LOW-STRESS BICYCLE LANES FOR THE URBAN CORE'S HIGH-STRESS STREETS

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The journey is just beginning.

Abstract

Bicycle facilities have become an integral pattern in the language of almost every metropolitan city in the United States (US). A successful pattern creates a smoother language throughout the city. A smooth language means that vehicles and pedestrians efficiently flow throughout the city.

For bicycle riding in urban streets, success occurs when bicycle facilities are safe, effective and inviting for cyclists—especially for less confident riders. Designers, planners, and engineers can either create safer conditions if done right or create conflicts if not thoroughly crafted.

Currently, many urban cities in the US do not have bicycle facilities that are comfortable enough for less-confident riders to utilize. I use case studies to determine the measure of low-stress and high-stress bicycle facilities and their effects on both cyclist volumes and urban core streets. Literature reviews, precedent studies, and data analysis are also used to understand the worries and desire of people who are interested in bicycling, but concerned about their safety. Their presence in the street is a measure of street's stress level.

My guidelines and designs in this dissertation aim to promote and create safe, comfortable, and pleasurable bike facilities for the category of "Interested but Concerned" bicycle riders. Accomplishing this will increase ridership and strengthen bicycling as a viable mode of transportation within the urban core.

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Introduction

A metropolitan environment is made up of a complex tapestry of symbiotic relationships that not only benefit from each other but also compete for prioritization. It is important to think about the people who cycle as well as the environment in which they ride.

Theoretically, moving around dense city streets by foot or bicycle feels easier than driving a car. This common feeling is supported by the increased presence and use of bike-share programs in cities from New York City to Honolulu. In most US cities, bicycles are underrepresented. This should change because the urban core is better suited for bicycles than cars. The narrow corridors, difficulty and expense of parking, as well as the close proximity to destinations make bicycles an efficient tool for transport.

With the increasing popularity of cycling, cities of the future would require fewer lanes for motor vehicles and more lanes for bicyclists. If bicycle lanes are designed to carry people efficiently through the urban core, the riders will be able to interact with the surrounding environment including street-side businesses. Riders will also enjoy the street's outdoor environment more because vehicle traffic will be calmer and the air will be less polluted from a reduction of car pass-through. These are only some of the benefits of supporting cycling as a form of transportation. Holistic design practices bring different users together harmoniously.

It is important to recognize that bicycle riding is a growing trend across US cities and to take action to support it. In the Netherlands, prioritizing bicycling over cars is

common logic. Progressive bicycle-friendly cities have governments that are supportive of policy changes and making bike infrastructure a priority. These cities have an increase in ridership and reduction of accidents. This proves that thoughtful bike facilities can be a viable form of alternative transportation and can help the entire city run more efficiently.

The US is not quite at the same level as the Netherlands. Many US cities are being progressive by setting goals to design city streets that are more accommodating to bicycle riders of all ages and skill levels. In the national bicycling community, the vision is mostly there, but there is more that can be done to truly make bicycle facilities comfortable for all types of riders. If the infrastructure can safely and comfortably accommodate everyone, then ridership can increase, which will also increase future government and societal support.

My research aims to enhance the design of low-stress bicycle facilities and make them inviting for everyone in the city. My design guides will help planners choose design treatments that fit within the acceptable range of comfort for less confident bicycle riders in high-stress urban streets.

The less-confident, also known as the “Interested but Concerned” make up the 60% majority of people who want to cycle in the urban core, but feel like the streets are too high-stress. My design guidelines are shaped based on their concerns. I chose to use case studies as a way to understand and prove why some bike lanes lead to higher ridership and more efficient street flow and why others do not. To further my knowledge of the current best practices in the US, I looked to the National Association

of City Transportation Officials (NACTO) and Peter Furth's measure of a street's Level of Traffic-Stress (LTS).

I concluded that three bike facilities are best suited for typical urban streets. These facilities deal with the typical urban street conflicts such as heavy intersections, high traffic-volume, narrow streets, high speeds, curb cuts, street parking, etc. The three chosen facilities ensure the highest possible amount of safety mostly by using spacing and physical barriers. Choosing a safe facility type is important, but it is only a part of the design process that goes into creating a comfortable cycling environment.

Based on the concerns of the "Interested but Concerned" I also concluded that they need more than barriers to convince them to ride. They also require a sense of comfort and pleasure. This comes in the form of shade, motion detectors, better night lighting, and increased visibility. These additional features help to increase actual safety as well as the perceived safety--increasing comfort.

My design solutions introduce innovative and novel solutions that reduce the level of traffic stress for the "Interested but Concerned." Reducing a street's level of stress involves designing facilities which make street conflicts easy and safe to maneuver. All bicycle facilities in the city should be not just safe, but also comfortable and pleasant for the "Interested but Concerned."

The design options in the guideline help to inspire interested people to ride in the urban streets. If bicycle facilities are designed to be safe, comfortable and visually stimulating they will decrease the level of stress in high-stress streets in the urban core.

The "Interested but Concerned" will choose to ride their bikes instead of driving cars.[1] Targeting their comfort level is important because the participation of this category of cyclists can propel the shift from a car-centric culture to one that bikes.[2]

I will conclude my dissertation with designing an urban street in Honolulu, Hawaii. When it comes to resistant government, Hawaii has struggled in the past. The islands are so isolated from competition and are sometimes limited in space and resources. Aside from these hardships, Hawaii has come a long way and is continuing to improve the city's bicycle infrastructure. Honolulu implemented its first protected bike lane in Hawai'i in 2014, and many successful facilities have been and are currently being implemented.

My facility will be placed on a commercial street--South Street in Honolulu's Kaka'ako district. South Street is a typical urban street. It has street conflicts that are seen in many urban cities. It will also be the site of on one of Honolulu's rails stations. This street will not only have many conflict areas, but is predicted to have high traffic, pedestrian, and cyclist volumes.

I started designing by choosing the best facility type out of the three that I outlined in my guidelines. To make these bicycle facilities comfortable for Honolulu's "Interested but Concerned" I analyzed the current and future site and street conditions. After choosing my facility, I implemented design features based on my guidelines.

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[1] Jennifer Dill, "Four Types of Cyclists," LinkedIn, last modified August 11, 2015, slide 9, https://www.slideshare.net/otrec/four-types-of-cyclists-a-national-look.

[2] Daniel Arancibia, "Cyclists, Bike Lanes And On-Street Parking: Economic Impacts"(Report, University of Toronto, 2013), 7, http://www.torontocycling.org/uploads/1/3/1/3/13138411/daniel_arancibia_ce_report_bike_lanes_december_10.pdf.

This design section is a guide that highlights a method showing how to plan and design bicycle facilities in the urban core effectively. I hope to justify to designers, planners, developers, and government why creating low-stress streets through effective bicycle infrastructure is important in creating a safer and more efficient urban environment.

Efficient urban environments have benefits ranging from the health of its citizens to the reduction of city costs in the long term. There are many people in support of better bicycle infrastructure, but there is also a lot of resistance. Advocates must acknowledge the concerns of the government while also coming up with innovative solutions to address those concerns.

Part 1: Reason and Scope

Why and How?

There has been a positive effect on health, economy, and the environment with the increase of bicycling in the US.[3] Bicycling to work has increased from about 488,000 in 2000 to about 786,000 in 2008–2012.[4] Serious injuries and fatalities have increased resulting from the growing popularity.[5] The risk of major injuries to bicyclists is much higher than that of automobile drivers.[6] Cities are in need of safer bicycle facilities and more efficient bicycle networks so that bicycle riding can be a realistic option for all ages and skill levels.

This research aims to decrease Levels of Traffic-Stress (LTS) in high-stress streets that are 25 miles per hour (MPH) or greater in the urban core for "Interested but Concerned" 60% population of cyclists. This Chapter will prove why creating bicycle facilities for all ages and skill levels is going to increase use and ridership in urban streets.

This dissertation outlines ways to design streets in the urban core, so that bicycle riders are comfortable with the idea of riding on the street.[7] Cycling facilities need to

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[3] Erica Simmons, Michael Kay, Amy Ingles, Monisha Khurana, Margueritte Sulmont, and William Lyons," White paper: Evaluating the Economic Benefits of Nonmotorized Transportation," pedbikeinfo.org, last modified March 2015, 11, http://www.pedbikeinfo.org/cms/downloads/NTPP_Economic_Benefits_White_Paper.pdf.

[4] Brian Mckenzie, "Modes Less Traveled—Bicycling and Walking to Work in the United States: 2008–2012," U.S. Census Bureau, last modified May 8, 2014, https://www.census.gov/content/dam/Census/library/publications/2014/acs/acs-25.pdf.

[5] Haizhong Wang, Matthew Palm, Chen Chen, Rachel Vogt, Yiyi Wang, "Does bicycle network level of traffic stress (LTS) explain bicycle travel behavior? Mixed results from an Oregon case study," *Journal of Transport Geography, no. 57 (December 2016): 8-18.*

[6] Laurie F. Beck Ann M. Dellinger Mary E. O'Neil, "Motor Vehicle Crash Injury Rates by Mode of Travel, United States: Using Exposure-Based Methods to Quantify Differences," *The USn Journal of Epidemiology, no. 166 (July 1007): 212-218, https://doi.org/10.1093/aje/kwm064.*

[7] Dill, "Four Types of Cyclists," 7.

attract the 60% of the cyclist community, the "Interested but Concerned," and also help encourage the 33% of the "no way, no how" population to bike as well.[8] If bicycling is going to be a viable form of alternative transportation, it has to be safe and pleasant. This involves resolving fears and making the bicycle environment one that is exciting while being safe for all ages and skill levels of riders.

[8] Geller, "Four Types of Cyclists," 3.

Chapter 1. Reason for Research

1.1 Benefits of Designing Effective Facilities in the Urban Core

The benefits of implementing safer bicycle facilities outweigh the costs. There is proven to be economical and societal benefits to having bicycling as an alternative form of transportation in urban streets. The economic benefits relate to the improvement in travel infrastructure and safety, and the societal benefits relate to improving well-being and connectivity within the community.

The urban core is made up of many vital destinations which are all near each other, making them potentially bike and pedestrian friendly. Cycling is quicker than walking. Bicycles allow for further travel distance, take up less space than automobiles, and do not exhaust chemicals into the air.

1.1.1 Economic Benefits

Cost savings from riding bicycles range from decreasing the amount of money spent on commuting to long-term benefits like lower health care costs due to healthier living. Being able to use alternative transportation to get around the city increases accessibility to businesses, especially when parking can be limited.[9]

Improving bicycle infrastructure and connectivity allows for people with limited means to have easy access to employment centers, goods, and services. With the

[9] Hawaii Department of Transportation, *Highways: Bike Plan Hawaii Master Plan* (Kimura International, Inc., 2003), 2, http://hidot.hawaii.gov/highways/bike-plan-hawaii-master-plan/.

savings in transportation cost, there can be more monetary exchange between people and businesses.

Increased connectivity can provide safer and easier access to business corridors, creating more pass-through by potential consumers.[10] Bicycle and pedestrian-friendly areas are more attractive to visitors and improve the business environment (Figure *1*).[11]

In New York City, streets with bicycle lanes saw a 49% increase in retail sales. There was also a survey done in Seattle Washington that showed that the elimination of street parking did not negatively impact the surrounding businesses.[12]

In urban cities, cars are not the most appropriate way to get around. People would prefer to walk or bicycle. If there are streets that are welcoming, they will occupy those streets.

For businesses, it is in their best interest to push for people-friendly streets because their consumers are people that are on the streets. In the New York City, Manhattan, less than five-percent commute by car. [13]

The addition of bicycle facilities does not mean the abolition of street parking. Parking is still necessary for parts of the urban core. There are a variety of creative ways to effectively accommodate street parking and bike facilities together.

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[10] Simmons, "White paper: Evaluating the Economic Benefits of Nonmotorized Transportation," 4.
[11] Daniel Arancibia, "Cyclists, Bike Lanes and On-Street Parking: Economic Impacts," (Research Report, University of Toronto, 2013), 9, http://www.torontocycling.org/uploads/1/3/1/3/13138411/daniel_arancibia_ce_report_bike_lanes_december_10.pdf.
[12] Arancibia, "Cyclists, Bike Lanes And On-Street Parking: Economic Impacts," 14.
[13] Arancibia, "Cyclists, Bike Lanes And On-Street Parking: Economic Impacts," 9.

It is important to think about the safety of the potential customers and cyclists. With cities having less space people are finding more efficient ways to get around. Supporting alternative methods like cycling will increase the desire for people to traverse through and explore the urban community.

Bicycle-friendly infrastructure has also had positive effects on tourism. The 60-100 million people in the US who cycle contribute to about $198.7 billion to the economy per year, and bike tourism contributes about $71 billion.

Bicycling is usually more appealing in rural areas because of the lower-stress streets, but in urban tourist destinations safer bicycle facilities could appeal to a more cautious crowd and lead to an increase in tourist-related cycling. It is important to have accommodating facilities and routes that allow people to explore and get to their destinations comfortably.[14]

Encouraging cyclists to explore the urban streets involves making the environment one that is pleasant and comfortable. Cycling helps to reduce automobile air pollution. Bicycle lanes could also be designed to include nature and visually stimulating art, lighting, shade, and even advertising.

Street art is growing in popularity around the world. It is seen as a medium for communication, expression, and excitement. The color and messages emitted by art can

[14] "Bicycle Tourism 101," Adventure Cycling Association, accessed January 28, 2018, https://www.adventurecycling.org/bicycle-tourism/building-bike-tourism/bicycle-tourism-101/.

stimulate people. For example, a building with art attracts more people than plain buildings. Some go as far to say that the stark city buildings can be oppressive.[15]

People feel more comfortable in human-centered streets. Planting strips were seen to be very impactful in increasing volumes of street-goers.[16] Trees also provide benefits such as natural cooling, which can help reduce the heat within the whole city.[17]

Being outdoors can benefit people in more ways than just exercising. Visual experiences have the power to reduce stress and boost good feelings. Implementing safe and attractive facilities to storefronts can be enticing. Creative signage can also be featured on bicycle facilities and can grab potential customers' attention. With added signage and bike facilities people can easily and efficiently move throughout the city. The ease of mobility will increase their exposure to all that the city has to offer.

[15] Ken Benfield, "10 Techniques for Making Cities More Walkable," published December 3, 2012, "https://www.citylab.com/solutions/2012/12/10-techniques-making-cities-more-walkable/4047/.
[16] Choi, J., Kim, S., Min, D., Lee, D., and Kim, S. (2016) Human-centered designs, characteristics of urban streets, and pedestrian perceptions. J. Adv. Transp., 50: 120–137. doi: 10.1002/atr.1323.
[17] Benfield, "10 Techniques for Making Cities More Walkable."

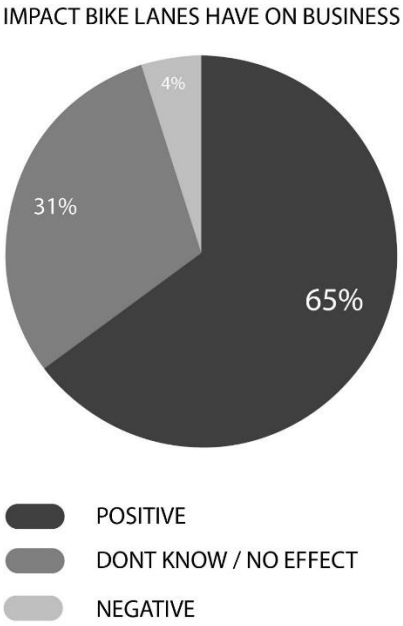

Figure 1: Merchants' Responses When Asked to Review the General Impact That Bicycle Lanes Have Had on Their Businesses in San Francisco.
Source:
Data: Arancibia, Daniel. “Cyclists, Bike Lanes and On-Street Parking: Economic Impacts.” Report, University of Toronto, 2013, 12, http://www.torontocycling.org/uploads/1/3/1/3/13138411/daniel_arancibia_ce_report_bike_lanes_december_10.pdf.
Graphic by: Author.

Figure 2: Merchants' Perceptions of Consumer's Mode of Transportation.
Source: Arancibia, Daniel. “Cyclists, Bike Lanes And On-Street Parking: Economic Impacts.” Report, University of Toronto, 2013, 12, http://www.torontocycling.org/uploads/1/3/1/3/13138411/daniel_arancibia_ce_report_bike_lanes_december_10.pdf.

1.1.2 Health and Safety Benefits

Having the opportunity to safely bicycle in city streets can have a positive impact on people's health and well-being. Health benefits from cycling include decreased rate of death and disease. In contrast, lack of physical activity can lead to increased risk of obesity, diabetes, heart disease, and other chronic illnesses.

These benefits can only start to happen if there is safe infrastructure. Safe infrastructure can decrease traffic-related injuries and fatalities. This is a concern of many government agencies that are looking to reduce their liability. With the increase of bicycling on the roadways and the popularity of bike-share programs, the most logical solution is to create safer spaces to decrease risk. [18] Theses safer spaces will ensure the safety for cyclists as well as pedestrians and motor vehicles. Clear boundaries and zones for all users of the street is vital when creating a safe and effective urban environment. Users will feel more welcomed to venture out into the streets if they feel like their environment is one that is not only safe, but can also benefit their health.

Air quality is another important factor when it comes to the health and safety of urban inhabitants. Motorized vehicle exhaust is one of the leading causes of air pollution. The negative effects of air pollution include respiratory distress, cardiac issues, and decreased immunity.[19] Providing healthier air can help to make the outdoor environment appealing so people can spend time enjoying their city rather than rushing through.

[18] Simmons, "White paper: Evaluating the Economic Benefits of Nonmotorized Transportation," 6.
[19] Simmons, "White paper: Evaluating the Economic Benefits of Nonmotorized Transportation," 7.

1.2 Justifying Bicycle Planning and Investment

Popular biking apps such as STRAVA, prove there is a need for cycling route information and increased infrastructure. The digital application provides cycling routes through global positioning systems (GPS) as well as data about the location and efficiency of particular bicycle routes. This application can collect data to identify areas of the city that are most used, most dangerous and popular routes where better infrastructure is needed.[20]

Many government agencies within the US understand that there is a need in their community. Government agencies would support the implementation of bicycle facilities if there were not perceived risks or budget shortages. In a Report put together in 2014, 52% of the US' most populous cities were surveyed, and researchers found that 11.4% of all trips are taken by bicycle or on foot, and 14.9% of roadway deaths are pedestrians & bicyclists. Still, only 2.1% of the federal transportation funds get allocated to bicycling and pedestrian projects. [21]

Advocates must prove that the rewards are worth the risks and it is important to be steadfast and creative when coming up with ways to support their projects. It is vital to find ways to get funding and work with the government to modify policies and

[20] Chen Chen, Jason C. Anderson, Haizhong Wanga, Yinhai Wang, Rachel Vogt, Salvador Hernandez, "How Bicycle Level of Traffic Stress Correlate with Reported Cyclist Accidents Injury Severities: A Geospatial and Mixed Logit," *Accident Analysis and Prevention* 108 (2017): 234-244, https://app.luminpdf.com/viewer/3jiFT6qxziS37M9Lt.

[21] Andrea Milne, Maggie Melin, "Bicycling and Walking in the United States: 2014 Benchmarking Report," AARP.org, accessed November 24, 2017, 14, https://www.aarp.org/content/dam/aarp/livable-communities/documents-2014/2014-Bike-Walk-Benchmarking-Report.pdf.

practices to encourage mixed-use development and make bicycle/pedestrian-friendly streets a standard practice in the urban core.[22]

1.2.1 Funding the Infrastructure

Communities around the world are wondering how to pay for efficient bicycle networks with safe bicycle facilities. Bicycle projects are typically low-budget unless they involve major road changes onto which bicycle lanes can be piggy-backed. Typically, facility improvements or additions are done as a part of a whole street design project. Since government budgets are so tight, communities must find creative ways to fund their bicycle projects. Funding sources can include, Federal, State, Local/Regional, or Private Agencies.

