live?

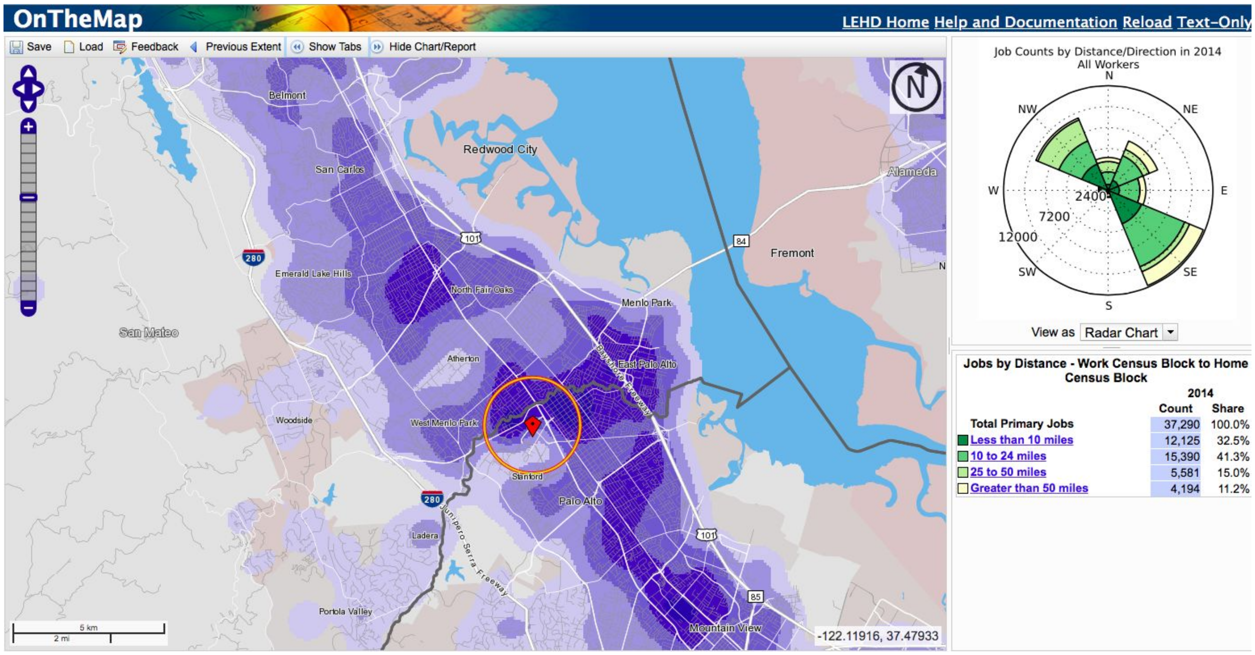
North Mountain View



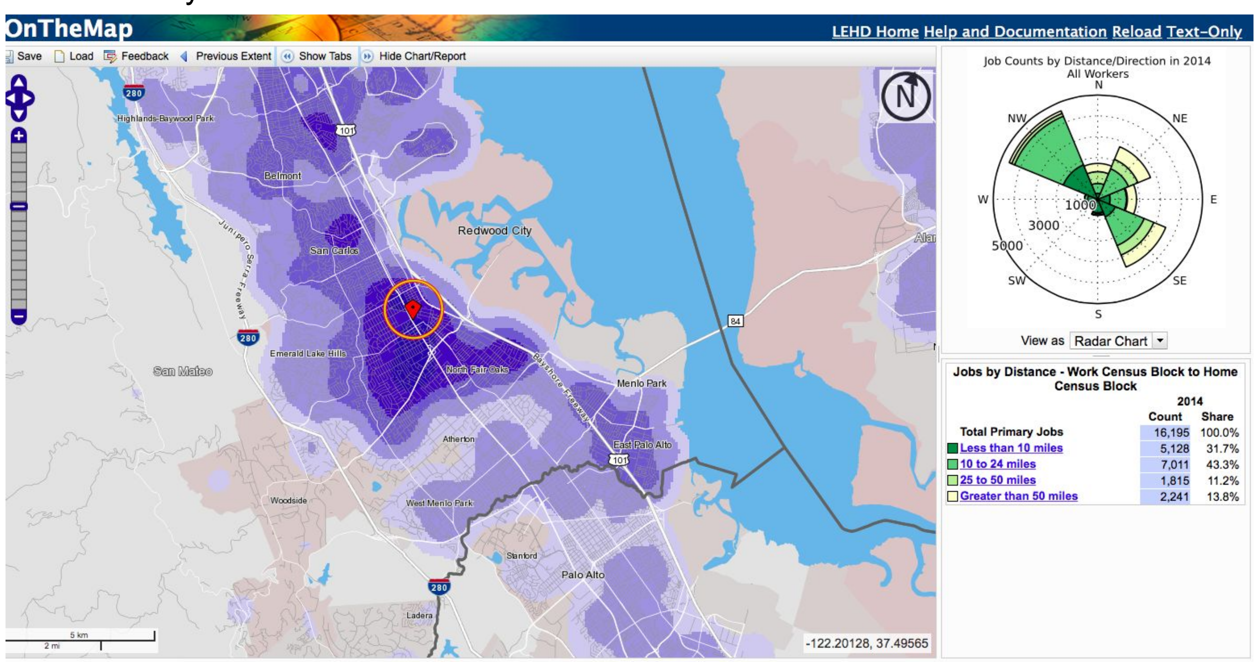
Southwest Palo Alto



North Stanford



Redwood City



Note: the framing of this map favors the north, outside the MMP region in order to show the large concentration of employees living to the north

Appendix 11.3: Policies and Innovative Measures used in Dutch, Danish, and German Cities to Promote Safe and Convenient Cycling[52]

Extensive systems of separate cycling facilities
- Well-maintained, fully integrated paths, lanes and special bicycle streets in cities and surrounding regions
- Fully coordinated system of colour-coded directional signs for bicyclists
- Off-street short-cuts, such as mid-block connections and passages through dead-ends for cars

Intersection modifications and priority traffic signals
- Advance green lights for cyclists at most intersections
- Advanced cyclist waiting positions (ahead of cars) fed by special bike lanes facilitate safer and quicker crossings and turns
- Cyclist short-cuts to make right-hand turns before intersections and exemption from red traffic signals at T-intersections, thus increasing cyclist speed and safety
- Bike paths turn into brightly coloured bike lanes when crossing intersections
- Traffic signals are synchronized at cyclist speeds assuring consecutive green lights for cyclists (green wave)
- Bollards with flashing lights along bike routes signal cyclists the right speed to reach the next intersection at a green light

Traffic calming
- Traffic calming of all residential neighbourhoods via speed limit (30 km/hr) and physical infrastructure deterrents for cars
- Bicycle streets, narrow roads where bikes have absolute priority over cars
- 'Home Zones' with 7 km/hr speed limit, where cars must yield to pedestrians and cyclists using the road

Bike parking
- Large supply of good bike parking throughout the city
- Improved lighting and security of bike parking facilities often featuring guards, video-surveillance and priority parking for women

Coordination with public transport
- Extensive bike parking at all metro, suburban and regional train stations
- 'Call a Bike' programmes: bikes can be rented by cell phone at transit stops, paid for by the minute and left at any busy intersection in the city
- Bike rentals at most train stations
- Deluxe bike parking garages at some train stations, with video-surveillance, special lighting, music, repair services and bike rentals

Traffic education and training
- Comprehensive cycling training courses for virtually all school children with test by traffic police
- Special cycling training test tracks for children
- Stringent training of motorists to respect pedestrians and cyclists and avoid hitting them