Federal funding has been provided for many projects across the US where states' Department of Transportations or regional governments will select a project to be funded. Some Federal sources include Congestion Mitigation and Air Quality Improvement Program (CMAQ), Highway Safety Improvement Program (HSIP), Surface Transportation Program (STP), and Transportation Alternatives Program (formerly known as Transportation Enhancements).

A protected bike lane for the city of Memphis was one of the first to use HSIP as a funding source. Their project was to install protected bike lanes to a road resurfacing project. The Tennessee Department of Transportation (TDOT) agreed to add the lanes and HSIP funded the cost of striping and delineators. Memphis has also recently been

[22] Andrea Milne, Maggie Melin, "Bicycling and Walking in the United States: 2014 Benchmarking Report," AARP.org, accessed November 24, 2017, 104, https://www.aarp.org/content/dam/aarp/livable-communities/documents-2014/2014-Bike-Walk-Benchmarking-Report.pdf.

working with CMAQ and has successfully implemented new protected bike lanes. As long as those bike lanes show that they improve the air quality, CMAQ will fund them.

State sources such as pedestrian grants, state multi-modal funds, and Safe Routes to School funds can also be useful. Advocacy Advance, a partner with the League of the US Bicyclists, supports local and state advocacy efforts. They created a list of state revenue sources where funds could be extracted to fund bike lanes. For example, Hawaii can extract funds from Bicycle Registration and School Zone Speeding fines.

Secondly, local and regional funds are commonly used to pay for protected bike lanes. Bond Measures, business improvement districts (BID), regional bike program funds, tax increment financing (TIF), and voter-approved sales tax are all places where cities can acquire funds.

Lastly, there are the Private Sources. These include but are not limited to, developers, hospitals, philanthropies, and universities. They are willing to implement safe facilities' to promote and create a safe environment surrounding their institutions.

Overall, it is important to remember that communities must be innovative when it comes to fighting through budgetary challenges. Looking at all options is important. It may be a lot of work, and there may need to be multiple investors involved, but sometimes that is what is necessary to implement innovative ideas.[23]

[23] "How Communities are Paying for Innovative On-Street Bicycle Infrastructure," Bike Walk Montana, last modified June 2014, 4, https://www.bikewalkmontana.org/wp-content/uploads/2013/01/PayingForInnovativeInfrastructure.pdf.

1.2.2 Managing Liability

Besides money, liability is another major roadblock. Without liability, the government would have little fear of bicycle lanes. Mixing bicyclists and motor vehicles is an understandable liability which can inhibit some cities from taking the risk.

City officials fear that adding more facilities will increase accidents. But nowadays, it must also be understood that with the addition of bike share programs around the world, streets in growing urban cores are becoming increasingly inundated with non-motor vehicle traffic.

Unconfident riders will not always abstain from riding bicycles if they feel like the street is not safe. Instead they will engage in unsafe practices. If there are no proper facilities for cyclists and bike-share users to ride their bikes, they run the risk of endangering themselves, other cyclists, pedestrians, or motor vehicle drivers.

It seems as though the solution to this liability is to provide acceptably safe streets and sidewalks. This involves the implementation of bike facilities, traffic control appliances, regular maintenance, and law enforcement.[24]

Bike-share programs emphasize the need for bike facilities. But here is more liability now having more cyclists on the road unprotected. It is vital to begin to take more precautions by adding bicycle facilities which will support the inevitable rise of bicycle use in the urban core.

[24] Kessler, "Real Justice for Real People," 66.

1.2.3 Trade-Offs

Trade-offs are necessary when retrofitting or adding bike facilities to a community. Drivers, residents, business owner, etc. are all affected by the implementation of bike facilities, and sometimes the impacts can change the way they live and do business.

It is important to consider all who are affected and make compromises to ensure that they are either affected minimally or prove that bike facilities will improve the status quo. For the trade-offs to be fair, all audiences need to be considered, and proper design must take place for there to be viable solutions that acknowledge their concerns.

Popular concerns include, bike facilities blocking storefronts and increased traffic congestions cause by eliminating traffic lanes. These issues can be solved by increasing the use of bicycle facilities and improving routes to make cycling safe and efficient, so a broad range of users feel like biking is easier than driving. Accomplishing this involves investing in better bicycle infrastructure. This means bike facilities that are safe, comfortable, and pleasant for a broad range of cyclists.

Improving bicycle connectivity and increasing safety, comfortability, and pleasure of bicycle facilities is the only way to get people on their bikes instead of driving their cars. Cities are proven to benefit the economy and enhance livability by favoring space-efficient ways of moving throughout the city. This includes walking, cycling, car-sharing, or public transportation. Because of the compact nature of these

modes, more people can traverse through a smaller area.[25] Businesses need to be convinced that pass-through will be improved because of the cyclists and the community needs to feel like they can get where they need to go efficiently, safely, and pleasantly using the provided infrastructure.[26]

Accomplishing a more accommodating bicycle infrastructure involves transitioning to a car-centric culture to one that bikes. Research has shown that many places are replacing car ownership with cycling. There is said to be great cost savings owning and using a bike as opposed to a car. In the US the average annual cost to own and operate a mid-sized car is $8,716. These cities also had reduced vehicle congestion, less crowded parking lots, and reduced wear on the streets.[27]

Overall, the best economic benefits stem from well-planned infrastructure that is well-connected as well as bike facilities that are inviting for users of all ages and levels. An increase in use of bicycle facilities and businesses pass-through is foreseeable with biking as long as the infrastructure is designed to be just as or more efficient and comfortable than other modes of transportation.

It is important to work together with the community to look for ways the city can function as a whole rather than separately existing parts. What is best for the city is

[25] Todd Litman, "Economically Successful Cities Favor Space-Efficient Modes," Planet Zen, published March 10, 2014, https://www.planetizen.com/node/67722.
[26] Elyse O'Callaghan, "Economic effects of cities becoming more bike-friendly," Sustainable Transportation Lab, published March 7, 2016, https://faculty.washington.edu/dwhm/2016/03/07/economic-effects-of-cities-becoming-more-bike-friendly/.
[27] Jennifer Dill, T. Carr, "Bicycle commuting and facilities in major U.S. cities: If you build them, commuters will use them," Transp. Res. Rec. 2003, 1828, 116–123.

what is best for the people in the city. The entire city can benefit if planners and the community work with each other as a team.

1.3 Setting Goals to Support Bicycle Facilities in Urban Cities

It is important to set a plan to have a clear vision of a project's goals. Having clear goals will lead to a clear plan on how to accomplish them. In 2012, 54% of states and 52% of cities had Complete Streets policies or legislation. Federal transportation funding was above two-percent and was dispersed to bike and pedestrian plans.[28]

In an urban environment, there are many different forces at play. People have their agendas. When trying to work through a project, it is challenging to understand the interests and demands of the many stakeholders. In metropolitan areas, there are not only challenges with cyclists, drivers, and pedestrians on the streets, but also between cyclists and the community and government. Plans for improving cycling conditions and facility improvements are not always popular. A harmonious relationship can potentially be developed by thinking of what is best for the city as a whole. Thinking holistically will ideally create an efficient system for the whole city network.

Government agencies and skeptics may not be convinced that there is a large enough population of cyclists or a need for safer facilities, but metropolitan cities in the US and Europe have justified that if you build it right, they will come.

In the US there is an increasing commitment to making sure the urban environment is safe for pedestrians and cyclists. In a benchmark report done in 2012, 52

[28] Milne, "Bicycling and Walking in the United States: 2014 Benchmarking Report," 14.

US cities were surveyed. Out of those 52, 47 set goals to increase cycling and 37 set goals to reduce cycling deaths (Figure *4*).[29]

Figure 3: Statewide Goals to Increase Safety and Increase Walking and Biking
Source: Milne, Andrea, Maggie Melin. "Bicycling and Walking in the United States: 2014 Benchmarking Report." AARP.org. Accessed November 24, 2017. https://www.aarp.org/content/dam/aarp/livable-communities/documents-2014/2014-Bike-Walk-Benchmarking-Report.pdf.

[29] Milne, "Bicycling and Walking in the United States: 2014 Benchmarking Report," 105.

Figure 4: Citywide Goals to Increase Safety and Increase Walking and Biking
Source: Milne, Andrea, Maggie Melin. “Bicycling and Walking in the United States: 2014 Benchmarking Report.” AARP.org. Accessed November 24, 2017. https://www.aarp.org/content/dam/aarp/livable-communities/documents-2014/2014-Bike-Walk-Benchmarking-Report.pdf.

Figure 5: Complete Street Policies in The US's States and Cities.
Source: Milne, Andrea, Maggie Melin. "Bicycling and Walking in the United States: 2014 Benchmarking Report." AARP.org. Accessed November 24, 2017. https://www.aarp.org/content/dam/aarp/livable-communities/documents-2014/2014-Bike-Walk-Benchmarking-Report.pdf.

Urban cities in Oregon, Minnesota, and places outside of the US such as Denmark have seen vast increases in cycling over recent years. With the setting of ambitious, yet attainable goals the number of safer facilities has spiked even further. This goes to show that there is a strong desire for facilities and a population of concerned cyclists just waiting for a safer environment so they can dust off their bikes and take to the streets.

It is important to move people through streets safely and efficiently. Separated bicycle tracks and buffered lanes can provide bicyclists with a high level of comfort in high-stress corridors when designed appropriately. The Cities below have made vast

improvements to their bicycle infrastructure over the years. Choosing goals is something that can be fraught with red tape and setbacks, but by communicating positive impacts and the need, it can bring skeptics one step closer to prioritizing bicycle infrastructure.

Table 1. Safety Goals and Solutions in Bike Friendly US and European Cities.

Bike Friendly Cities	**Goals**	**Solutions**
Portland, Oregon -bicycle commuting increasing from 4.2% in 2006 to 7.2% in 2014[30]	-Attract a wider variety of users with safe low-stress and attractive bikeways -Easily find a route in an interconnected network -Create more direct routes -Better visibility of cyclists on the roadway -Increase community support -Interim facilities where implementation cannot be immediately added. [31]	-Facilities in road sections -Traffic speed and volume reduction -Non-motorized/off-street sections -Signalization -Intersection treatments -Signage and markings -Transit and bicycle streets comfortable for Interested but Concerned -Trampe (bicycle lift).[32]
Minneapolis, Minnesota -bicycle commuting rate increasing from 2.5% in 2006 to 4.6 in 2014[33]	-Increase on-street protected bikeways -Increase connection to downtown where there is increased bicycle demand by	-Road diet & changing amount or types of lanes and widths of lanes to accommodate bicycle facilities

[30] "A Look at the Nearly 1 Million Who Ride Their Bikes to Work in the U.S.," U.S. Census Bureau, last modified May 19, 2016, https://www.census.gov/newsroom/blogs/random-samplings/2016/05/a-look-at-the-nearly-1-million-who-ride-their-bikes-to-work-in-the-u-s.html.
[31] Portland Bureau of Transportation, "Strategic Implementation Plan," in *Portland Bicycle Plan for 2030*, 115, https://www.portlandoregon.gov/transportation/44597?a=379136.
[32] David Amiton et. al., "Bikeway Facility Design: Survey of Best Practices," in *Portland Bicycle Plan for 2030* (Denver Igarta January, 2010), 5, https://www.portlandoregon.gov/transportation/article/334689.
[33] "A Look at the Nearly 1 Million Who Ride Their Bikes to Work in the U.S.,"

Table 1. (Continued) Safety Goals and Solutions in Bike Friendly the US and European Cities.		
Bike Friendly Cities	**Goals**	**Solutions**
	adding trails or bike boulevards [34]	
Copenhagen, Denmark -bicycle commuting rate is 62% - Currently, 64% of transport space allocated to cars, but only 9% drive a car to work and 7% space allocated to cyclists when 62% of population bike[35]	-Make moving around the city faster than driving -Uniform bike network -Traffic calming -Fix infrastructure by allocating more space for cyclists -Have politicians understand conditions and having a desire for improvement -Innovative ideas[36]	-Bicycle bridges/elevated bike ramps -Road diets -Conversion of roads to dedicated cycle tracks to accommodate cyclist population -Prove how the economy benefits -Currently looking into best-practice strategies for creating a cycling city[37]

[34] U.S. Census Bureau, "Protected Bikeway Update to the Minneapolis Bicycle Master Plan." minneapolismn.gov, last modified April 17, 2015, 1, https://www.census.gov/newsroom/blogs/random-samplings/2016/05/a-look-at-the-nearly-1-million-who-ride-their-bikes-to-work-in-the-u-s.htmlhttp://www.minneapolismn.gov/www/groups/public/@publicworks/documents/images/wcms1p-140315.pdf.

[35] Mikael Colville Andersen, "The Greatest Urban Experiment Right Now," The Blog, last modified July 2, 2014, http://www.copenhagenize.com/2014/07/the-greatest-urban-experiment-right-now.html.

[36] Mikael Colville Andersen, "The 20 Most Bike-Friendly Cities on the Planet," Wired, last modified June 2, 2015, https://www.wired.com/2015/06/copenhagenize-worlds-most-bike-friendly-cities/.

[37] Ibid.

Chapter 2. Scope of Research

2.1 Types of Cyclists

"Riding a bicycle should not require bravery. Yet, all too often, that is the perception among cyclists and non-cyclists alike." says, Roger Geller.[38] Geller goes on to talk about his analysis of the different rider groups in Portland's urban streets. These city streets typically have high-stress streets with narrow, high traffic-volume corridors within their urban core—not unlike most US city streets. Cities like Portland, Oregon, and Davis, California have a similar attitude toward bicycling as most American cities, but they have some of the most bicycle commuters in the US. The city's investment in best-practice facilities can take credit for high ridership.

Most bicycle lanes and bike routes in the urban core are suitable for the "Strong and Fearless" and the "enthused and confident," which is a small portion of the population of people who cycle. [39] Overall, the "Interested but Concerned" take up the majority of people who ride bicycles and is, therefore, the target audience who will benefit from bicycle facility improvements.

[38] Roger Geller, "Four Types of Cyclists," Portland Office of Transportation, accessed November 29, 2017, 1, https://www.portlandoregon.gov/transportation/article/264746.
[39] Geller, "Four Types of Cyclists," 3.

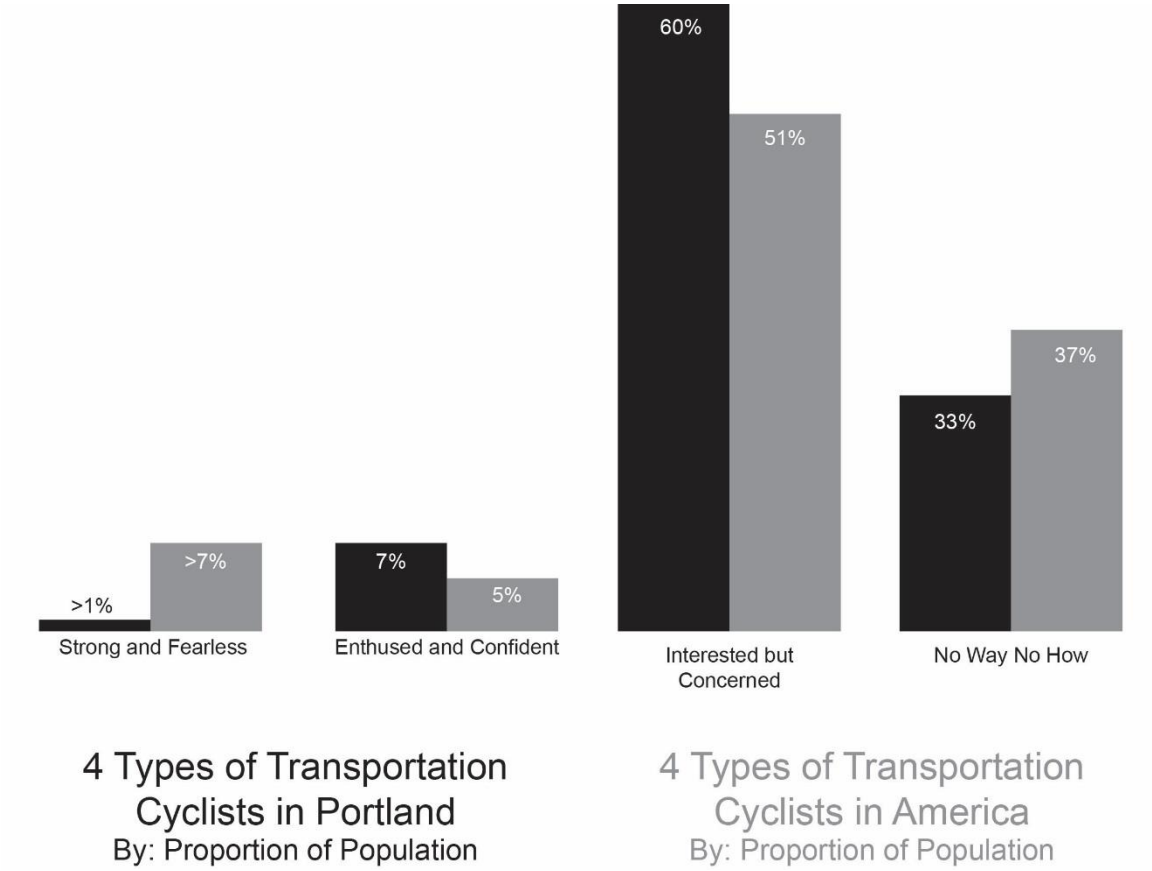

Figure 6: Comparing Cyclists in Portland and the US.
Source: Data from Geller, Roger, "Four Types of Cyclists," Portland Office of Transportation. Accessed November 29, 2017, 3-7, https://www.portlandoregon.gov/transportation/article/264746.
Graphic by: Author.

Roger Geller's survey results give insight into user groups. He used a preference-based survey that measured perception of safety based on preference. A preference-style survey is a good way to determine the desires of the "Interested, but Concerned." This audience does not actively participate in cycling activity in the urban street, so they only have a perception of what it feels like to be comfortable cycling there.

The goal is to get people to get out and experience cycling in the city. The only way to entice this audience is to understand what they perceive as dangerous and what they would prefer. The survey focused on:

1. Attitudes towards different forms of mobility (driving, walking, bicycling, transit)

2. Screening questions about physical ability to ride a bicycle and broad cycling habits

(I never ride a bike, I ride a bike occasionally, I ride a bike regularly);

3. The frequency of bicycling in the past month (30 days) for commuting, other utilitarian purposes (e.g., shopping), and recreation/exercise only;

4. Past bicycling behavior, motivations for cycling, and future intentions;

5. Comfort level for bicycling on different types of facilities;

6. Perceptions of their neighborhood regarding bicycling, traffic, and safety;

7. Attitudes and concerns about bicycling; and

8. Demographics" [40]

Portland State University planners, Jennifer Dill and Nathan McNeil performed a similar study to Roger Geller's, but instead of just Portland, they surveyed 3,000 residents from all 50 states in the US.[41] The results were very similar to Roger Geller's results from his Portland Study (Figure 6).[42]

[40] "People Who Cycle," NZ Transport Agency, accessed March 14, 2018, https://www.nzta.govt.nz/walking-cycling-and-public-transport/cycling/cycling-network-guidance/cycle-network-and-route-planning-guide/principles/people-who-cycle/#interested.

[41] Eric Jaffe, "The 4 Types of Cyclists You'll Meet on U.S. City Streets," last modified January 6, 2017, https://www.citylab.com/transportation/2016/01/the-4-types-of-cyclists-youll-meet-on-us-city-streets/422787/.

[42] "Bicycle Friendly State: 2015 Ranking," bicycleleague.org, accessed November 23, 2017, http://www.bikeleague.org/sites/default/files/2015_state_ranking_chart.pdf.

Many bicycle planners and advocates have chosen to use Geller's findings because his typology shows how a "potential expansion of bicyclists could be attracted by investing in a better, safer bikeway system." Geller collected this data through a random phone survey of 902 adults in Portland in the summer of 2011. [43]

[43] Jennifer Dill, "Four Types of Cyclists," linkedIn, last modified August 11, 2015, https://www.slideshare.net/otrec/four-types-of-cyclists-a-national-look.http://web.pdx.edu/~jdill/Types_of_Cyclists_PSUWorkingPaper.pdf

Table 2. Defining Cyclist Typologies with Survey Responses.

Assigned Type	**Interest in Cycling** (Answer to "I would like to travel by bike more than I do now.")	**Comfort Category**
"Strong and Fearless"	-Either	-Any condition-no facilities -"Very comfortable" on non-residential streets with bike lanes
"Enthused and confident"	-Either	-Willing to share road with cars, but prefer minimal facilities -"Very comfortable" on non-residential streets with bike lanes
"Interested but Concerned" (target group, 60% of people who ride bikes)	-Agreed strongly or somewhat -Disagreed and cycled for transportation in the past 30 days -Disagreed and did not cycle for transportation in the past 30 days	-Streets designed well for bicyclists-even if they are a little out of the way -"Not very comfortable" on non-residential streets with bike lanes
"Now, no how"	-Disagreed and did not cycle for transportation in the past 30 days -Not applicable	-No interest in riding a bike. Very uncomfortable -Physically unable to ride a bicycle -"Very uncomfortable" on trails/paths

Source: Dill, Jennifer. "Four Types of Cyclists." LinkedIn. Last modified August 11, 2015, slide 9. https://www.slideshare.net/otrec/four-types-of-cyclists-a-national-look.
Research survey for US Cyclists. It was conducted by, Jennifer Dill and in cooperation with the National Association of Realtors®. Data was taken during May 13-19, 2015, using 3,000 adults from 50 of the largest statistical areas in The US were surveyed.[44]
http://web.pdx.edu/~jdill/Types_of_Cyclists_PSUWorkingPaper.pdf

[44] Jennifer Dill, "Four Types of Cyclists," LinkedIn, last modified August 11, 2015, slide 9, https://www.slideshare.net/otrec/four-types-of-cyclists-a-national-look.

Geller based his determinations on cycling for transportation only and asked participants to react to hypothetical scenarios that described a particular bicycling environment. The level of comfort was based on the environments that describe scenarios on non-residential streets with and without bike facilities. The "Interested but Concerned" fell into an uncategorized section. They were not "very comfortable" on non-residential roads or "very uncomfortable" on bike paths and trails.

They were also found to be interested in riding their bike more than they currently ride. Participants who did not feel comfortable cycling in non-residential, but have used cycling as a form of transportation within the past 30 days were also placed into this category.

About 2% of the "Interested but Concerned" felt comfortable on the street with four lanes with a speed limit of 30-35 mph, on-street parking with only a conventional bike lane. After suggesting the idea of a separated bike lane, 43% survey participants said they would feel comfortable with this type of bike facility in the same street environment. This evidence is key to figuring out how to attract more cycle riders on the city streets. [45]

More than bike facilities, research finds that there are societal and personal factors that may attract or detract the "Interested but Concerned" from riding in city streets. They need facilities that visually stand out. Somewhere where they can picture themselves riding safely and comfortably.

[45] Jennifer Dill, "Four Types of Cyclists," linkedIn, last modified August 11, 2015, slide 14, https://www.slideshare.net/otrec/four-types-of-cyclists-a-national-look.http://web.pdx.edu/~jdill/Types_of_Cyclists_PSUWorkingPaper.pdf

Some of their personal factors that need to be considered in facility design are communicated in the following data;

-32% are worried about falling off their bicycles

-52% don't feel safe riding in the dark

-78% don't feel comfortable riding in rain

-72% require different clothes to ride

-84% are afraid of getting hit by a vehicle

-68% say drivers speed in the streets

-61% say the amount of traffic makes riding unpleasant [46]

Facilities that add shade, lighting, visual clarity and psychological comfort can help to address the concerns of the majority. This involves not just safely engineered bike facilities, but also facilities that can help to reduce stress-levels.

2.2 Bicycle Design Guides

There are a few places where transportation engineers and designers turn to for guidance on bike facility design. Two well-known guides are, The American Association of State Highway and Transportation Officials (AASHTO) and National Association of City Transportation Officials (NACTO).

AASHTO sets the standards for guidelines, test methods, recommended practices and manuals. They aim to promote efficient construction and design, support care, facility maintenance, and create safe and fitting designs for streets. They work with the

[46] Jennifer Dill, "Four Types of Cyclists," linkedIn, last modified August 11, 2015, slide 9, https://www.slideshare.net/otrec/four-types-of-cyclists-a-national-look.http://web.pdx.edu/~jdill/Types_of_Cyclists_PSUWorkingPaper.pdf

state's Departments of Transportation and the federal government to implement technical guidelines. [47]

AASHTO has been a dominant force and the leader in bikeway guidance. Things started to change when other organizations started coming out with more progressive design models. In 2013 they still had yet to implement protected bike lanes into their guidebook. European design guides had not been recognized by AASHTO--even amidst evidence that these designs made for safer cycling environments.

In the fall of 2013, the Federal Highway Administration (FHWA) declared that another bicycle guide—NACTO, would be valuable to look at because of its recognition of European design practices. [48] Like AASHTO, NACTO also had fairly respectable technical guidelines, but since European designs had not been respected and acknowledged in the past, they had not become as influential as AASHTO.

The FHWA's recent support of NACTO comes from the acknowledgment that the US needs safer, more efficient and more progressive bicycle street designs. The FHWA promotes flexible bikeway design that takes into account context and holistic practices.[49]

Safe technical design for the facility is the first step in safe and comfortable bicycle facilities. To do this, the designer must look at the environment around which the facility sits as well as the people it is attracting and *not* attracting.

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[47] "American Association of State Highway and Transportation Officials (AASHTO)," IHSmarkit.com, accessed February 16, 2018, https://ihsmarkit.com/products/aashto-standards.html.
[48] Angie Schmitt, "FHWA to Transportation Engineers: Use the NACTO Bikeway Design Guide," Streetsblog.org, published September 9, 2013, https://usa.streetsblog.org/2013/09/09/fhwa-to-transportation-engineers-use-the-nacto-bikeway-design-guide/.
[49] Schmitt, "FHWA to Transportation Engineers: Use the NACTO Bikeway Design Guide."

The progression of bikeway design is moving toward allowing for all ages and skill levels of cyclists to ride in urban streets. In 2017 NACTO introduced its design guide that promotes bikeway design for all ages and skill levels (Figure 7).

A European model similar to the guide shown above was done by Copenhaganize Design Company in Montreal, Quebec (Figure 8). The Copenhaganize Bicycle Planning Guide represents the four types of bicycle infrastructure that has made Copenhagen one of the most bike-friendly cities in the world. The four patterns shown in the diagram below should fit every city street in the world. [50]

Copenhaganize's four types of bicycle infrastructure include;

1. 10-30 km/h (7-19 mph)—no separation
2. 40 km/h (25 mph)—painted lanes
3. 50-60 km/h (30-38 mph)—curb separated lanes
4. 70-130 km/h (44-81 mph)—fully separated by median

NACTO's recognition and reflection of the practices of Copenhagen show that the progression and importance of bicycle planning at an international scale.

Design guides are necessary, but just one piece of the puzzle. One size does not fit all, and it is the designer's responsibility to create a holistic environment that fits its context.

[50] Mikael Colville-Andersen, "The Copenhagenize Bicycle Planning Guide," The Blog, last modified April 19, 2013, http://www.copenhagenize.com/2013/04/the-copenhagenize-bicycle-planning-guide.html.

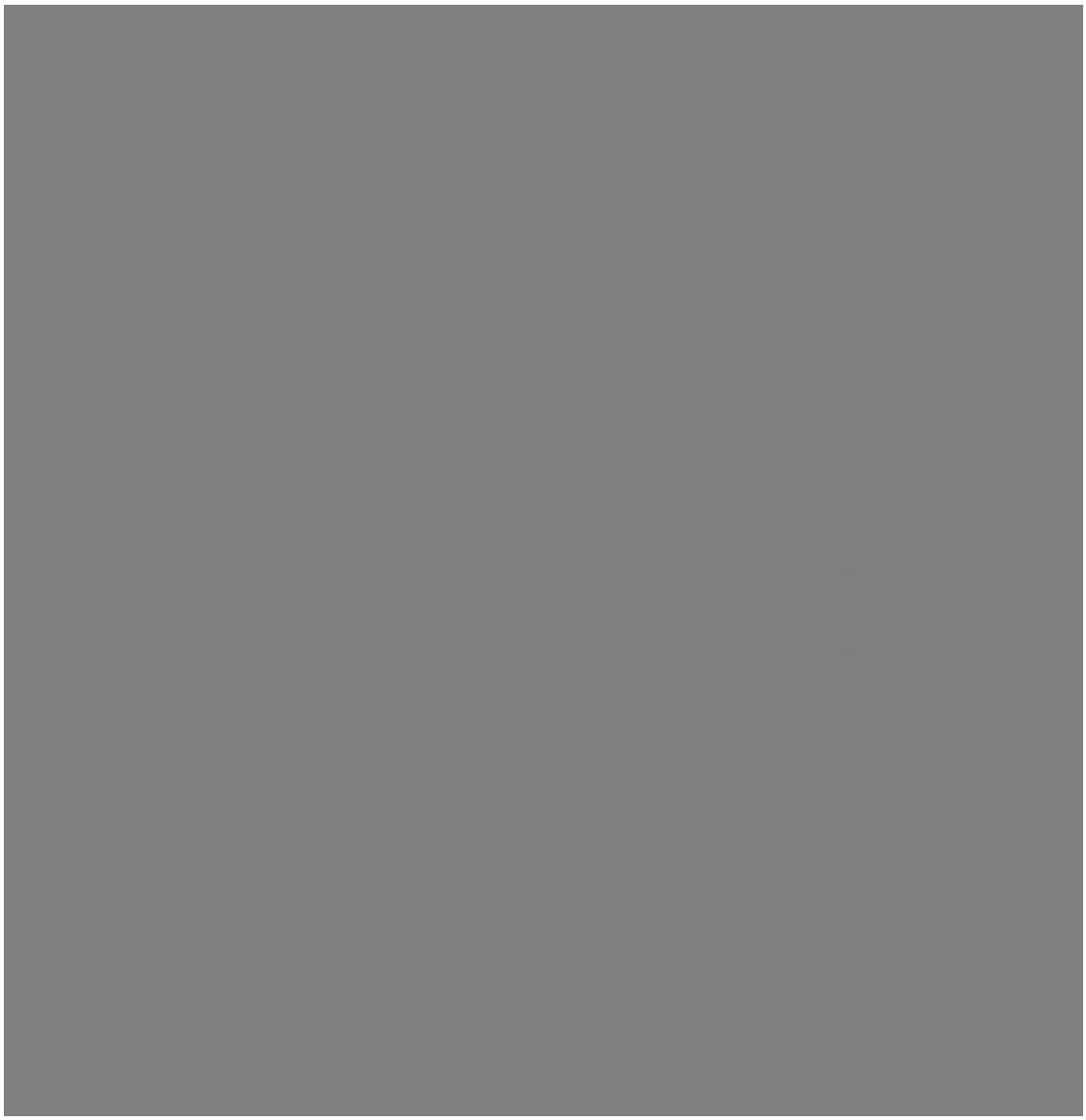

Figure 7: NACTO's 2017 Contextual Guidance for Selecting All Ages & Abilities Bikeways.
Source: http://peopleforbikes.org/blog/sneak-peak-nactos-new-guide-advises-when-to-protect-bike-lanes/.

Figure 8: 4 Types of Bicycle Infrastructure.
Source: http://www.copenhagenize.com/2013/04/the-copenhagenize-bicycle-planning-guide.html.

2.3 Levels of Traffic Stress (LTS)

There are NACTO guidelines that offer a safer bicycle facility design, but determining how stressful a street can be subjective. For this research, it is key to determine if a street is low-stress and comfortable enough for the "Interested, but Concerned."

Determining how stressful a street is to the "Interested but Concerned" population is key. Peter Furth, a Professor of Civil Engineering at Northeastern University figured out a quantitative measure of traffic-stress based on the concerns of the "Interested, but Concerned."

He concluded that they are most comfortable at Levels one and two (Table 3). It is the designer's responsibility to determine what level of stress the existing street is then designed the street to an adequate level for the audience above. With the addition of bicycle-sharing programs as well as the increased popularity of cycling in the urban core, the infrastructure needs to accommodate experienced cyclists and less-experience cyclists.

The challenge of creating safe bicycle infrastructure is not a new one. Transportation agencies and advocacy groups find it difficult to make an argument for better bike planning and investment because of lack of data to prove the issues. In addition to old-fashioned surveys and accident reports, there is GPS technology that can analyze cyclists' behavior and the routes they take. This type of information can help inform engineers and city planners about which streets are safe and which streets need improvements.

There have been studies done about the spatial relationships between cyclist accidents, and the level of traffic stress (LTS) felt on a particular roadway.[51] This study aims to measure bicycle accessibility.[52] Level of traffic stress is primarily determined by perceived dangers and stressors relating to cycling being near motor vehicles.

The qualitative measurements evaluate bikeways in relation to roadway style, traffic volumes, and motor vehicle speed limits. These stressors can range from noise and car exhaust to heavy or fast traffic.[53] The "Interested but Concerned" would be a part of the large majority of people who would be "traffic-intolerant," based on the analysis of their comfortability.

Peter G. Furth came up with his way of measuring, "Level of Traffic Stress" in 2017. He wanted to develop a more quantitative method for classifying a street's LTS. Traffic-stress analysis looks at the street holistically. Street conditions such as lack of protected bike lanes, bike and automobile shared lanes, poor intersection interactions, road width, traffic speed, parking lanes, etc. are taken into account. Furth's LTS ranges from, one to four. [54]

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[51] Chen Chena, Jason C. Anderson, Haizhong Wanga, Yinhai Wang, Rachel Vogt,Salvador Hernandez, "How Bicycle Level of Traffic Stress Correlate with Reported Cyclist Accidents Injury Severities: A Geospatial and Mixed Logit," *Accident Analysis and Prevention 108* (2017): 9, https://app.luminpdf.com/viewer/3jiFT6qxziS37M9Lt.

[52] Stephanie P. Dock et al., "Low-Stress Lts: District of Columbia's Innovative Approach to Applying Level of Traffic Stress," Transit Research Board, last modified November 15, 2016, https://trid.trb.org/view.aspx?id=1438715.

[53] Maaza C. Mekuria, Peter G. Furth, Hilary Nixon, "Low-Stress Bicycling and Network Connectivity," Mineta Transportation Institute, published May 2012, http://transweb.sjsu.edu/PDFs/research/1005-low-stress-bicycling-network-connectivity.pdf.

[54] Mekuria, "Low-Stress Bicycling and Network Connectivity."

Table 3. Level of Traffic Stress (LTS).

Level of Traffic Stress (LTS)	Definition	Example Condition
LTS 1	Tolerable by most children ("Interested but Concerned")	A street with level-one stress could be thought of as having: -buffered bicycle lane -low-speed -low-volume traffic street -high visibility intersection with low traffic pass-through This low-stress street type and wide and buffered bicycle facility allows a street that is suitable for children [55]  Figure 9: LTS 1: For Bikers In The Contraflow Lane And Shared One-Way Traffic Lane With Cyclists (Speed Limit Is 25 Mph).

[55] Peter G. Furth, "Level of Traffic Stress," Northeatern.edu, accessed November 24, 2017, http://www.northeastern.edu/peter.furth/criteria-for-level-of-traffic-stress/.

Table 3. (Continued) Level of Traffic Stress (LTS).

Level of Traffic Stress (LTS)	Definition	Example Condition
		 Figure 10: LTS 1: Protected Bike Lane With Parked Cars Buffering Cyclists From The Street. Painted Buffer Is Protecting Cyclists From "Dooring."  Figure 11: LTS 1: Mixed Two-Way Traffic On Low Traffic, Low-Speed Residential Street
LTS 2	Tolerable by average population ("Interested but Concerned")	Cyclists can share the road with motorists in: -low-speed -low-volume traffic -zones where cyclists have their own place to ride that keeps them from having to interact with traffic except at formal crossings (can include physical separation from high-speed and multi-lane traffic) -crossings are easy for an adult to navigate (criteria follow Dutch bicycle route facilities)

Table 3. (Continued) Level of Traffic Stress (LTS).

Level of Traffic Stress (LTS)	Definition	Example Condition
LTS 2 (Continued)		 Figure 12: LTS 2: Bike Lane Adjacent To Parking Lane With Space To Avoid Open Car Doors (30 Mph).  Figure 13: TS 2: Conventional Bike Lane On A Two-Way, Four-Lane Street, Separated By A Raised Median Parking (30 Mph).

Table 3. (Continued) Level of Traffic Stress (LTS).

Level of Traffic Stress (LTS)	Definition	Example Condition
LTS 2 (Continued)		 Figure 14: LTS 2: Street With Two-Way Mixed Vehicle Traffic (25 Mph).
LTS 3	The US cyclist (comfortable for the "enthused and confident", but not "Interested but Concerned")	-moderate speed traffic -mixed traffic -two-lane traffic -close proximity to higher speed traffic -street parking -commercial area -narrow street width -winding roads  Figure 15: LTS 3: Two-Way Street With Bike Space Adjacent Mixed Traffic To Street Parking. In Commercial Area With Limited Street Width Making Cyclists Vulnerable To Dooring. Vehicles Frequently Double Parking In Bicycle Lane Pushing Cyclists.

Table 3. (Continued) Level of Traffic Stress (LTS).

Level of Traffic Stress (LTS)	Definition	Example Condition
LTS 3 (Continued)		 Figure 16: LTS 3: Two-Lane With Mixed Traffic (30 Mph).
LTS 4	Experienced Cyclist (comfortable for the "strong and fearless," but not "Interested but Concerned")	-moderate speed traffic -multi-lane traffic -close proximity to high-speed traffic -narrow traffic lanes -winding roads  Figure 17: LTS 4: Mixed Traffic On A Multilane Road (30 Mph).

Table 3. (Continued) Level of Traffic Stress (LTS).

Level of Traffic Stress (LTS)	Definition	Example Condition
LTS 4 (Continued)		 Figure 18: LTS 4: Mixed Traffic On 4-Lane Street (30 Mph).

Source: Furth, Peter G. "Level of Traffic Stress." Northeastern.edu. Accessed November 24, 2017. http://www.northeastern.edu/peter.furth/criteria-for-level-of-traffic-stress/.

2.4 Levels of Urbanization

Levels of traffic stress can greatly depend on the level of urbanization in a particular area. There are rural settings, suburban settings, and urban settings. This research will focus on the urban setting defined in this section.

In a Rural Setting, there is more recreational bicycle riding than functional riding. This setting is low-density with a greater distance between destinations and a large amount of open space. The bike facilities in these communities focus on interacting with nature and culture. These rural communities are usually laterally spread along busy highways.

The Suburban Setting is denser than the rural setting. Its connections to local civic centers and roads have more pass-through which can raise cyclists' stress levels.

Arterial streets in this setting may have high-traffic volume and higher speeds. Heavier on-street facilities may be required here.