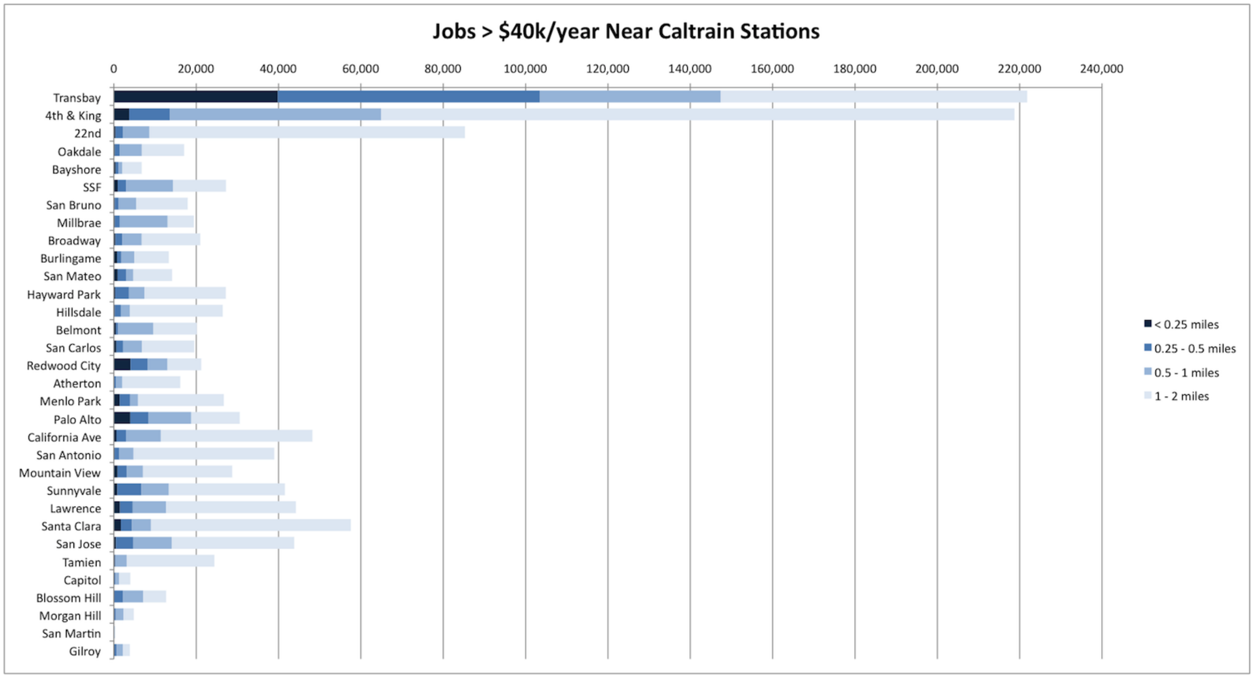
Traffic laws
- Special legal protection for children and elderly cyclists
- Motorists assumed by law to be responsible for almost all crashes with cyclists
- Strict enforcement of cyclist rights by police and courts

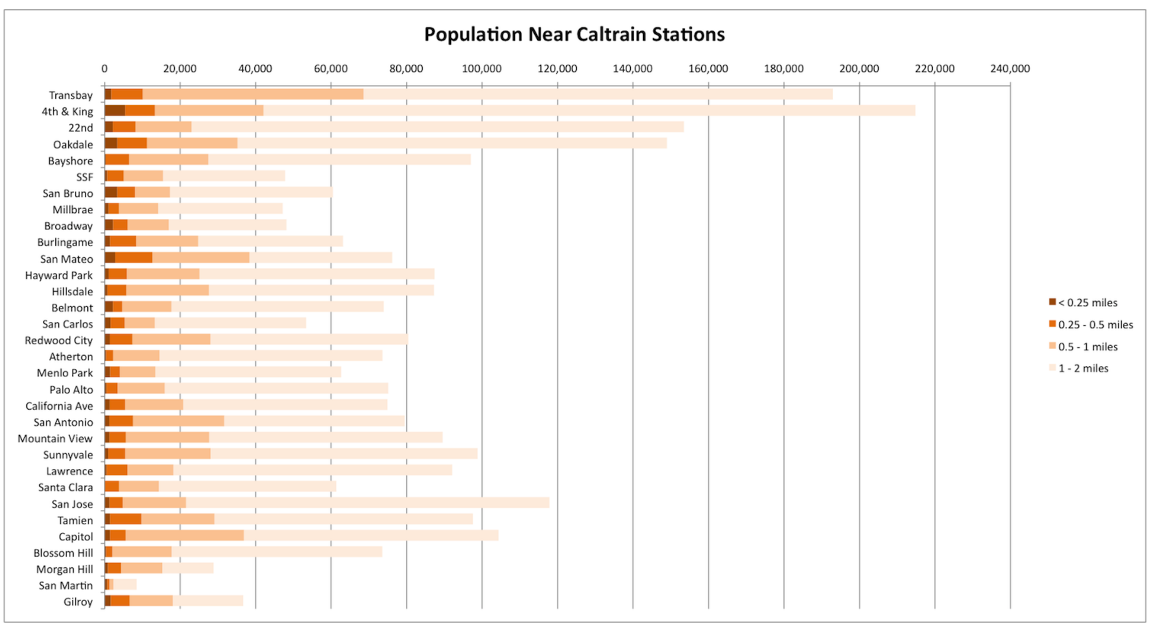
Source: Information provided directly to authors by bicycling coordinators in the Netherlands, Denmark and Germany

[52] Pucher and Beuhler. "Making Cycling Irresistible: Lessons from the Netherlands, Denmark and Germany". Transit Reviews, Vol. 28, No. 4, 495-528, July 2008.

Appendix 11.4: Employment and Population Density Near the Caltrain [53]

(Source 2010 Census)





(Source: 2010 Census)

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[53] http://caltrain-hsr.blogspot.com/2012/01/peninsula-rail-corridor-census.html

Appendix 11.5: Additional Cost Information[54]

TABLE 5-9 ANNUAL OPERATION AND MAINTENANCE COST ESTIMATES FOR HIGH PRIORITY PROJECTS			
Facility Type	**Unit Cost**	**Annual Cost**	**Notes**
Class I Multi-use path	per mile	$60,000	Maintenance costs assume minimal landscaping, no lighting
Class II Bike Lane	per mile	$15,000	Assumes current street sweeping program
Class II Buffered	per mile	$15,000	Assumes current street sweeping program
Class III Bike Route	per mile	$5,000	Assumes current street sweeping program
Class III Bike Boulevard	per mile	$7,500	Assumes current street sweeping program
Class IV Protected Bike Lane	per mile	$25,000	Assumes bikeway accessible to current street sweeping program
Bicycle marking improvements	Intersection	$2,000	Assumes 2 approaches modified.
Bicycle crossing and turning improvements	Intersection	$2,500	Assumes 2 approaches modified.
Bicycle Signal Detection	Intersection	$2,500	Assumes 2 approaches modified.
Protected Intersection	Intersection	$4,000	Assumes 4 approaches modified.

[54] Alta Planning. "City of Mountain View Transportation Update." 2015.

TABLE 5-5 ESTIMATED BIKEWAY UNIT COSTS			
Facility Type	**Unit Cost**	**Cost**	**Notes**
Class I Shared-Use Path	Per Mile	$ 775,000	Class I bikeways do not include right-of-way, retaining walls, bridge, lighting, costs.
Class II Bike Lane	Per Mile	$ 52,000	Class II and III bikeways do not include right-of-way, re-striping, changes to curb, gutter, or medians. Assumes current street sweeping program
Class II Buffered Bike Lane	Per Mile	$ 140,000	
Class III Bike Route	Per Mile	$10,000	
Class III Bike Boulevard	Per Mile	$42,000	
Class IV Protected Bike Lane	Per Mile	$200,000	Class IV bikeways do not include right-of-way, re-striping, changes to curb, gutter, or medians. Class IV bikeway assumes use of plastic bollards.
Bicycle marking improvements	Intersection	$10,000 - $25,000	Assumes two approaches modified. May include, but are not limited to: extending the bike facility to the intersection, adding intersection crossing markings, and green striping in conflict/merge zones.
Bicycle crossing and turning improvements	Intersection	$10,000 - $75,000	Assumes two approaches modified. May include, but are not limited to: adding two-stage left-turn queue boxes to facilitate left turns without using the left-turn lane, bicycle signal phase, median refuge, advanced warning signs, HAWK signal.
Bicycle Signal Detection	Intersection	$10,000 - $15,000	Assumes two approaches modified. Assumes existing controller can accommodate new detection.
Protected Intersection	Intersection	$100,000-$300,000	Cost depends on signal modification, if new medians/islands are needed, etc.