The focus area of my research is the Urban Setting. This dense setting has heavy development and shorter distances between destinations. Getting around with motor vehicles can be challenging because of limited parking and congested streets. Urban cycling is becoming increasingly popular in the US and has become an efficient choice for "Strong and Fearless" and "Enthused and Confident" bicycle commuters.

Because of the tight grid structure of most city streets, this setting presents the most conflict points with motorists.[56] A city street is defined as a zone that provides access to properties or businesses and has high vehicular traffic movement within narrow, dense, and high-traffic volume streets.[57]

It is important to increase ridership in urban streets—especially targeting the 60% of the "Interested but Concerned" population. According to their concerns, creating comfortable, safe and pleasant routes in "high-stress" streets will attract them. More bicycle riding in the city can increase efficiency and eventually cycling can become another viable form of alternative transportation.

2.4.1 General Conflicts in Urban Core Streets

"High-stress" streets are typically streets that present conflicts for cyclists. NACTO and LTS analysis and my innovative design solutions aim to mitigate the hazards of these conflicts. This involves identifying unsafe areas and points of conflict in city

[56] Hawaii Department of Transportation, *Highways: Bike Plan Hawaii Master Plan*, 2-3.
[57] "Roadway Design Manual," Texas Department of Transportation, accessed March 15, 2018, http://onlinemanuals.txdot.gov/txdotmanuals/rdw/urban_streets.htm.

streets and finding solutions to lower stress for cyclists and drivers. These common conflicts include; intersections, high-traffic volume, high-bicycle volume, high-parking turnover, one-way streets that do not allow travel in the opposite direction.[58]

2.4.1.1 Intersections

Intersections are major conflict areas for cyclists. They are complex because there are many different users' crossing over paths and competing for prioritization. It is very important for bicyclists to be clearly visible to drivers and pedestrians.

In some instances, when approaching the intersection, the facilities may change to a different type of facility or end. This can alarm cyclists who don't know how to change over to a different lane or know how to share the road with cars. This situation leaves the cyclist vulnerable and unsure causing stress and confusion.

Besides crossing the intersection, turning in an intersection can be risky. The right turn in known to be the cause of many accidents. The cyclist is vulnerable to getting sandwiched between or clipped by the car and edge of the curb. The cyclists lack protection from cars entering their travel zone.

Even protected bike lanes are safe until they have to confront an intersection. When the cyclist enters the intersection, the protection disappears. The cyclist becomes vulnerable to getting hit by vehicles. There needs to be better ways to organize intersections to attend and protect all intersections participants.

[58] Ibid.

2.4.1.2 High Traffic-Speed

High traffic-speeds tend to make cyclists uncomfortable because drivers are more likely not to notice cyclists on the roads. Also, injury in a higher speed crash can be more severe. In the urban street, most roads are 25-35 mph. Speeds above 25 mph tend to be riskier because the higher speed is usually coupled with high-traffic volumes.

2.4.1.3 High Traffic-Volume

High traffic-volumes are typical in urban streets. The amount and frequency of cars passing through a street can increase the risk of accidents or conflicts. The narrow streets being cyclists and cars within close proximity to one each other. In many narrow urban streets, sudden small shifts can startle and even clip a nearby cyclist. Many different types of streets are seen in the urban core, and some can accommodate high-traffic volumes more safely than others.

2.4.1.4 One-Way Streets

One-way streets can be seen as safer for high-traffic streets because they are simply one-directional. This can be a difficulty for cyclists if they want to travel in the opposite direction.

One-way streets without the option to travel in opposite direction can result in wrong-direction travel. This typically happens when it is easier for a cyclist to go against the flow of the existing bicycle lane or on a sidewalk. This can be dangerous to cyclists traveling in the bike lane going the correct direction, causing a head-on collision. Cyclists can also to decide to ride off the street.

Riding on the sidewalk is seen as the most comfortable place for less-confident cyclists. This is dangerous for unsuspecting pedestrians especially the elderly because of their slow reaction times.

Bicycle riders will resort to unsafe practices if the action will save them time or if riding in a certain route makes them encounter more conflicts. These issues are commonly solved by adding contra-flow lanes or two-way protected bicycle lanes.

All in all, one-way streets with limited bicycle infrastructure runs an increased risk of out-of-direction travel. Improving bicycle facilities by creating opposite-direction bicycle lanes on a one-way street can make it easier and simpler to travel. This can potentially reduce the length of the trips, lessening the number of conflicts between cyclists and drivers.

2.4.1.5 Street Parking

It is not just moving cars that pose risks to cyclists, but street-parking lanes as well. High parking-turnover can cause the vehicle to frequently cross over the bicycle lane. They can cross over the lane when they are coming and going from the parking spot or when they open their doors.

Dooring is also a big issue. When parked cars open their car doors into the bicycle lane cyclists become surprised. If they do not have time to stop they could collide with the door or another car if they drift into the moving motor vehicle lane. Cyclists are forced to be able to handle maneuvering around blocked paths.

2.4.1.5 Bus Stops

Bus stops are another vehicle that can block the paths of cyclists. Buses tend to make frequent stops and can constantly interrupt cyclists. Usually, the bus and bus riders block the bicycle lane to access the bus.

Protected bicycle lanes cannot be used on the outside of the street sidewalk because the bus must pull up to the curb to shuttle passengers. This can be troublesome for planners who want to place a protected bike lane on a potentially less conflicting side of the street.

2.4.1.5 Loading Zones/Driveways

Another street conflict that interrupts cyclist travel is curb cuts caused by loading zones and driveways. These minor crossings can be no-big-deal, except when a street multiple in a short span. Having frequent curb cuts is a typical situation in commercial districts around the city.

Loading zones can be small in dense urban streets and sometimes the vehicles parked there block the bicycle travel lane. This condition forces cyclists onto the street. Cycling on a contra-flow lane in this condition could be very hazardous. For example, if an incoming car is blocked by the loading zone vehicle then the cyclist might not see it when passing, causing a head-on collision.

Part 2: Major Argument

About Guidelines

Compared to the Netherlands, the US is relatively new to designing bike facilities for the "Interested, but Concerned." NACTO has guidelines that recognize European design practices. With the growing population of cyclists there is increased interest in bicycle lane design. Also, people are more open to designing best-practice facilities for a broader range of users. It is important to keep increasing the standards of best-practice so that bicycling can be taken seriously as an alternative form of transportation throughout the city.

Placing "bike facilities" in its suitable context is important to creating a comfortable riding experience for people of all ages and comfort levels.[59] If accomplished, that would invite 60% of the people who ride bikes--the "Interested, but Concerned." Allowing this group of people to feel comfortable riding on streets in the urban core will vastly increase bicycle facilities' use making alternative transportation a viable alternative for US cities.

Creating the guidelines in the following chapters involved reviewing case studies to understand and prove how successful or unsuccessful urban bike facilities can be. The measure of success is based on cyclist volumes, the number of accidents as well as how many street conflicts are not attended to after the facilities are implemented. I also researched NACTO guidelines, European guides, analyzed a street's Level of Traffic Stress (LTS) and looked at surveys showing the concerns and desires of the "Interested

[59] Ibid.

but Concerned" to understand the current standards, urban street types, and the concerns of less-confident bicycle riders.

With this understanding, I concluded that the "Interested but Concerned" will be most comfortable riding in the urban street if there are at least one of three types of bicycle facilities; buffered bicycle lane, one-way protected bicycle lane, and two-way protected bicycle lane.

The "Interested but Concerned" believe that cycle lanes should be wide enough to accommodate passing cyclists and separated far enough from traffic, so they are not alarmed by the passing vehicles.

In addition to safely engineered bike facilities, many "Interested but Concerned" prefer design features that increase safety and comfort while riding. Many of the "Interested but Concerned" are fond of riding and say they need safe facilities, but even for some safe facilities are just the tip of the iceberg.

This discomfort comes from concerns about being too sweaty for work, or even just not wanting to be exposed to the urban grit.[60] These concerns can be taken care of personally such as, showering at work, going slow and be extra cautious but it is important for designers to take on more responsibility to create more human-friendly bike lanes. Pedestrians have "pedestrian-friendly" design, can bicyclists have "cyclist-friendly lanes" design?

[60] Adrian Lobo, "Solutions to Common Barriers of Cycling," accessed, February 23, 2017, http://www.betterbybicycle.com/2013/12/solutions-to-common-barriers-to-cycling.html.

Chapters three, four, five, and six showcase guidelines for three best-practice bike facilities. The designer or planner can choose which facility best fits the proposed street. Determining the correct facility means taking into account safety. The guidelines use case studies, LTS guides, European-inspired best-practice guidelines that take into account European practices that can ensure comfortable facility layout for the "Interested, but Concerned."

After the layout of the facility is chosen it is important to add design features to make the riding experience more pleasant while also increasing safety. Chapter 6 will introduce guidelines for innovative design features that are not yet used in many US cities. These design solutions are based on literature reviews based on the concerns of the "Interested, but Concerned."

This method of choosing a safe facility and also adding enhancing design features will ensure that users will be provided with a safe, low-stress (LTS 1/2), and pleasant cycling environment. Designing bicycle facilities that provide adequate protection and space in these typical urban streets are crucial to creating low-stress bicycling for the majority of people are open to riding bicycles.[61]

[61] "NACTO's New Guide Spells Out Which Bike Lanes Should Get Protection," People for Bikes, last modified October 31, 2017, http://peopleforbikes.org/blog/sneak-peak-nactos-new-guide-advises-when-to-protect-bike-lanes/.

Chapter 3. Buffered Bicycle Lanes

3.1 About Buffered Bicycle Lanes

Many less-experienced cyclists choose to ride on sidewalks instead of high-stress streets. Many arterial streets and corridors are narrow and can have high-traffic volumes. This creates close physical relationships between cyclists and automobile drivers.

The National Cooperative Highway Research Program (NCHRP), states that the presence of even just a three-foot conventional bike lane reduced the number of bicycle collisions with automobiles by 36% and provides a better sense of comfort and security between drivers and cyclists than shared lanes or wide curb lanes. [62]

Bicycle lane markings decrease the chance that drivers will overestimate the space needed for bicyclist and increases the chance that the bicyclists will stay in their designated area. The instances where drivers encroached on adjacent driving lanes decreased by 40%.

The survey evidence also shows that drivers will drive three-five inches closer to bicyclists when there are lane markings. This may seem more unsafe because there is a closer physical relationship between bike and car, but the bicycle lane boundaries help the driver to be aware of boundaries rather than overestimating unknown lane spacing.

[62] William W. Hunter. "Effects of Wide Curb Lane Conversions on Bicycle and Motor Vehicle Interaction" 2004.

The awareness each other's presence on the street can create a better sense of control and a safer street practices for all parties.[63]

Although these minimal treatments make a difference for the more advanced cyclists, the majority of the population who ride bikes needs to feel a high level of comfort. On urban streets, conventional bicycle lanes are considered the least protected safe facility and sometimes requires a buffer space for the cyclist to feel a lower level of stress.

A buffered bike lane is a conventional bicycle lane with added buffer space. It is a minimum four-foot wide dedicated bicycle zone with a minimum two-foot painted buffer with white painted lane lines measuring 6-8 inches adjacent to and usually going the same traffic direction as the automobiles. Acceptable on single lane bi-directional or single lane one-way streets with speeds of 25 mph or less with a target motor vehicle volume of less than or equal to 1,500-3,000 per day. [64]

They are usually located on the right side of the street adjacent to the vehicle travel lane, on the side of the road, or next to a parking lane. When it comes to one-way traffic, a contra-flow lane can be implemented to allow cyclists to ride against the flow of traffic. These lanes can be implemented in lower stress urban collectors/arterial

[63] Darren J. Torbic, Karin M. Bauer, Chris A. Fees, Douglas W. Harwood, Ron Van Houten, John LaPlante, and Nathan Roseberry. "Recommended Bicycle Lane Widths for Various Roadway Characteristics." In NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM, edited by Doug English, 63. (Washington D.C.: Transportation Research Board, 2014), 7.
[64] People for Bikes, "NACTO's New Guide."

streets where instead of no lane, a marked lane would be an improvement.[65] To increase the visibility of the bike lanes bright colors can be painted to the street surface.

Simply coloring lanes can increase visibility and remind cyclists and pedestrians of the presence of cyclists, potential conflict zones, and can dissuade drivers from unlawfully parking in the bicycle lanes.[66]

Buffers should be added alongside the bike lane. The desirable and comfortable minimum width is three feet and fits between the bicycle lane and vehicle lane or the bicycle lane and parking lane. This extra space provides greater protection from drifting cars, drifting cyclists, and greater protection "dooring" when parked cars open their doors. Additional Lane Spacing is always helpful when placed next to a curb, physical barrier, parked car, or on a high-stress street that cannot be retrofitted for a buffer or protected lane.

When a bicycle lane is adjacent to a solid curb, the cyclists have few places to move. The desired lane space is six feet. When riding next to a curb or guardrail, the minimum is two feet wider than what the condition permits. When the lane is placed next to parking lane, the minimum lane is five feet because of the threat of dooring and drifting cars. In a high-stress roadway where a protected bicycle lane is not possible, a

[65] Christopher Monsere, Nick Foster, "Lecture 7 Bicycle Facility Design: Design and Operation of Bicycle and Pedestrian Infrastructure," Portland State University, accessed November 19, 2017, lecture slides, 26, https://www.pdx.edu/ibpi/sites/www.pdx.edu.ibpi/files/CE493_593_Lecture_7_BicycleFacilityDesign_0.pdf.

[66] "Bikeway Design Guide," Bikeplan.org, accessed November 19, 2017, lecture slides, 1, http://bikeplan.org/BikewayDesignGuide_DRAFT.pdf.

minimum of five feet is given to the cyclist. This gives them more freedom when it comes to sudden conflicts that may arise on a high-stress street. [67]

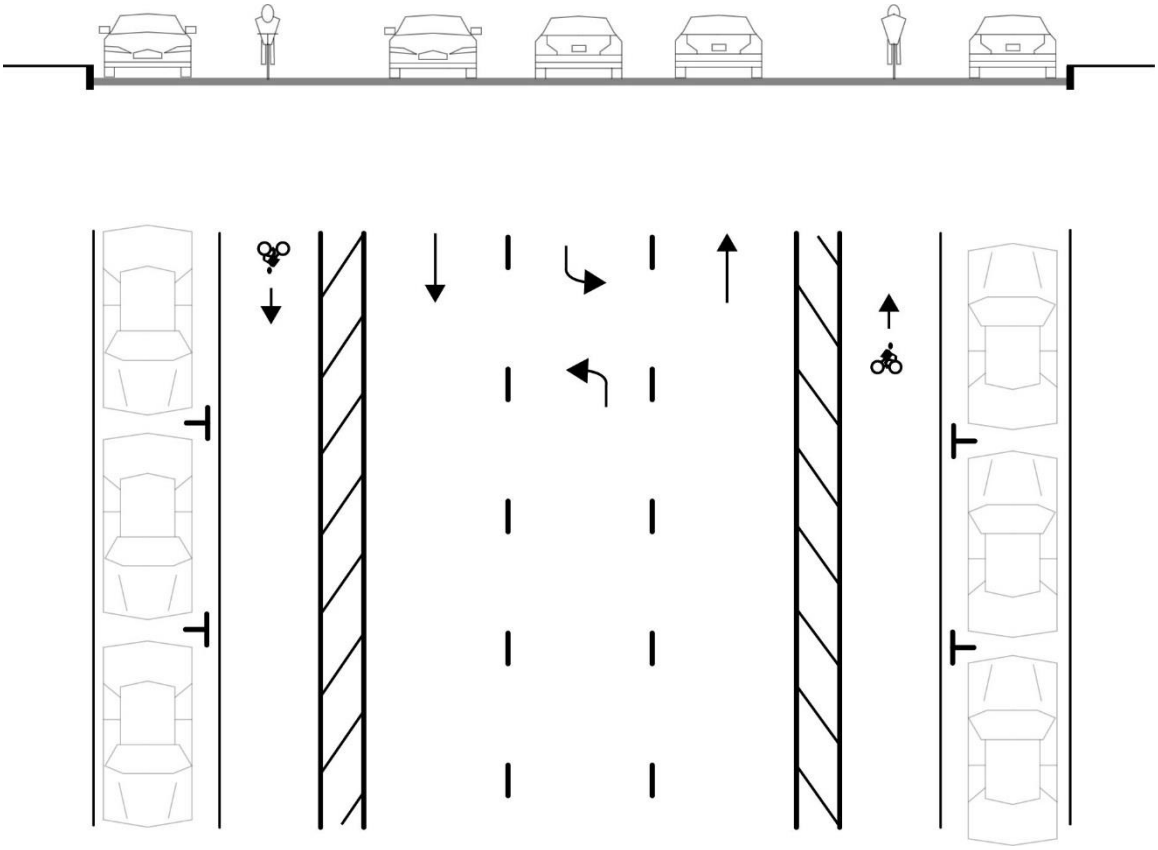


Figure 19: Buffered Bicycle Lane.
Graphic by: Author.

[67] "Conventional Bicycle Lanes," National Association of City Transportation Officials, last modified 2017, https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/two-way-cycle-tracks/.

3.1.1 Guidelines

Table 4. Required Features for Conventional Buffered Bicycle Lanes.

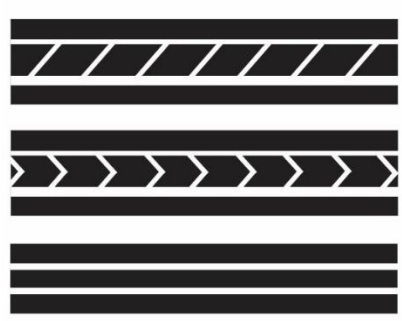
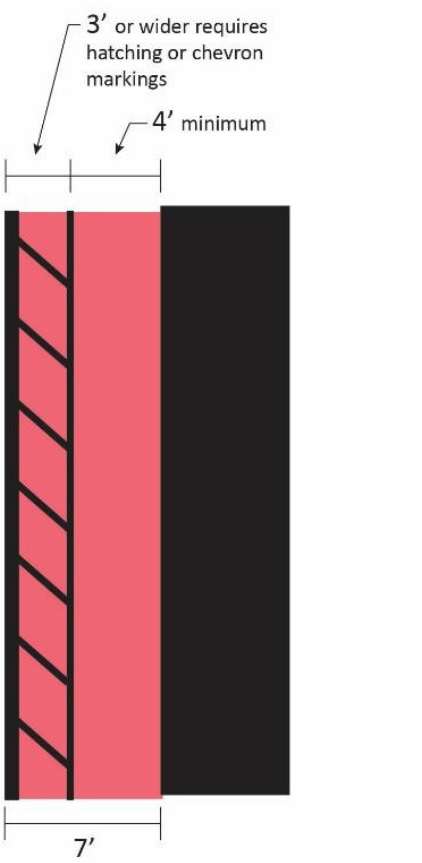
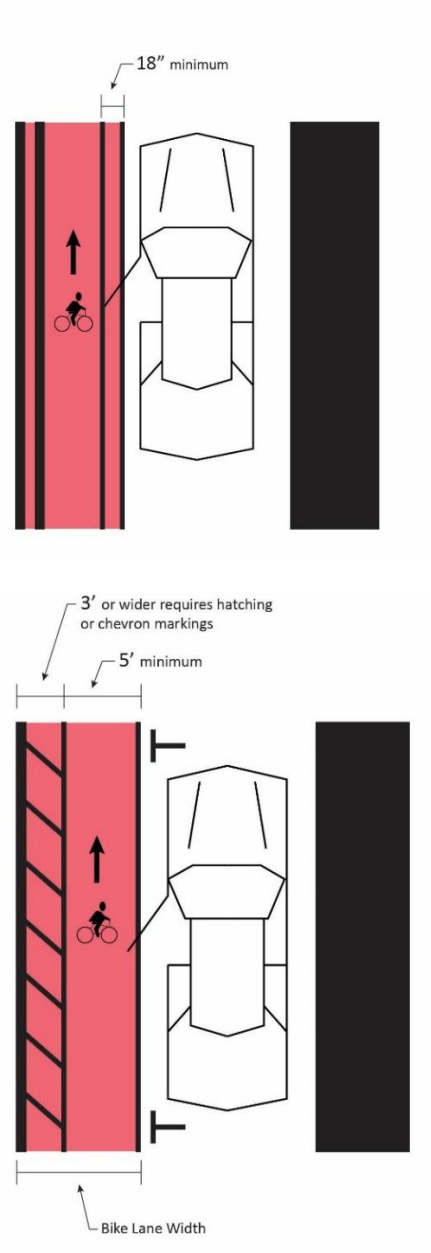
Guideline Graphics	Guideline Text
Buffer Lane Markings  	-word, symbols, arrow markings: keep them away from vehicle tread areas to decrease wear and tear -bike lane and vehicle lane separation line: solid white, six to eight inch line -buffer has two solid white lines on either side, and at crossings, white lines can be dashed to communicated that crossing can be expected -buffer width minimum is 18 inches -buffer should have diagonal crosshatched -if buffer is three feet or greater, use chevron markings -add additional lane width when adjacent to street parking -**pink** highlights placement of colorful pain for bike lane which will increase visibility of the cyclist and facility

Table 4. (Continued) Required Features for Conventional Buffered Bicycle Lanes.