Appendix 11.6: Summary of Community Research

A. Redwood City

Demographics:

- Age:
  - Under 14: 20.2%
  - 15-24: 11.3%
  - 25-44: 32.4%
  - 45-64: 25.7%
  - 65 and older: 10.6%
- Race/Ethnicity:
  - White: 44%
  - Hispanic/Latino: 38.8%
  - Asian: 10.5%

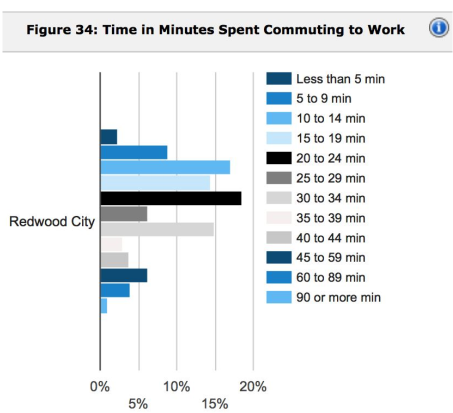
- Black/African American: 2.2%
- Pacific Islander: 1.0%
- Other: 4.6%

- Household Data:
  - Median household income: ~$76,500
  - Median Home Price: $764,500
  - Number of Housing Units: 29,167
- Size: Approximately 19 square miles

Priority Hubs:

- Where residents are traveling:
  - Both residents and visitors/employees: Caltrain, Pacific Shores (many existing companies, and future development), downtown (huge draw), Redwood Shores, Cañada College, Kaiser Hospital, and Sequoia Hospital. Caltrain has station boarding/alighting data, where you'll find information about all the cities your team is researching
- Where visitors travel within the city:
  - Driving: 101, 280, El Camino Real, Woodside Road, Farm Hill Boulevard/Jefferson, Broadway, Middlefield.
- Connectivity Gaps:
  - Significant gaps and barriers along El Camino Real and Woodside Road, and crossing 101. Bay and Broadway can also be difficult for cyclists.

Commuter Data:



B. Menlo Park

Bicycle Development Plan (2005)

City Aerial View

Demographics:

- Population: 32,026
- Age:

    - 86.3% of residents younger than 65
- Race/Ethnicity
    - 70.2% white
    - 29.8% of color
- Household Income
    - Median household income: $113,774
    - 6.4% living in poverty

Priority Hubs:
- Santa Cruz Avenue (downtown)
    - Currently Class II (striped) bike lane
- El Camino Real (shopping trips, Safeway)
    - In need of bike lane solutions; construction of bike lanes on this road was recently shelved by Menlo Park City Council vote
- Sand Hill Road
    - Alpine Road Class I: provides off-street connection to Sand Hill Road
- Areas east of US-101 and near Facebook
    - Willow Road majority Class II (striped) bike lane
- San Francisquito Creek Bike Trail
    - At Willow Place, Alma Street, San Mateo Drive; provide important connections for cyclists wishing to avoid the busy motorized vehicle crossings at Middlefield and El Camino Real

Commuter Data:
- Where residents are traveling:
    - Downtown (Santa Cruz Avenue)
    - El Camino Real areas (for shopping trips, Safeway)
    - Schools
- Where visitors travel within the city:
    - Employees of local companies (mostly off of Sand Hill, El Camino or area east of US 101)
        - Facebook
    - Downtown/shopping areas.
- Peak commuter hours
    - 7:00am-9:30am
    - 4:30pm-7:00pm

Other Considerations:
- Multi-Modal Connections

    - Need improved bike parking facilities at bus stops and bike racks on trains and buses
    - Bus connections to Millbrae BART: SamTrans
    - Bus connections to Union City BART: Dumbarton Expressway
- “Limited continuous/direct routes connecting Palo Alto, Menlo Park and Atherton” (qtd from Nikki Nagaya’s email)
    - Focusing on North-South connectivity through our region, I think our best option is to focus on a bike rail elevated above the Caltrain

C. Palo Alto

Demographics:

- Population: 65,998
- Median Age: 41
- Median household income: $126,771 (Census)

Priority Hubs (Chris Corrao Email):

- El Camino Real
    - Heavy traffic morning and evening
    - No bike lanes accounted for
- Middlefield Rd.
    - 1.3 Miles of Class II bike lanes
- Bryant Street
    - Class III Bicycle Boulevard
- Page Mill Road
    - Undeveloped bike plan

Commuter Data (Chris Corrao Email)

Peak Commuting Hours

- 7-9:30 am
- 5-7:00 pm

Places of Interest

- Caltrain stations
- Page Mill Road
- 101 & 280 up to SF and SJ
- Downtown Palo Alto and Menlo Park

Other Considerations (Chris Corrao Email and link):

- Follow all the streets that get repaved
    - Aggressive repaving schedule (2012)
- New Traffic signals
- One way street sharing plan
- Parking Protected bike lanes

- Around 60-80 bicycle collisions per year. 420 over 2004-2009
- El Camino and Middlefield are at the top of the list for amount of accidents

D. Stanford

*Already has bike protected lanes around campus with many different routes, so there is not much need for better bike infrastructure on campus

Demographics:
- 33,980: 19,372 students, 2,959 faculty, and 11,649 staff (Fall 2015 Population Report)
- 48.9% Women, 51.1% Men (Class of 2018)
- 35.2% White, 23.4% Asian, 10.6% African American, 30.8% other (Class of 2018)

Priority Hubs:
- Entrance and exit routes onto and off of campus to be better for bikers
    - Crossing over Caltrain tracks to get to Stanford through Palm Drive.
    - Easier access points from Sand Hill and Page Mill Rd.

Commuter Data:
- peak hours 8-9am inbound, 5-6pm outbound
- Main form of transportation for employees: 51% automobile, 22% bike, 20% public transportation
- most of our residents travel to main campus, though we know spouses, children and roommates do go off-campus

Time Spent in Commute

One-Way Travel Time	Weighted Percent
0-4 minutes	0%
5-9 minutes	4%
10-14 minutes	12%
15-19 minutes	15%
20-29 minutes	21%
30-44 minutes	18%
45-59 minutes	14%
1 hour or more	18%

Grand Total	**100%**

Source: Stanford P&TS

Other Considerations:

- Need better signage for people to understand their location and route through campus

E. Mountain View

Demographics:[55]

- Ethnicity:
  - White: 56%
  - Asian: 26%
  - Hispanic or Latino: 21.7%
  - Black or African American: 2.2%
  - Other: 1%
- Housing:
  - Number of housing units: 34,136
- Square miles: 12.0
- Age:
  - Persons under 5: 7.1%
  - Persons under 18: 19.7%
  - Persons 65 and over: 10.6%

Priority Hubs:[56]

- Major employment hubs are located in the North Bayshore Area
  - Google, Intuit, LinkedIn, Microsoft[57]
  - ~22,700 employees commuting in the morning, with only 7% walking or biking

North/South Bikeway Options[58]

- Middlefield Road
  - Currently Class II, 3.55 miles
  - Identified quality gap through fieldwork
  - Recommended improvements to existing facilities, priority project
  - 9 identified spot improvements along the trail, 3 priority spots
- Central Expressway
  - Santa Clara county jurisdiction
  - No current cycling infrastructure, (3.95, miles?)
  - Proposed Class I facility
  - One of the “most frequently mentioned least-friendly bicycle facilities”

[55] City of Mountain View
[56] Shoreline Transport Study
[57] North Bayshore Trip Cap
[58] Mountain View Bike Plan

- Google Bike Vision Plan:[59]
  - high bicycling stress: numerous challenging crossings, high speeds, and lack of facilities
  - identified as barrier to bicycling
  - priority corridor
- El Camino Real
  - Caltrans jurisdiction
  - Currently “undetermined” classification of facilities
  - Proposed Class II, with buffer zone
  - El Camino Precise Plan
- US 101 and Stevens Creek provide physical limitations to N. Bayshore commute access
- Permanente Creek Trail (I), Shoreline Blvd. (II) and Stevens Creek Trail (I) are popular bikeways through Mountain View[60]