Guideline	Description
Buffer Lane Markings (Continued) 	
Bike Lane Width Adjacent to guardrail/physical barrier	-add two feet to the condition's standard lane width

Source: Data from-National Association of City Transportation Officials. "Conventional Bicycle Lanes." Last modified 2017. https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/two-way-cycle-tracks/.
Graphics by: Author

Table 5. Best Practices for Conventional Buffered Bicycle Lanes.

Guideline	Description
Standard Bike Lane Width	-make wider than minimum widths to allow side-by-side riding -if there is enough space then buffered bicycle lane would be desirable. The buffer may be placed between vehicle travel lane and bicycle lane (keep in mind that if the lane is too wide with no buffer, the lane may be used for illegal parking) -desirable lane widths should be used. Only use minimums when other street elements have also been minimized -areas with high bicycle volumes, a travel area of seven feet is desired for side-by-side riding
Bike Lane Width w/ Parking Lane	-lane line between parked car and bicycle lane (minimize encroaching): four inches -wider parking lane to reduce chance of door collisions -buffer between parking lane and bike lane -lane next to parked car should ideally be five feet so riders can ride outside of the door zone
Gutter Seams, Drainage Inlets, and Utility Covers	-level with ground to minimize bumps for cyclists
Markings	-dashed lines in high-traffic areas where drivers can cross over bike lane -dashed striping should be used 50-200 feet from intersection when motor vehicle is expected to make a turn and cross over bicycle lane -interior diagonal crosshatching if lane is three feet or greater in width -any crosshatching lines in the buffer area should be four inches," and a 30-45 degree angle and the stripes should be 10-40 feet apart, but the closer the

Table 5. (Continued) Best Practices for Conventional Buffered Bicycle Lanes.

Guideline	Description
Markings (Continued)	striping, the more visible to the motorists. -colors at beginnings of bicycle lanes to avoid motor vehicles from entering -use white striping between parking lane and bike lane to create explicit boundaries which can act as a buffer and reduces door zone hazards
Additional Features 	-if space does not permit a buffer, add a rumble strip on painted line marking -different paving materials to delineate bike lane -"bike lane" signs before bike lane begins -"no parking" signs to discourage parking in bike lane -bike traffic signals -motions detectors and flashing lights at crossing to notify drivers of incoming cyclist
Intersections	-when approaching a right turn only lane, the bike lane must lead to the left of the lane, or if space is too limited for a dedicated lane, the bike lane must transition into a combined bike lane/turn lane -at an intersection, with no dedicated right turn lane the buffer markings should transition into a single dashed line with a bike box or turn box at the intersection

Source: Data from-National Association of City Transportation Officials. "Conventional Bicycle Lanes." Last modified 2017. https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/two-way-cycle-tracks/.
Graphics by: Author.

Context

A conventional lane is not ideal for long spans of high-stress streets. If there are short transitional spaces with minimal street conflicts, this facility could work. It will almost always be best practice to add a buffer to this lane type. Adding a buffer widens the cyclist's zone which decreases stress. The buffer allows for more space for a cyclist to react to conflicts and emphasizes the boundary between the cyclist and car. Buffered Bicycle Lanes are most beneficial for conditions where:

-traffic volume is no greater than 3,000 vehicles per day

-speed limit of 25 mph or less[68]

-urban collectors/arterial streets that are straight with good visibility with low levels of conflict areas on the street

-short cuts or short stretches between routes or city corridors where conflicts such as speed, traffic volume, and parking turnover are less severe.

Overall, conventional bike lanes or buffered conventional bike lanes provide minimal separation, exclusive space for cyclists, better visibility, less sidewalk riding-if placed in suitable context, low maintenance, and are relatively easy to retrofit.[69]

In an effort to make protected bike lanes the standard, Portland, Oregon road designers are required to state a case as to why a city street should have unprotected bicycle lanes as opposed to protected lanes.[70] Many cities might forego a protected lane

[68] People for Bikes, "NACTO's New Guide."
[69] Monsere, "Lecture 7 Bicycle Facility Design."
[70] James Ayre, "Portland Regularizes Protected Bike Lanes With New Policy," Clean Technica, last modified January 31, 2016, https://cleantechnica.com/2016/01/31/portland-regularizes-protected-bike-lanes-new-policy/.

when they need to maximize the amount of motor vehicle through traffic while at the same time needing a bicycle-accessible street. Adding multiple narrow lanes will cause higher traffic volume, but the narrow lanes will allow for traffic speed control thus making car and cyclist interaction less severe. The case studies below will show examples of low-stress and high-stress unprotected conventional/buffered bicycle lanes.

3.1.1.1 Case Study 1 on Conventional Bike Lanes: Successful (LTS 2)

Figure 20: South St. and Pohukaina St. Intersection.
Source: Jayna McClaran.

This stretch of South Street in Honolulu, Hawaii is a four-lane bi-directional street with two lanes devoted to each traffic direction and conventional bicycle lanes on each side of the street. The stretch spans a short distance between Pohukaina St. and

Ala Moana Blvd. Across the intersection shown in (Figure *20*), the street transitions into a three-lane one-way with a two-way protected bike lane.

Before the installation of the bicycle facilities, Traffic Volumes reported in 2013 showed that the maximum volume during typical weekday peak hours, 7:30 am-8:30 am, was 477 vehicles per hour (VPH). The two-directional street section had an afternoon peak, at 4 pm-5 pm of 542 VPH. By 6 pm the two-directional traffic drops to 300 VPH and by 6:30 pm, 100 VPH. Overall, South Street was reported with seeing around 6,214 average daily traffic (ADT).

According to NACTO guidelines, any street with an ADT greater than 6,000 and multiple lanes requires a protected bicycle lane. Unfortunately, this stretch of the street had bus stops, loading zones, and driveways making protected facilities a challenge—especially for surrounding businesses.

The Level of Traffic Stress (LTS) is a two on a scale of four. It is a low-stress street with some high-stress conflicts.

Low-Stress:

-short and straight

-low-speed at 25 mph

-buildings along the street are less-dense with primarily just residential high-rises

-no large intersections

-bi-directional, so it is easier for cyclists to enter South Street from Ala Moana Boulevard and then transition into the two-way protected bicycle lane at at the South Street and Pohukaina Street Intersection

-minimal residential high rise driveways

-conventional bicycle lane causes less obstruction to commercial loading zones and residential driveways

-lane marking such as green paint and dotted lane markings at driveways/loading zones

-bike boxes and turn boxes transition from conventional bicycle lane to the two-way protected lane along the busier portion of the street contributes to the lower the stress factor according to the “Interested but Concerned”

-unwinding street increases visibility

High-Stress:

-two loading areas where cars encroach on the bike lane

-high-traffic volume

-bike box

-bus stops

-cars drive into bike boxes, so cyclists are not ensured visibility when turning to transition into the protected bike facility on the other side of the intersection

To try to make the high-stress conflicts less severe, some design features were implemented (Table 6). These interventions, however, are minimal and do not ensure that the conflicts are resolved.

Table 6. Conflicts that Create Stress and Resolutions for South Street Corridor.

Conflicts and Potential Interventions	**Conflict Image**
Conflict: Vehicles Encroaching on/or Blocking Bike Lanes Intervention: -dashed lanes markings and green paint were added to highlight conflict zones, but cars still encroach on the bike lane and dooring is a possibility	

Table 6. (Continued) Conflict that Create Stress and Resolutions for South Street Corridor.

Conflicts and Potential Interventions	**Conflict Image**
Conflict: Intersection Intervention: -bicycle signal when transitioning from two-way protected bike lane to conventional bike lane crossing Pohukaina St. intersection going southbound	

Table 6. (Continued) Conflict that Create Stress and Resolutions for South Street Corridor.

Conflicts and Potential Interventions	**Conflict Image**
Conflict: Intersection (Continued) Intervention: -bike box helps cyclists become visible and get a head start when the light turns from red to green -green paint shows visibility of lanes and conflict zones -signage directing cyclist to bike box and prohibiting right turns on red -cars still drive over the bike box making it harder for cyclists to gain priority Intervention: -turn box transitions cyclists into the two-way protected bike lane as South Street switches to a one-way street	 

Source: Jayna McClaran.

To conclude, I justify my rating of this portion of South Street with a Level of Stress of two because this street is not high-stress. It is comfortable enough for most of the "Interested but Concerned," but there may be some not completely convinced.

With the bus stops, there are interrupted bike lanes, and an added buffer would allow for more space for cyclists to react to the street's conflicts—especially at the loading zones.

With bike-share programs, the increasing popularity of bicycling, and the community around South St. growing, there are and will be more inexperienced cyclists riding there in the near future. This growing area of Honolulu is constructing high-rise residential and mixed-use buildings as well as a rail station on the corner of South Street and Halekauila Street.

Traffic, pedestrian, and bicycle volumes are predicted to increase vastly. These conventional lanes are barely adequate now. With the future development, they should be upgraded to allow for a broader age range and skill level of riders. The new facilities need to be safe and comfortable to make cycling an easy option. In spite of the critique, I rated this case study as successful because it shows the city has made a serious effort to try to address the street conflicts.

3.1.1.2 Case Study 2 on Conventional Bike Lanes: Unsuccessful (LTS 4)

Figure 21: City Mill Driveway On Wai'alae Avenue. An Unsuccessful Portion Of The Bikeway From Kaimuki To The University Of Hawaii At Manoa. Numerous Cyclists Have Been Hit By Cars In This Driveway. Source: Jayna McClaran.

Wai'alae Avenue-Dole Street route of bicycle infrastructure leads to the University of Hawaii at Manoa's Campus. This stretch of high-stress streets in Honolulu has both conventional bike lanes and shared bike routes spanning about, 1.2 miles.

The area of Wai'alae Avenue in front of City Mill, pictured in (Figure 21) consists of four-lanes of bi-directional 25 mph street with two lanes devoted to each traffic direction. The downhill stretch of Wai'alae going in the west direction runs towards the University of Hawaii at Manoa. This street has heavy traffic and heavily used driveways.

Measured in 2011, there were about 400 bicycles counted from 6:30 a.m. to 6:30 p.m. On Fifth and Wai'alae Avenue, near the previously mentioned City Mill driveway. The traffic volume count for Wai'alae Avenue's west-bound traffic had a peak of 2,000 cars from 7:00 a.m. to 8:00 p.m. It was suggested by community members that better street lighting should get installed to increase the visibility of the cyclists by drivers during the later times.

During the morning peak times, the spillover from nearby McDonald's drive-thru line blocks the entire right lane, including the conventional bicycle lane and prevents cyclists from being able to pass through. Currently, there are no signs or colored marking to remind drivers that there are cyclists present before they cross into the bicycle lane.[71]

This street is heavily used by students and faculty of University of Hawaii at Manoa (UHM). The UHM Shuttle drives through Wai'alae Avenue and connects to the far edge at Dole St. and University Avenue.

[71] "Kaimuki Neighborhood Board Minutes," kaimukihawaii.com, last modified October 19, 2011, http://www.kaimukihawaii.com/news/201111/3540.html.

Figure 22: Dole Street and University Avenue Intersection.
Source: Jayna McClaran.

The intersection of Dole Street and University Avenue marks the end of the bike lane in this analysis. In 2012, Dole St. had traffic count data indicating an average daily traffic volume of 9,500 cars driving through the four-lane street. The intersection at Dole and University is a major crossroads that marks access points to the University of Hawaii at Manoa campus, the University parking structure, and the H-1 freeway. This area of Dole Street is often congested and the four-foot conventional bike lane is not adequate or safe for less experienced riders, especially students around the university.

According to, NACTO's 2017 Contextual Guidance for Selecting All Ages & Abilities Bikeways it states that it is ideal to implement protected bike lanes in streets that have multiple lanes per direction as well a traffic volumes over 6,000 vehicles per

day. In 2012 there were a total of six reported bicycle accidents at/approaching this intersection alone.[72]

The Level of Traffic Stress (LTS) for this street is a four on a scale of four. It is a high-stress street with some high stress conflicts.

Low-Stress:

-bicycle lane separation

-bicycle lane makings

High Stress:

-multiple lanes of traffic

-high traffic volume

-bicycle lane that is in close proximity to the narrow lanes of traffic

-parked cars

-frequent driveways

-heavy intersections

-minimal bike lane widths and no use of buffers

The "Interested but Concerned" would not feel comfortable here—especially with the little notice of their presence at intersections, driveways, and bus stops. Indicators that could remedy the lack of visibility could include technology similar to what intersections and pedestrian crossing use such as, motion sensors that trigger a

[72] City and County of Honolulu: Department of Transportation Services, "Honolulu Complete Streets Implementation Study Location Report: University Ave. and Metcalf St .Final" (SSFM, 2015), 9.

flashing light for drivers, bike signals, or bright lane markings that emphasize cyclist zones and communicate their overall presence.

Table 7. Fixing the Problem. Current Issues and Possible Resolutions with Existing Infrastructure and Solutions for Wai'alae Avenue/Dole Street.

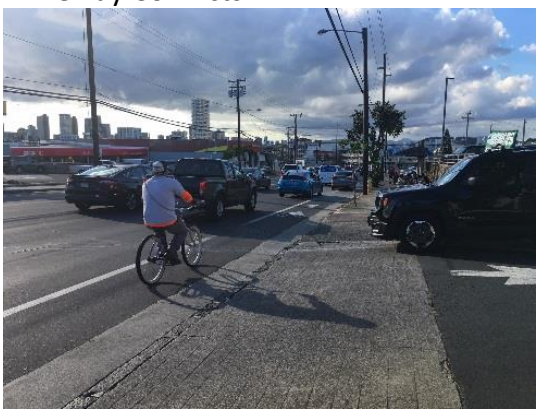
Conflict	**Suggested Resolution**
Encroaching Into Bike Lane/Bike Box 	-create protected bicycle lanes and/or use physical barriers so that moving vehicles do not encroach into bike lane -bright colored paint in bike lane can make drivers more aware of the road/bike lane boundaries
Driveway Conflicts 	-bright colored paint in bike lane can make drivers more aware of the bicycle lane when crossing through to a driveway -in heavily used driveways, install a traffic signal -signage to remind drivers to look out for incoming cyclists
Bike Lane Suddenly Ending/Beginning From Sidewalk 	-signage acknowledging the changes so cyclist can get off the street at a crosswalk curb entrance before entering a shared road condition at a busy intersection -create a continuous track or path that leads off the road -continuous bicycle infrastructure to eliminate gaps that force less experienced cyclists to use pedestrian sidewalks and crosswalks

Table 7. (Continued) Fixing the Problem. Current Issues and Possible Resolutions with Existing Infrastructure and Solutions for Wai'alae Avenue/Dole Street.

Conflict	Suggested Resolution
Sudden Lane Narrowing 	-widening of bike lane so cyclists do not have to swerve to avoid grates and utility holes that are located inside the bicycle lane

Source: Jayna McClaran.

Overall, it should be highlighted this street runs through the college campus, which has a large population of cyclists, many inexperienced and sometimes reckless. It is important to consider the context and this population to think smarter about the safety of this demographic. Not only should there be best practices facilities connecting people to hot spots around the city, but designers should be especially thoughtful when planning for areas where there are many young riders and high-traffic volumes.

3.1.1.3 Case Study 3 on Buffered Bike Lanes: Best success (LTS 2)

Figure 23: Ala Napunani St. Buffered Bicycle Lane.
Source: https://www.honolulu.gov/rep/site/dts/te/bike_imgs/OBP_bike-facilities.png.

In 2017, Hawaii's City and County of Honolulu resized, Ala Napunani St in Moanalua. This four-lane bi-directional street with street parking was notorious for high-speed traffic and was resized to encourage safer driving. Now, the street includes a two-way left turning lane in the center, buffered bicycle lanes on each side of the street as well as street parking. The six-foot buffered bicycle lane allows for protection from dooring and potential vehicle drifting.

Before the resizing, this street had a history of speeding, so the narrowing of the lanes was done to decrease that likelihood. Michael Packard, the city's Complete Streets program administrator, said, "For pedestrians the safety goes up much higher, for cyclist you're adding a dedicated space that didn't exist before, and then for vehicles--the history shows that the percentage of accidents goes down upwards of 50

percent-- and the highest-end speeders drop significantly." [73] This project is a great example of a holistic design that creates a safer environment for all the different users of the street.

The Level of Traffic Stress (LTS) for this street is a two on a scale of four. It was a previously high-stress street that is now low-stress because of thoughtful solutions.

Low-stress:

-buffer to allow cyclists to move and react freely

-traffic lane and reduction narrowing to decrease car speeds

-low speed limit at 25mph

-single lane bi-directional street

-street lights for increased visibility

Moderate-stress:

-sporadic residential driveways

-winding road

-street parking

The “Interested but Concerned” would feel comfortable because there are not many visibility obstructions besides the parked cars. Also, the bike lane is wide enough to react and not be vulnerable to contact with cars in the driving lane. Overall, the street and bike lane is visible to street users. The adequate space and visibility decrease the chances of getting hit by a motor vehicle.

[73] "Ala Napunani Street Upgrades Designed to Improve Safety," KITV 4 News, accessed November 19, 2017, http://www.kitv.com/story/34418354/ala-napunani-street-upgrades-designed-to-improve-safety.

Table 8. Conflict and Resolution for Ala Napunani Street.

Conflict	Resolution
Pedestrian Safety	-Motor vehicle lanes, less in number and narrower in width reduce the distance that pedestrians have to cross the streets
Speeding	-Reduce travel lane widths to slow traffic -Adding a bicycle lane buffer tells drivers they are not the only ones on the roadway
Parked Cars	-Six-foot buffered bike lane allows for space for cyclists to react to car door movement
Cars Drifting Into Bike Lane	-Six-foot buffered bike lane allows for drivers to be aware of adjacent bicycle lane and for cyclists to have enough space to react and move if a car enters the buffer space

Source: http://www.kitv.com/story/34418354/ala-napunani-street-upgrades-designed-to-improve-safety.

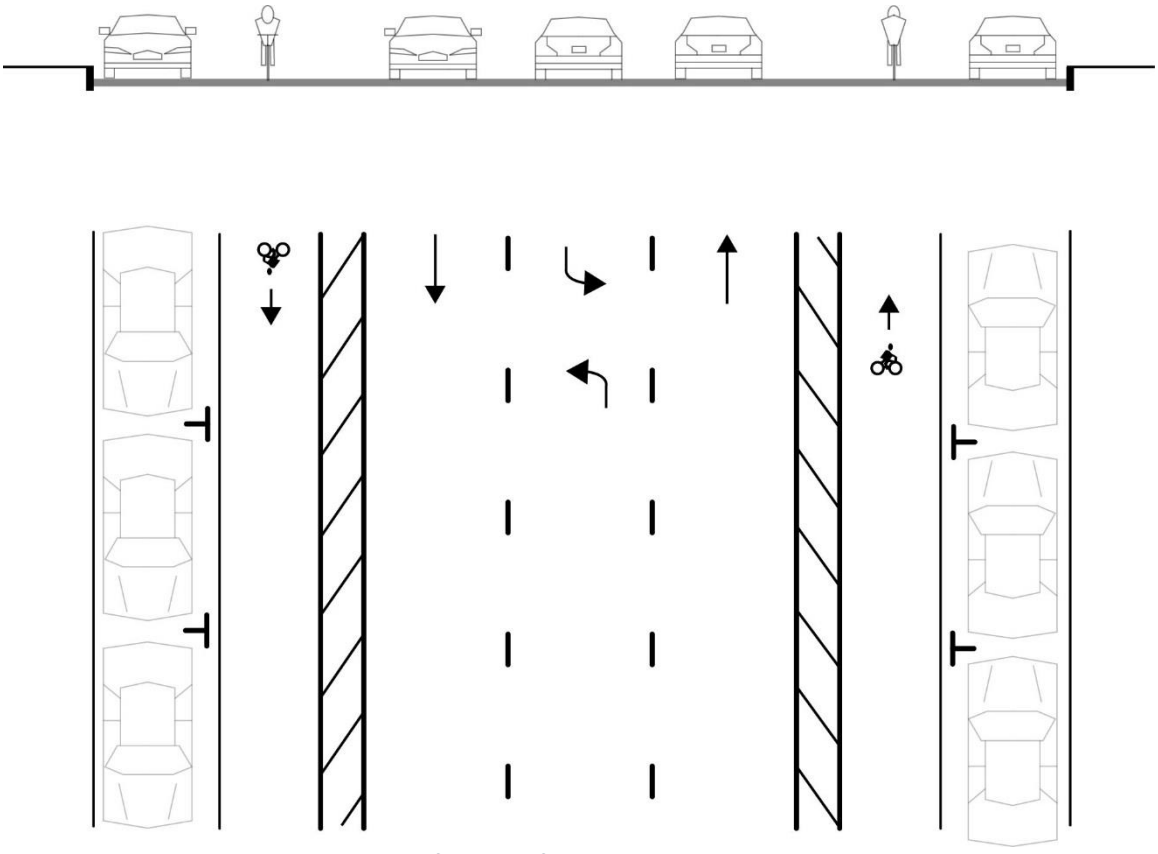


Figure 24: Ala Napunani Street Layout after Retrofit.
Source: Data from: City and County of Honolulu and http://www.hawaiinewsnow.com.
Graphic by Author.

Figure 25: Ala Punani Street Map.
Source: Data from City and County of Honolulu and http://www.hawaiinewsnow.com.

Chapter 4. One-Way Protected Bicycle Lanes

4.1 About One-Way Protected Bicycle Lanes

A one-way protected bike lane has much of the same behavioral characteristics as a conventional bicycle lane, but with required buffers, space, and physical boundaries separating it from driving lanes, parking lanes, or sidewalks.

These lanes should be used in streets with a speed limit greater than 25 mph and traffic volumes above 6,000 vehicles per day.[74] Protected bicycle lanes are usually placed on the curbside of street parking. The safety provided by physical barriers and a one-way direction provide greater levels of comfort.

Novice cyclists may prefer this option as opposed to a two-way bike lane. The lane is one-directional, so there is less chance of head-on collisions between cyclists drifting into each other's lanes. This is also a safer lane in intersections and driveways because the driver primarily has cyclists coming from one direction.

In order to make these lanes stand out to drivers, coloring lanes is a simple way to increase visibility. Color differentiation also reminds cyclists and pedestrians of potential conflict zones. It also dissuades drivers from unlawfully parking in the bicycle lanes. [75]

To reduce cars from encroaching on the bicyclists' space, bicycle lanes can be raised to create vertical separation between drivers and cyclists. The height of the raised lane is often sidewalk level—sometimes slightly higher or lower.

[74] People for Bikes, "NACTO's New Guide."
[75] Bikeplan.org, "Bikeway Design Guide."

Street level lanes can be separated from motor traffic by raised medians, on-street parking, or bollards. The raised lanes can be at an intermediate level which is between street level and sidewalk level. A one-foot mountable curb can create separation from the motor vehicle lane, and a three-foot parking buffer can separate the lane from parked cars. Separating cyclists and pedestrians using pavement color/texture can differentiate the bike lane from the sidewalk.

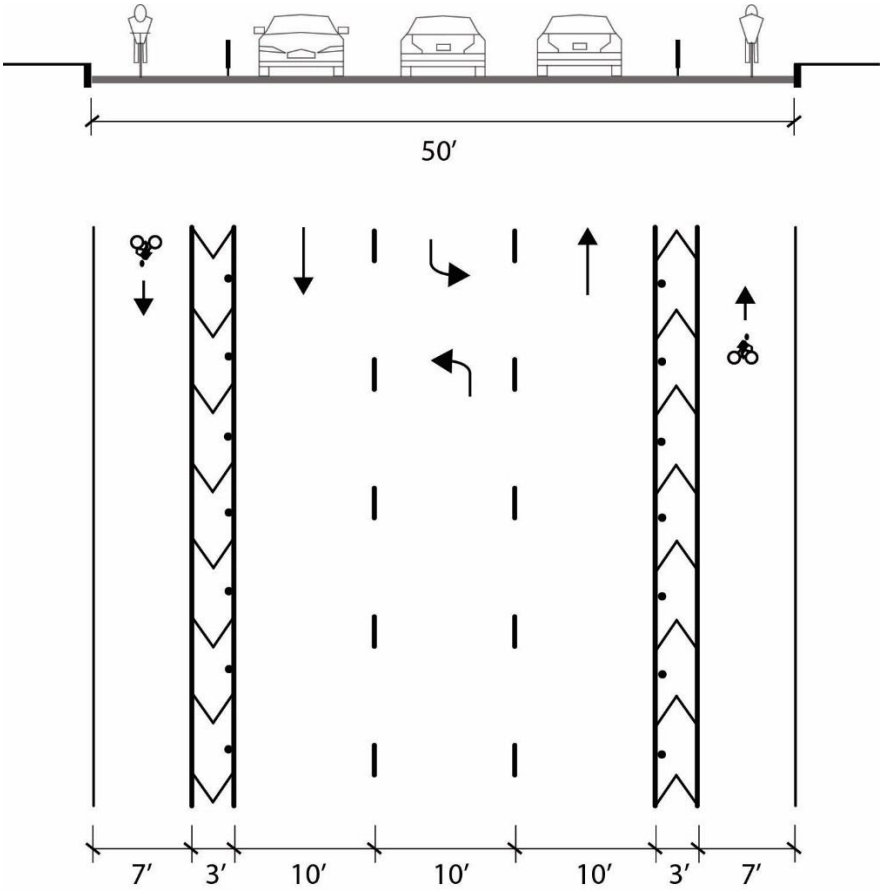


Figure 26: One-Way Bicycle Lane.
Graphic by: Author.

4.1.1 Guidelines

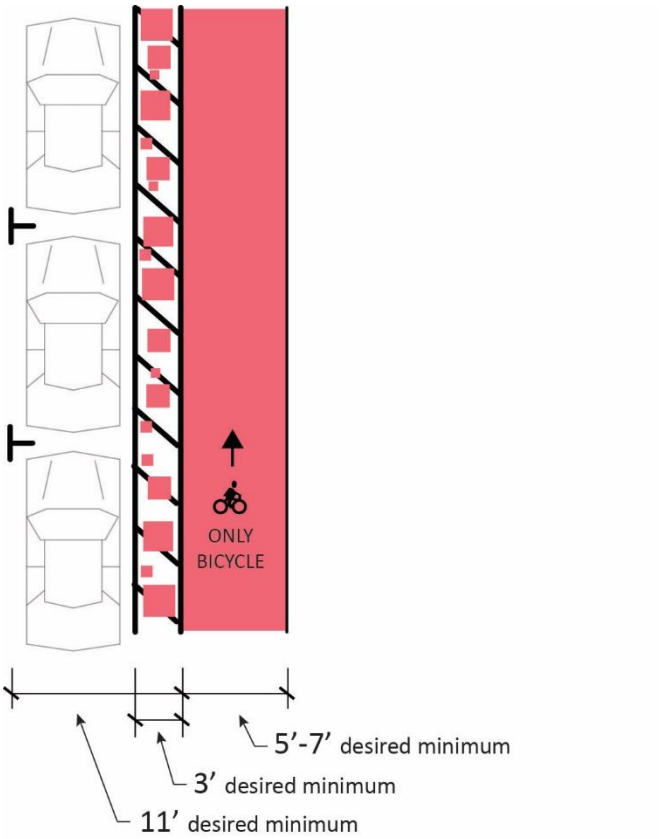


Figure 27: Design Guidelines for One-Way Protected Bicycle Lanes.
Source: Data from: NACTO, "One-Way Protected Cycle Track".
Graphic by Author.

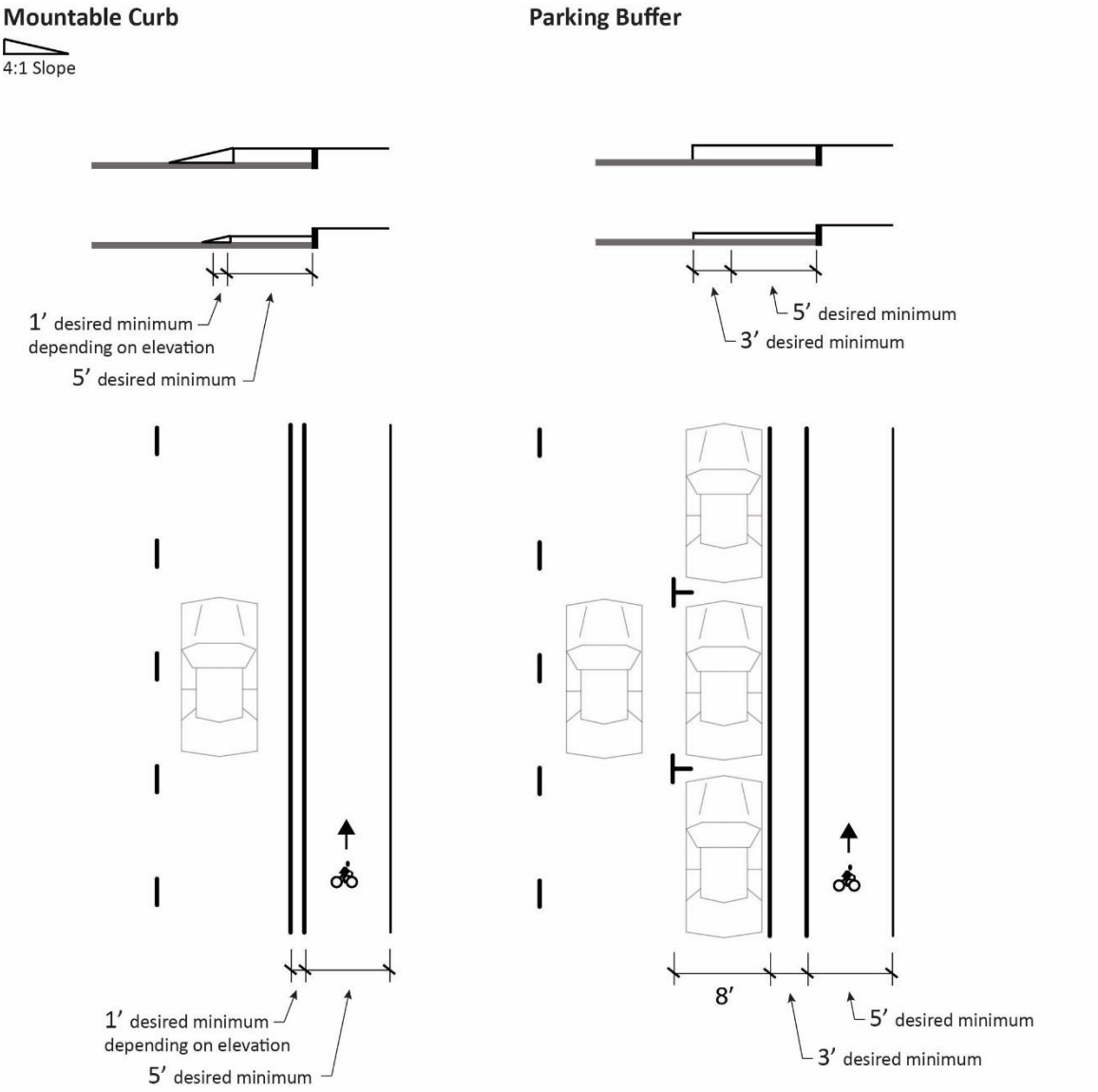


Figure 28: Design Guidelines for One-Way Raised Cycle Tracks.
Source: Data from: NACTO, “One-Way Protected Raised Cycle Track”.
Graphic by Author.

Table 9. Required Features for One-Way Cycle Tracks.

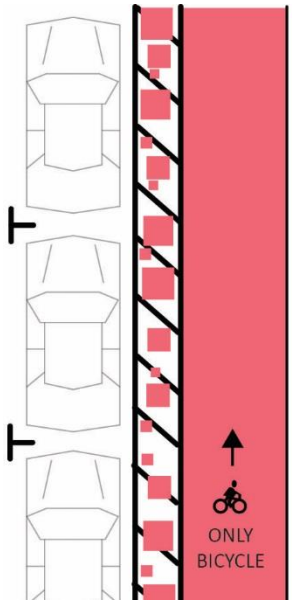
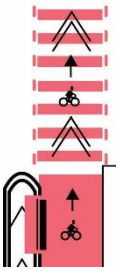
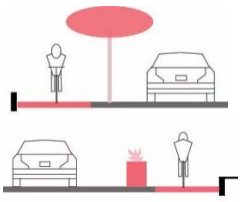
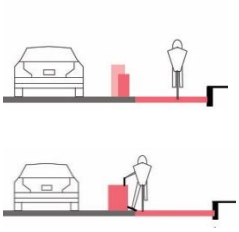
Guideline	Description
Preferential Lane 	-a lane designated for a particular traffic use such as a bike lane or a cycle track -pink highlights placement of creative: shading, bike lane treatment, lighting treatment, and street protection
Markings  	-word, symbol, and arrow at the beginning and throughout cycle track -solid white line pavement markings and crosshatches in places that need emphasis
Physical Barriers 	-pink highlights placement of creative physical separation to protected lane such as bollards or parked cars

Table 9. (Continued) Required Features for One-Way Cycle Tracks.	
Guideline	**Description**
Physical Barriers (Continued) 	

Source: Data from: NACTO, "One-Way Protected Cycle Track." https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/one-way-protected-cycle-tracks/. Graphic by Author.

Table 10. Best Practices for One-Way Cycle Tracks.

Guideline	**Description**
Protected Bike Lane Width	-minimum 5 feet -high bicycle volume areas/hills: 7 feet (for passing)
Protected Bike Lane w/ Parked Cars Adjacent	-buffer between car and track: 3 feet -parking lane and buffer: 11 feet total
Buffer Width	-minimum 3 feet painted -physical barriers should be placed in the buffered space
Driveways and Intersections	-street parking should be set back at least 30 feet from the intersection to improve visibility -sight triangle of 20 feet from minor street crossing to the cycle track and Sight triangle of 10 feet from driveway to the cycle track
Markings	-coloring lanes to increase visibility

Source: https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/one-way-protected-cycle-tracks/.

Context

One-Way Protected bicycle lanes are usually an ideal option for high-stress streets, depending on the immediate context of the particular street. This facility is best suited for:

-streets with high traffic-volume

-streets with high bicycle-volume

-streets with minimal intersections/driveways

-streets with high parking turnover

-streets with parked car as a buffer between the motorists and cyclists

-high-stress streets with bike-share and want to increase ridership of various levels of cyclists

- one-way streets to reduce the risk of out-of-direction travel, the length their trip, and the number of conflicts between cyclists and drivers

-use on one side of a two-way street, typically placed when there is not enough space for one-way protected lanes on either side of the street

4.1.1.1 Case Study 1 on One-Way Raised Protected Bicycle Lane: Successful (LTS 2)

Figure 29: Market St. One-Way Protected Bicycle Lane Bicycle Lane.
Source: http://www.sfbike.org/news/better-market-street-is-here/.

In 2010, San Francisco, California retrofitted Market Street's 2.2-mile corridor with one-way protected bicycle lanes on each side of the two-way street. Initially, there were transit-only lanes and bike lanes, but delivery trucks and taxis would constantly be blocking the lanes intensifying conflict areas for cyclists and increasing traffic delays.[76]

The addition of safe-hit posts and green paint allowed for more protection, but in 2015, the one-way bike lane was elevated to sidewalk level with no physical separation barrier from adjacent traffic.

Unfortunately, research proved that cyclists did not feel like it was just as safe as a physically separated bicycle lane. Their latest plan expected in 2018 will add physical separation to the raised one-way protected bicycle lanes for extra protection.[77]

The Level of Traffic Stress (LTS) for this street is a two on a scale of four.

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[76] "Market Street Protected, Buffered Bicycle Lane, San Francisco, CA.," National Association of City Transportation Officials, accessed November 19, 2017, https://nacto.org/case-study/market-street-protected-buffered-bicycle-lane-san-francisco-ca/.
[77] Janice Li, "Better Market Street Is Here," San Francisco Bicycle Coalition, last modified August 2, 2017, http://www.sfbike.org/news/better-market-street-is-here/.

Low-stress:

-raise bicycle lanes

-green paint

-safe-hit posts

High-stress:

-heavy commercial traffic as well as taxis, cyclists, and private vehicles, light rail, and buses

-heavy intersections

-minimal physical protection

Using surveys and constantly trying to improve facilities are what makes this case study stand out. This project makes safety and comfort of cyclists its top priority.

Figure 30: Raised Bike Lane on Market Street.
Source: http://www.sfbike.org/news/better-market-street-is-here/.

Table 11. Conflict and Resolution for Market Street Corridor Improvement.

Conflict	**Resolution**
Vehicles Encroaching on/or Blocking Bike Lanes	-Retro-reflective “safe hit posts” were installed as a physical boundary in the painted buffer zone between the traffic lane and bike lane (resulted in 84% reduction in bike lane encroachment by automobiles) -Raised bike lanes allow for emergency vehicles to have access. Raised bike lanes usually can have a mountable curb but still define the cyclist zone as to decrease the likelihood of motor vehicle conflicts. -Physical barriers increased perceived safety in this particular high-stress corridor [78]
Visibility of Lanes	-Green painted bike lane (addition of green paint increased perceived safety in Eastbound travelers, but made no difference for westbound travelers)
Transit Stops	-Green marking shown in conflict zones, so pedestrians and cyclists are aware of each other and their boundaries

[78] Paolo Cosulich-Schwartz, "Construction Begins on San Francisco's First Raised Bike Lane," San Francisco Bicycle Coalition, last modified October 19, 2015, http://www.sfbike.org/news/construction-begins-san-franciscos-first-raised-bike-lane/.

Figure 31: Plans for Raised Bike Lane on Market Street.
Source: https://nacto.org/wp-content/uploads/2011/03/Market-st_Str-7694-12th-St-to-8th-St.pdf.