<u>Commuter Data</u>:
- “Commute trips are equally divided among short (0 to 5 miles), medium (5 to 30 miles) and long (30+ miles) travel markets”

Appendix 11.7: E-Bike

CALIFORNIA ELECTRIC BICYCLE POLICY

VEHICLE TYPE	VEHICLE		USER				BIKEWAY ACCESS			
	PEDAL OPERATED	MAXIMUM MOTOR-ASSISTED SPEED (MPH)	MINIMUM AGE (YEARS)	DRIVER'S LICENSE	LICENSE PLATE	HELMET	CLASS I BIKE PATH	CLASS II BIKE LANE	CLASS III BIKE ROUTE	CLASS IV PROTECTED LANE
BICYCLE	YES	N/A	N/A	NO	NO	17 AND UNDER	YES	YES	YES	YES
TYPE 1 E-BIKE*	YES	20	N/A	NO	NO	17 AND UNDER	YES	YES	YES	YES
TYPE 2 E-BIKE*	NO	20	N/A	NO	NO	17 AND UNDER	YES	YES	YES	YES
TYPE 3 E-BIKE*	YES	28	16	NO	NO	YES	NO	YES	YES	YES
MOPED	NO	N/A	16	YES	YES	YES	NO	YES	YES	NO

*PENDING AB-1096

peopleforbikes

(Source: peopleforbikes.org)

[59] Google Vision Plan
[60] Mountain View Bike Plan

Appendix 11.8: Rails with Trails Additional Information

This proposed bike route is an example of a Rail with Trail. By definition Rails with Trails are trails adjacent to active railroad lines. There are two main resources we reference to guide our prototype. The first is the 2013 Report, *Rails with Trails* created by the U.S. Department of Transportation in conjunction with other safety and transit related groups. A second more recent guide is *Rails with Trails: A resource for planners, agencies, and advocates on Trails Along Active Railroad Corridors* sponsored. This resource "provides a collection of data, examples and practical tools to assist trail planners and advocates in increasing awareness of the rail-with-trail concept, and advancing local and state policies and practices that support rail-with-trail development." The Rails-to-Trails Conservancy would be a useful point of contact for any transportation planners exploring the feasibility of a Rail with Trail. More specifically, their report states that "Rails-to-trails Conservancy (RtC) "has identified 161 Rails-With-Trails in 41 States"[61] and these bike trails also have international traction. "Hundreds of kilometers of RWTs traverse Western Australia, Canada, and European countries such as Switzerland, Denmark, and the Netherlands."[62] In particular the report provides numerous case study examples which are useful points of reference for conveying the possibility and feasibility of future endeavors. A bike track alongside the Caltrain was proposed in 1997 and was initially called a dangerous idea. However the article also acknowledged that there had only been one train accident in the Mid-Peninsula 31 years, which may indicate that potential issues might be overstated[63].

Appendix 11.9: Further Details from Chapter 1000.3 from the Highway Design Manual

Specifications for Traveled Way:

Specifications for the traveled way for Class I bikeways include a minimum total paved width of 8 feet with 10 feet preferred, and 12 feet in high traffic areas. They also include a minimum 2 foot shoulder (3 feet where feasible) and "where the paved bike path width is wider than the minimum required, the unpaved shoulder area may be reduced proportionately"[64]. We interpret this to mean that if the paved pathway is 12 feet

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[61] Pack and Tomes. America's Rails With Trails. 2016
[62] Rails with Trails Lessons Learned. 2002.
[63] Mitchell. "Bike Path by Caltrain called Dangerous Idea". 1997.
[64] "Highway Design Manual". 2015. http://www.dot.ca.gov/hq/oppd/hdm/pdf/english/chp1000.pdf

we do not need an additional shoulder. However, we may delineate the added area with a white line.