Figure 32: Plan Set of 9th Street.
Source: https://nacto.org/wp-content/uploads/2011/02/MD-762_1A_9th-Ave.pdf.

4.1.1.2 Case Study 2 on One-Way Protected Bicycle Lanes: Moderately Unsuccessful (LTS 3)

Figure 33: King Street Two-Way Bicycle Lane at Driveway with Street Parking.
Source: Jayna McClaran.

King Street is a five-lane one-way street with bus stops on the right and street parking on both sides of the street. Due to the desire to ride bi-directionally, the original one-way protected bike lane that opened on December 6, 2014, later became a two-way on May 15, 2015.

There was heavy discussion on whether to place the bicycle lane on the left or right side of the street. Officials concluded that even though there are fewer driveway conflicts, the lane should be placed on the left side of the street because of the frequent transit stops on the right side of the street.[79]

The Level of Traffic Stress (LTS) for this street is a three on a scale of four.

Low-Stress:

-10-foot curbside bicycle lane

[79] Ibid.

-six-inch asphalt berms and bollards within the three-foot buffer between parked cars and motor vehicle traffic[80]

-parked cars as buffer

-green paint at driveway crossing

High-Stress:

-high amount of driveway conflicts

-high traffic-volume

-higher speeds at over 25mph

-frequent driveway interruptions

-heavy intersections

-no paint markings in intersection

As Hawaii's first protected bicycle lane the implementation this type of facility proves that Hawaii is on the right track to becoming a bicycle-friendly city. In 2014 King Street had an original ridership of 380 riders, 67% of which were on the sidewalk because of the one-way only direction. Following the two-way bikeway construction, in 2016, King had a ridership of 784 riders, five-percent of which were on the sidewalk. Currently, ridership is around 1,000 riders per day. The city anticipates an increase as it continues to implement Honolulu's bicycle facility network.

[80] "King Street Protected Bike Lane," City and County of Honolulu, last modified June 30, 2016, http://www.honolulu.gov/bicycle/bicyclefacilities/bicycle-projects/821-site-dts-cat/site-dts-bicycle-program-cat/22456-king-street-cycle-track-2.html.

Table 12. King Street's Resolutions of Conflicts Surrounding Protected Bike Lane.

Conflict	**Suggested Resolution**
Intersection	-Bike signals at intersections
Physical Protection	-Delineators/bollards with reflective tape -3 foot wide painted buffer -6" asphalt berm
Visibility	-Street parking set back at intersections -Pylons and
Markings	-Repaint green markings at driveway crossings -add green paint to intersections -Bike symbol and arrows -Dividing line marking bi-directional travel
Signs	-"Look both ways for bikes" signs at driveways and intersections

Source: http://www.honolulu.gov/rep/site/csd/King_Street_Protected_Bike_Line_Fact_Sheet.pdf.

Table 13. Current Conflicts and Why They are Conflicts.

Remaining Conflict	**Why is it a Conflict?**
Driveway	-Multiple driveways on the left side of King Street -No visual hierarchy or priority is given to cyclists at driveway crossings
Visibility/Awareness	-Parked cars still surround driveways and are not set back far enough to make cyclists visible to drivers when turning left into the driveway

Figure 34: Design Sheet from Intersection at South King St and Ward Avenue.
Source: http://www.honolulu.gov/bicycle/bicyclefacilities/bicycle-projects/821-site-dts-cat/site-dts-bicycle-program-cat/22456-king-street-cycle-track-2.html#Construction.

The green highlights the grey driveway showing the conflict zones. There are much fewer driveways on the right side of King Street showing that there would be less interaction with cars and thus fewer conflicts if it were implemented on the opposite side of the street. Although one of the main reasons for placing the protected lanes on the left was because of the City bus presence, there are ways to design around transit stops that would be much safer overall for cyclists than having them cross driveways.[81] I discussed potential design solutions later in Chapter 6.

[81] Ibid.

4.1.1.3 Case Study 3 on One-Way Protected Bicycle Lane: Best Success (LTS 2)

Figure 35: 9th Avenue, Manhattan One-Way Protected Bicycle Lane.
Source: https://nacto.org/case-study/ninth-avenue-complete-street-new-york-city/.

In 2007, New York, New York's 9th Avenue in Manhattan the New York City Department of Transportation (NYCDOT) designed the first in-street and signal protected bike facility in the United States. The one-way 70-foot wide street now accommodates three traffic lanes rather than four.

NYCDOT worked with the community, stake holders, specialists, and city departments to make the design and implementation process more pleasant for residents, business owners, and customers. To act faster, the project used the operating revenues under the supervision of NYCDOT. [82]

[82] "9th Avenue on-Street Protected Bike Path, New York, Ny," National Association of City Transportation Officials, accessed November 19, 2017, https://nacto.org/case-study/ninth-avenue-complete-street-new-york-city/.

Most of the creative design solutions are at the intersections, and the table below is a summary of how NYCDOT sought to resolve these conflicts making the corridor more comfortable to cycle through.

The Level of Traffic Stress (LTS) for this street is a two on a scale of four.

Low-stress:

-parking set back before intersection

-low buffer approaching intersection

-wide bike lanes

-frequent bike lane markings

-bike signals at intersection

-dedicated loading zones where street parking sits, so buffers block the bike lane from the large vehicles

-“no car” signage at openings of bike lanes

-minimal driveways/curb cuts

High-stress:

-no bright colored paint

-heavy intersection crossings

Table 14. Conflicts and Solutions for Manhattan, New York's 9th Avenue Corridor.

Conflict	**Resolution**
Blocked Visibility from Street Parking	-parking set back at intersections with raised curb and low planter 
Intersection Crossing/Turning Conflicts	-cars have dedicated turning lane and signal -cyclists have dedicated signal and are told not to ride when the motor vehicle's turning signal is green 

Table 14. (Continued) Conflicts and Solutions for Manhattan, New York's 9th Avenue Corridor.

Conflict	**Resolution**
Intersection Crossing/Turning Conflicts (Continued)	-pylons are placed at the intersections as more transparent physical barrier so cyclist remain comfortable yet visible to drivers -turn bays adjacent to cycle lane 
Pedestrian Crossing	-shorter crossings with raise concrete islands and low-planters for rest areas 

Table 14. (Continued) Conflicts and Solutions for Manhattan, New York's 9th Avenue Corridor.

Conflict	Resolution
Signs	-A "Bike Path, Do Not Enter" sign posted for motor vehicles at entrance of bicycle lane 
Markings	-arrow pavement marking at intersection crossings -pavement markings along bike path showing directional arrows and cyclist symbols 
Loading zones	- dedicated loading areas around businesses using multi-space parking meters

Source: https://nacto.org/case-study/ninth-avenue-complete-street-new-york-city/

Figure 36: Plan with Pavement Markings, Design of the Track and Turn Bay, and Intersection Re-Design.
Source: http://www.nyc.gov/html/dot/downloads/pdf/rr_ite_08_9thave.PDF.

Figure 37: Timing of the Traffic Signals, Drivers, and Cyclists.
Source: http://www.nyc.gov/html/dot/downloads/pdf/rr_ite_08_9thave.PDF.

Chapter 5. Two Way Protected Bicycle Lanes

5.1 About Two-Way Protected Bicycle Lanes

Two-way protected bicycle lanes integrate physical boundaries to keep automobiles from drifting into the dedicated bicycle zone. Having bi-directional bicycle lane allow cyclists to pass each other.[83]

These lanes should start being used in streets with a speed limit greater than 25mph and traffic volumes above 6,000 vehicles per day. [84] This facility is one of the safer bike facilities, aside from the one-way protected bicycle lanes.[85]

For additional protection, coloring lanes can increase visibility and remind cyclists and pedestrians of potential conflict zones. The paint is also used to dissuade drivers from unlawfully parking in the bicycle lanes.[86]

If space and conditions permits, the two-way protected bicycle lanes can be raised to provide vertical separation between drivers and cyclists. The height of the raised bike lane can range from street level to sidewalk level.

A street-level lane can be separated from motor traffic by raised medians, on-street parking, or bollards. A one-foot mountable curb can create separation from the motor vehicle lane, and a three-foot parking buffer can separate the lane from or

[83] "Two-Way Cycle Tracks," National Association of City Transportation Officials, last modified 2017, https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/two-way-cycle-tracks/.
[84] "NACTO's New Guide Spells Out Which Bike Lanes Should Get Protection," People for Bikes, last modified October 31, 2017, http://peopleforbikes.org/blog/sneak-peak-nactos-new-guide-advises-when-to-protect-bike-lanes/.
[85] NACTO, "Two-Way Cycle Tracks."
[86] Bikeplan.org, "Bikeway Design Guide."

parked cars. To separate cyclists from the pedestrians, pavement color/texture can be used to highlight different zones.

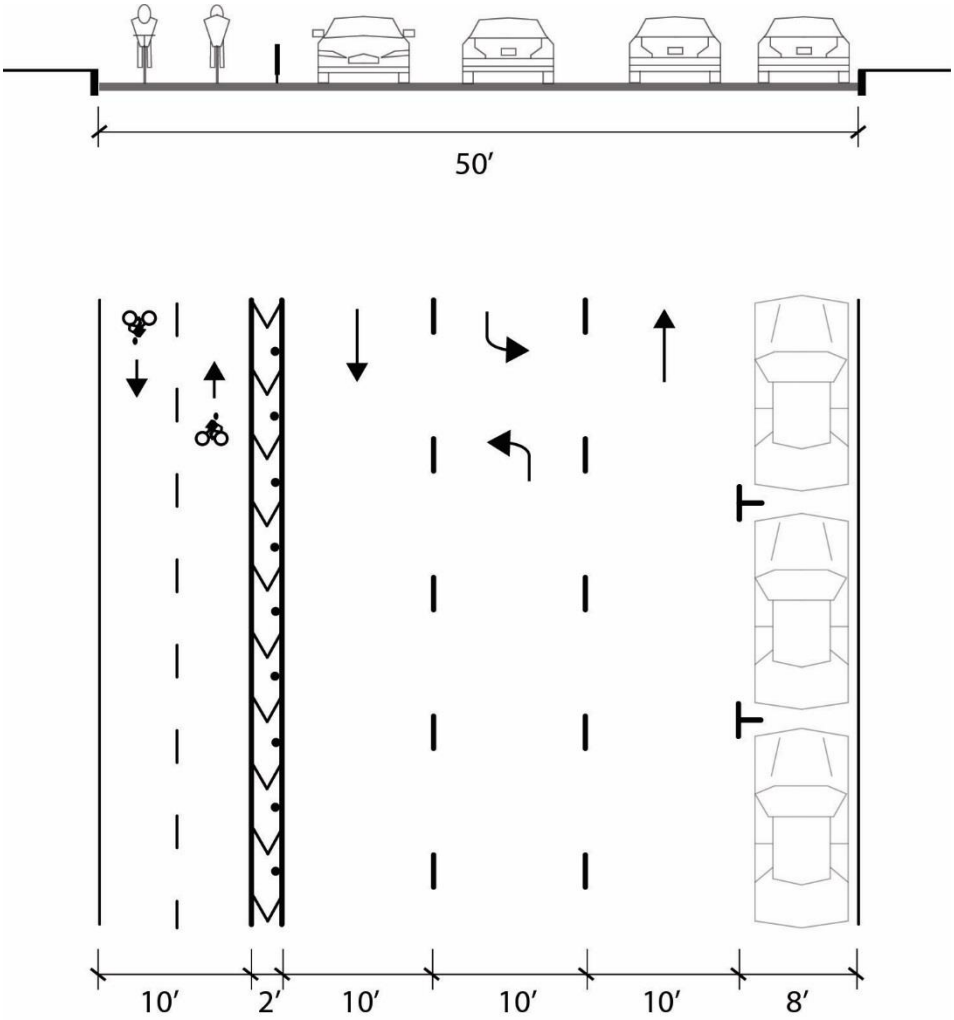


Figure 38: Two-Way Bicycle Lane
Graphic by: Author

5.1.1 Guidelines

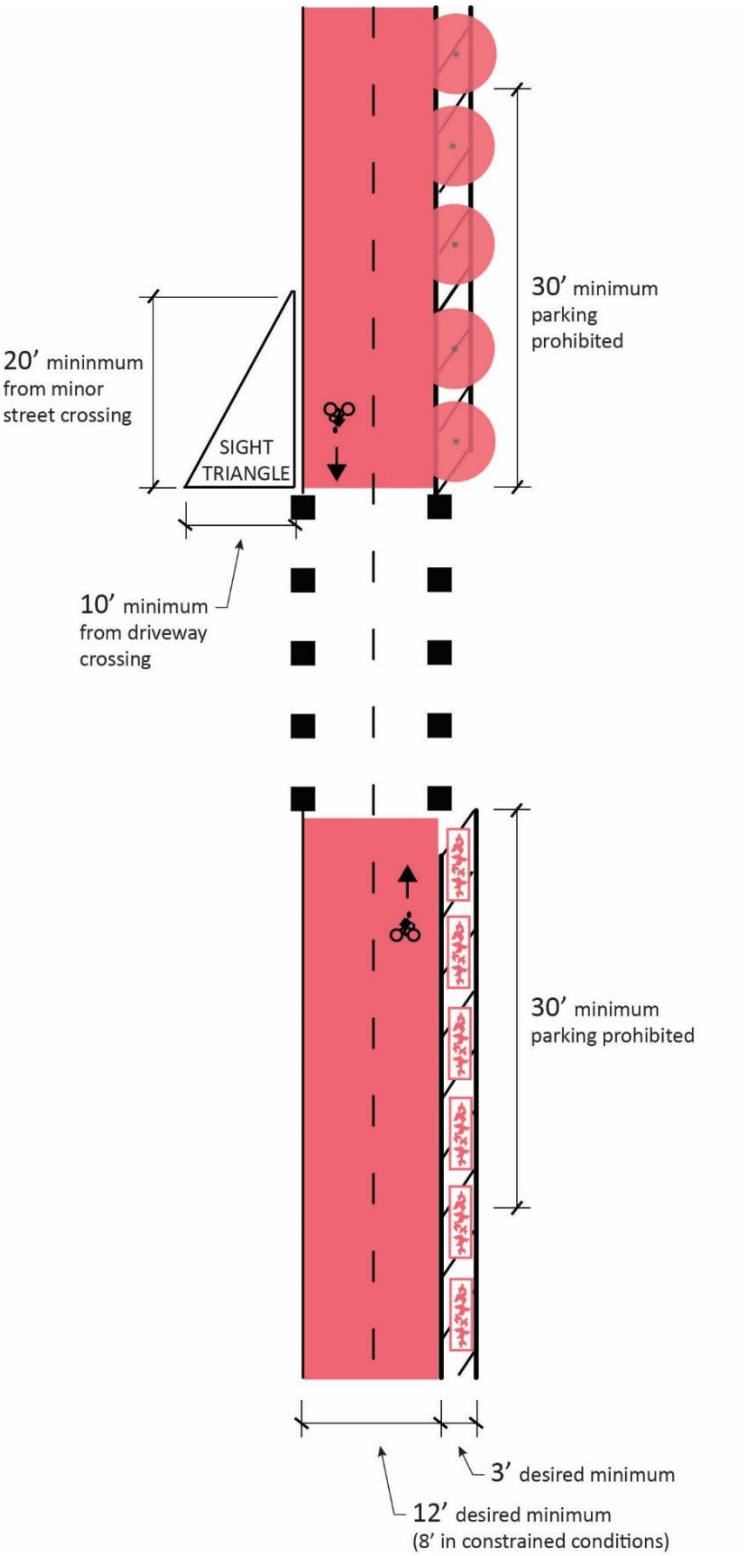


Figure 39: Design Guidelines for Two-Way Protected Bicycle Lanes
Source: https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/two-way-cycle-tracks/

Table 15. Required Features for Two-Way Cycle Tracks.

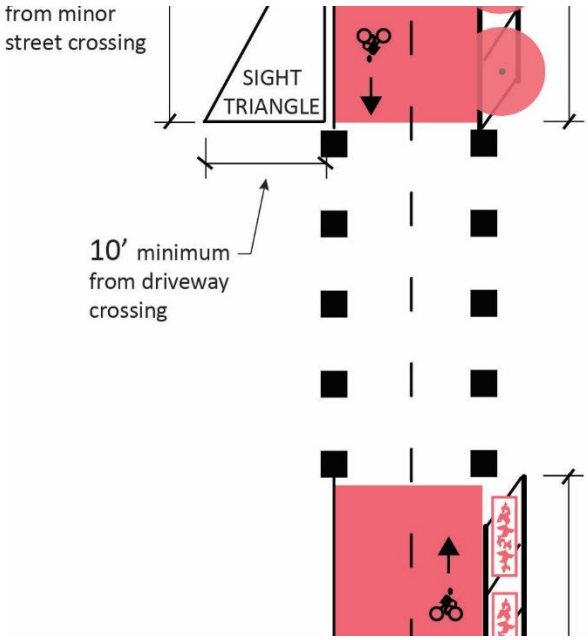
Guideline	Description
Markings  	-word, symbol, and arrow at beginning and throughout cycle track
Signs/Signals	-for a two-way cycle track on a one-way street, there should be an "except bikes" sign telling cyclists and drivers that bike flow goes both directions -"Do not enter sign" in cycle track telling drivers that they are not permitted to enter track with motor vehicle -for contra flow cyclists, there should be stop signs or traffic signals at intersections

Table 16. Best Practices for Two-Way Cycle Tracks.

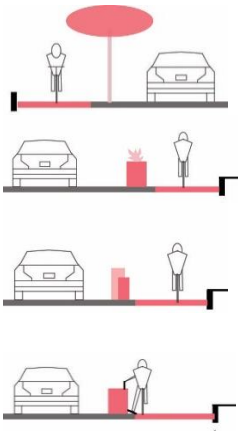
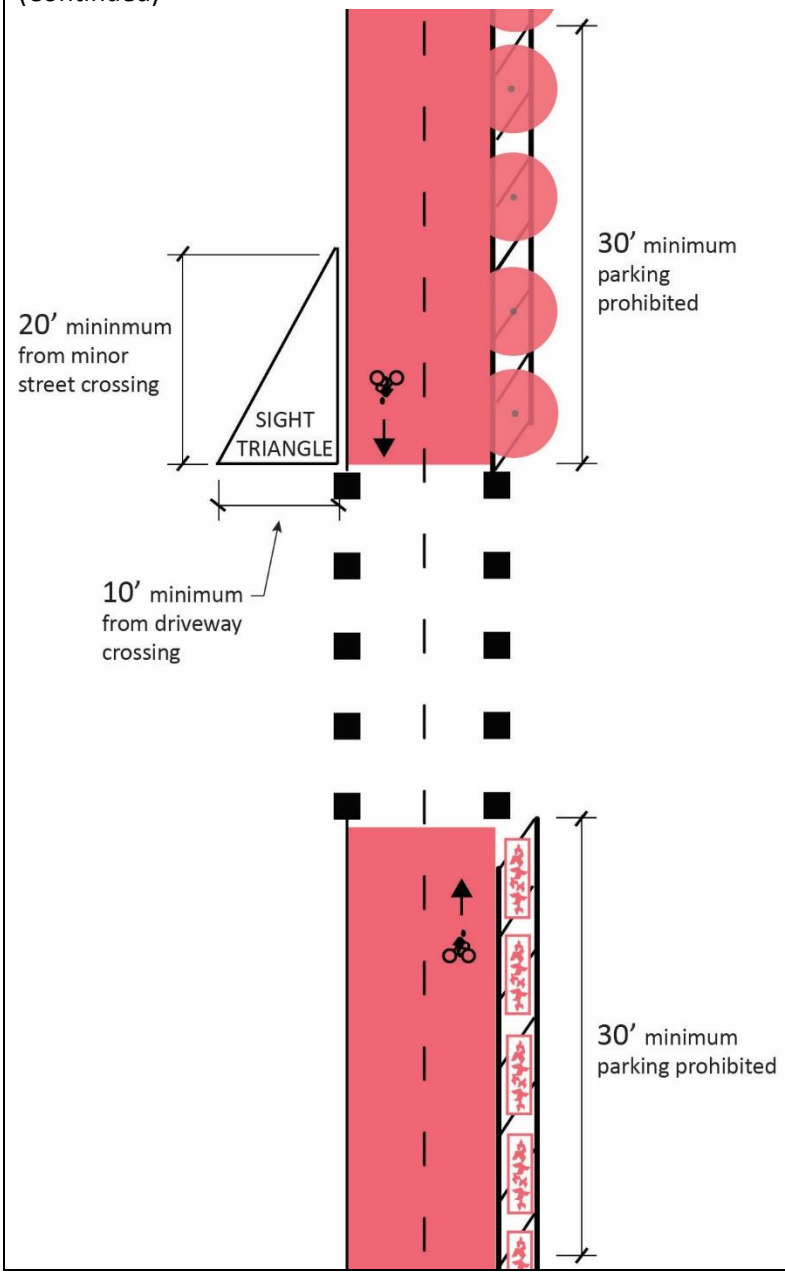
Guideline	Description
Two-Way Cycle Protected Bicycle Lane Width	-12 feet, minimum 8 feet
Parking Lane Buffer	-3 feet buffer between parking lane to minimize door opening conflicts -allow for creative: shading, bike lane, and street protection
Traffic Lane Buffer 	-3 feet buffer with physical protection -**pink** highlighted area allows for creative street protection
Cycle Lane Separation	- dotted yellow like to separate two-way bicycle traffic and visually separates cycle track from pedestrian area
Driveway/Minor Street Crossings	-street parking 30 feet from intersection to improve visibility -sight triangle of 20 feet from minor street crossing to the cycle track

Table 16. (Continued) Best Practices for Two-Way Cycle Tracks.