Bike Path Separation from a Pedestrian Walkway:

If the Class I bikeway is next to a pedestrian walkway, the design manual stipulates that “the edge of the traveled way of the bike path is to be separated from the pedestrian walkway by a minimum width of 5 feet of unpaved material.” The unpaved area “may include landscaping or other features that provide a continuous obstacle to deter bike path and walkway users from using both paths as a single facility”[65].

Clearance to Obstructions:

When the Class I bikeway is paved next to a continuous fixed object, the Highway Design manual articulates that “a 4-inch white edge line, 2 feet from the fixed object, is recommended to minimize the likelihood of a bicyclist hitting it. The clear width of a bicycle path on structures between railings shall be not less than 10 feet”[66].

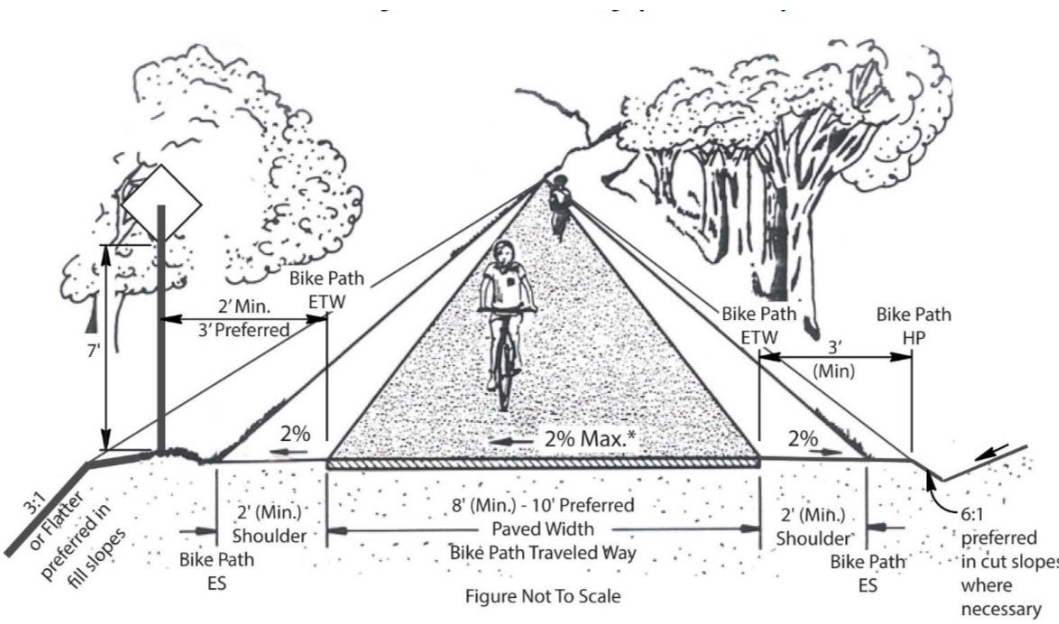
Bike Paths Parallel and Adjacent to Streets and Highways:

When there are bike paths parallel and adjacent to streets and highways, “the minimum separation between the edge of pavement of a one-way or a two-way bicycle path and the edge of traveled way of a parallel road or street shall be 5 feet plus the standard shoulder widths. Bike paths within the clear recovery zone of freeways shall include a physical barrier separation”[67].

These physical design criteria lead to four main points which guide this prototype:

1. The minimum path width will be a total of 12 feet (more if possible) in the case of a typical path
2. Five feet must be added to our estimate if the bike path is next to a pedestrian walkway
3. The minimum path width will total 14 feet if the path is next to a continuous fixed object
4. If the path is going to adjoin a street on one side, which it will in many cases, there has to be 5 feet between the edge of the street or highway pavement and the bike path.

[65] “Highway Design Manual”. 2015.http://www.dot.ca.gov/hq/oppd/hdm/pdf/english/chp1000.pdf
[66] “Highway Design Manual”. 2015. http://www.dot.ca.gov/hq/oppd/hdm/pdf/english/chp1000.pdf
[67] “Highway Design Manual”. 2015. http://www.dot.ca.gov/hq/oppd/hdm/pdf/english/chp1000.pdf



Two-Way Class I Bikeway (Source: Highway Design Manual 1000.3)