Guideline	Description
Driveway/Minor Street Crossings (Continued) 	Sight triangle of 10 feet from driveway to the cycle track -add color to conflict zone, which is the area the motor vehicle would cross into cycle track communicating that cyclist has priority -channel and constrain turning area to create sharp turns into conflict zone to decrease speed before crossing -if track is designed to be raised, keep the track elevated at crossing to act as a speed bump to slow cars -**pink** highlighted area allows for creative: bike lane treatment, lighting treatment, and street protection

Source: https://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/raised-cycle-tracks/.

Context

A two-way protected bicycle lane is beneficial for a high-stress street in the urban core, depending on the immediate context of the particular street. This application could be used on:

-streets with high traffic volume

-streets with high bicycle volume

-streets with minimal intersections and driveways

-streets with high parking turnover

-high-stress streets with bike-share and want to increase ridership of various levels of cyclists

-one-way streets would allow travel in the opposite direction thus reducing the risk of out-of-direction travel, potentially reducing the length of their trip, and lessening the number of conflicts between cyclists and drivers if the cyclists had to travel to an adjacent street to get to their destination.

-on one side of a 2-way street-typically placed when there is not enough space for one-way tracks on either side of the street.

-streets with parked cars with the parked car acting as a buffer between the motorists and cyclists.[87]

[87] Ibid.

5.1.1.1 Case Study 1: Successful (LTS 2)

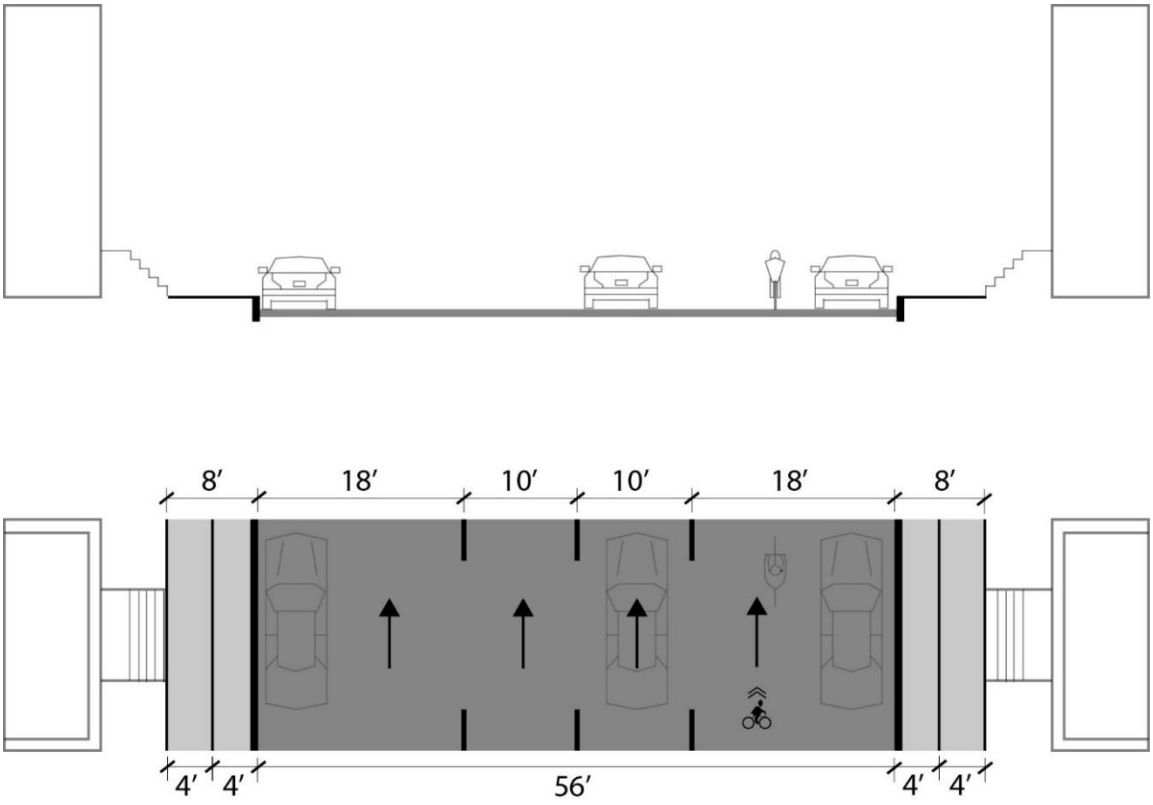
Figure 40: 15th St, Washington, D.C. Two-Way Protected Bike Lane.
Source: https://nacto.org/case-study/two-way-cycle-track-15th-street-washington-d-c/.

Fifteenth Street is a 2.1-mile two-way cycle track between Pennsylvania Ave. and V St., Washington D.C. Fifteenth Street is a three-lane one-way street with street parking on both sides of the street. The total cost for this project was around $250,000.

Originally, this street was a four-lane, one-way street with a shared bicycle lane, and street parking on both sides (Figure 41). To improve comfortability for cyclists, a contra-flow cycle track was later installed. Even after the contra flow lane was installed, cyclists would often be seen riding in the wrong direction, so the one-way street was finally retrofitted to accommodate a two-way cycle track (Figure 42).

The implementation of the track increased the amount of cyclists on the street by 40%. Cycling in a safer environment and against traffic flow helped to decrease sidewalk riding by 12%, and 14% are of current cyclists are riding against the flow of

traffic, proving the need. It turns out that there is decreased street traffic with around 39 fewer motorists on-street during peak hours per day. [88]



BEFORE

Figure 41: Before Implementation of Two-Way Cycle Track on 15th Street, Washington D.C.
Source:
Data by: NACTO.org.
Graphic by: Author.

[88] NACTO, "Two-Way Cycle Tracks."

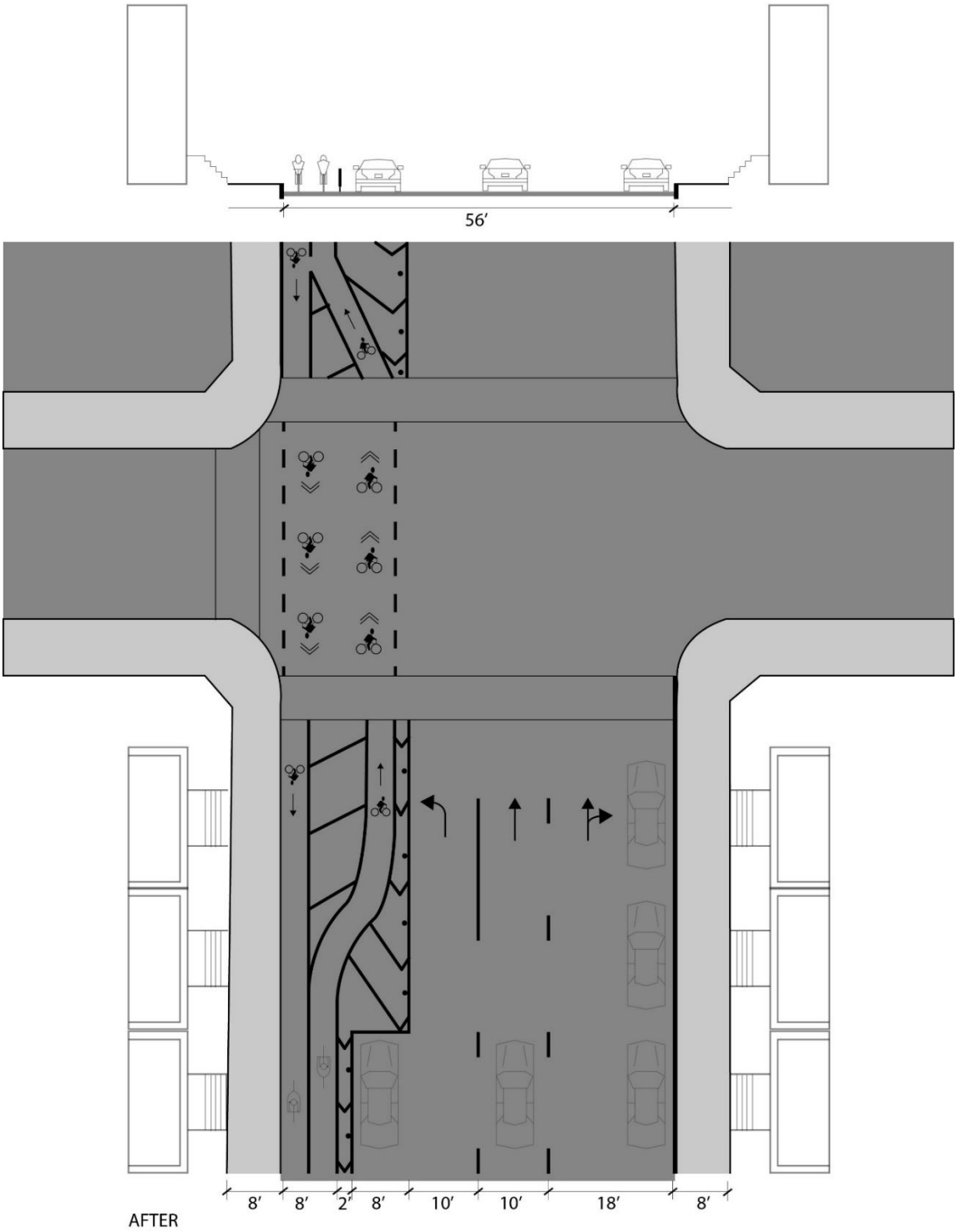


Figure 42: After Implementation of Two-Way Cycle Track on 15th Street, Washington D.C.
Source:
Data by: nacto.org.
Graphic by: Author.

The Level of Traffic Stress (LTS) for this street is a two on a scale of four.

Low-stress:

-protected left turn lane, chicane is used to increase cyclist visibility at intersection

-buffer between parked car and bike lane

-signage reminding drivers of pedestrians' and cyclists' presence

-traffic signals at intersections

-separate bike and pedestrian crossing paths at intersection

-lane narrowing to reduce motor vehicle speeds

High-stress:

-minimal/no physical protection at approach to intersection or along bike lane, parked cars encroaching onto buffer

-heavy intersections

-frequent driveways

-no colored markings

-bike lane is in need of maintenance, piles of leaves cause cyclist to encroach in oncoming bicycle lane

Table 16. Conflict Resolution for 15th Street Retrofit.

Conflict	**Resolution**
"Dooring": On a high-stress street that allows for parking, "dooring" is a big concern. "Dooring" is when a cyclist runs into a parked car's open door.[89]	-Placed protected bicycle lane between parked car and sidewalk -Adequate buffer space for door openings -Physical barriers delineating obvious boundaries
Intersections: A major conflict that can arise when tucking cyclists away from the streets with parked cars is that drivers may not see incoming cyclists at intersections. [90]	-Created a "chicane" boundary using pylons that prevents street parking up to 50ft. back from intersection to make cyclists visible to motorists approaching the intersection -Dedicated left-turn lanes and traffic signals at the intersection to lessen distractions from all street users. -Signs advise cyclists to use the pedestrian crosswalk signals. [91] -Separate bicyclists and pedestrian crosswalks.[92]
Traffic Speeds: Planners and engineers use the idea of "traffic calming" which involves creating narrow or winding roads makes vehicles go slower.[93]	-Using pylons to create Chicanes offer a physical boundary to encourage drivers to stay in their lane and slow their speed.[94] -Traffic lanes are set to a minimum of 10 feet wide - The visual presence of the pylons, colored paint markings remind motorists there are others to be aware of nearby.[95]

Source: Mike Goodno, "Cycle Tracks and Green Lanes in Washington, DC Overview and Research Results Regional Bicycle and Pedestrian Subcommittee Item #5" (District Department of Transportation, 2013), 11-13.

[89] "Dooring Self Defense for Cyclists," Dutch Reach Project, accessed November 19, 2017, https://www.dutchreach.org/dooring-defense-for-cyclists2-2-2-2-2/.
[90] NACTO, "Two-Way Cycle Tracks."
[91] Mike Goodno, "Cycle Tracks and Green Lanes in Washington, DC Overview and Research Results Regional Bicycle and Pedestrian Subcommittee Item #5" (District Department of Transportation, 2013), 11-13
[92] Goodno, "Cycle Tracks and Green Lanes in Washington, D.C.," 15.
[93] "Traffic Calming 101," Project for Public Spaces, last modified January 1, 2009, https://www.pps.org/reference/livememtraffic/.
[94] Goodno, "Cycle Tracks and Green Lanes in Washington, D.C.," 11-13.
[95] Ibid.

5.1.1.2 Case Study 2: Unsuccessful (LTS 3)

Figure 43: Shintora Dori, Tokyo, Japan's Two-Way Protected Bike Lane.
Source: http://www.tokyobybike.com/2014/09/tokyo-bicycle-lane-designs.html.

The two-way protected bike lane of Shintora Dori in Tokyo, Japan was a project implemented by Tokyo Metropolitan Government. Tokyo has bike lanes popping up all over. Their support of bicycle is positive, but the designs of the infrastructure are much to be desired. Their strategy is to take advantage of redevelopment projects to widen sidewalks and implement sidewalk-level bicycle lanes.

The major issue with this bi-directionally facility is that it is narrow, heavily frequented by pedestrians, and does not have safe intersection and driveway treatments. [96]

The Level of Traffic Stress (LTS) for this street is a four on a scale of four.

Low-stress:

-bright colored physical barrier stands out visually

-lack of barriers at intersections makes cyclists visible to drivers

High-stress:

-infrequent lane markings, causing pedestrians to walk in lanes

-narrow lanes

-no markings at driveway or intersection approach

-no signage

-no colorful paint

-heavy intersections

[96] Byron Kidd, "The Varied Designs of Tokyo's Bicycle Lanes," Tokyo by Bike, last modified September 6, 2014, http://www.tokyobybike.com/2014/09/tokyo-bicycle-lane-designs.html.

Table 17. Conflict Resolution for Shintora Dori.

Conflict	**Suggested Resolution**
Narrow Bike Lanes 	-widen lane to 12 feet, minimum 8 feet
Pedestrian Traffic 	-colored paint to create visual separation and delineation -bike symbol and arrows intermittently spaced throughout the lane -"Bike Only" signage and clearer bike lane markings
Disappearing Lanes Approaching Intersection 	-lanes that continuously run through the intersection -Read NACTO's guidelines on intersection treatments -pedestrians mix at intersection crossings -no intersection treatments for safe crossing -no markings at driveways to communicate cyclist presence

Source: http://www.tokyobybike.com/2014/09/tokyo-bicycle-lane-designs.html.

5.1.1.3 Case Study 3: Best success (LTS 2)

Figure 44: Broadway Street, Two-Way Protected Bike Lane at Intersection Crossing.
Source: http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/.

Broadway Street, bordering downtown Seattle has one of the more evolved two-way cycle track bike facility in The US. This facility was a part of the First Hill Street Car Expansion which included a bike facility in its 138 million dollar budget. This neighborhood has many civic buildings as well as high-density housing complex with residents of varying income levels.

There is also a street car system integrated into the transportation infrastructure and working together with an underground rail station started in 2016, buses, cars, and cyclists forming a cohesive union. Before the implementation of the cycle track, these commercial roads were not options for cyclists with the number of driveways, large vehicles, and heavy vehicle traffic.[97]

[97] Michael Andersen, "7 Lessons From Seattle's Spectacular Protected Bike Lanes On Broadway," People For Bikes, last modified August 19, 2014, http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/.

Broadway Street is a two-way street with a two-way protected bicycle lane. Usually the two-way protected bike lane is not popular in areas where there are many turning conflicts, but this study shows that if done right, this facility can be safe and effective.[98]

The Level of Traffic Stress (LTS) for this street is a two on a scale of four.

Low-stress:

-bright green paint and bike markings at intersection crossings

-physical protection, pylons

-turn boxes

-bike signals at every intersection

-street parking set back at intersections

-creative, colorful, and eye-catching physical barriers

-raised bike lanes at street car stops

-chicanes at bus stops

High-stress:

-heavy intersections

-frequent driveways

-street parking

-hills

-street car and bus stops

[98] Anderson, "7 Lessons."

Table 18. Conflict Resolution for Broadway Street Retrofit.

Conflict	Resolution
Intersection crossings  Source: http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/ 	-green marking at intersection crossings where cyclists and motorists potentially cross paths -dedicated bike signal at every intersection that gives cyclists a three-second head start on cars after a red light -underground detection loops at bike signals that detect cyclists' presence. -"no right turn" signals at the intersections -two-stage left turn boxes -traffic signs for drivers to yield to cyclists [99] - yellow pylons at bike lane opening at intersections to keep motorists from driving into cycle track thinking it is an automobile lane -parking setback at intersection -curb cuts at intersection to avoid cutting into cycle lane when turning

[99] "Seattle Broadway Cycle Track," Alta Planning + Design, accessed November 19, 2017, https://altaplanning.com/projects/seattle-broadway-first-hill-streetcar/.

Table, 19. (Continued) Conflict Resolution for Broadway Street Retrofit.

Conflict	Resolution
Driveway crossings  Source: http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/	-green marking at driveway crossing -extended curb cut fronting gas station -raised curb buffers between driveway to stop drivers from drifting into the track -prohibit parking approaching driveway

Table 19. (Continued) Conflict Resolution for Broadway Street Retrofit.

Conflict	Resolution
Street car stops  Source: http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/	-raised track at street car stops -bike lanes extend between transit stop and sidewalk -raised cycle track at transit stops to communicate to cyclists that they are sharing space with pedestrians and that yielding to them if necessary -the green delineates conflict zone and the cyclists' boundary
Protection techniques for minimal buffer space 	-Colorful and eye-catching separation barriers -heavy separation barriers -raised curbs -pylons

Table 19. (Continued) Conflict Resolution for Broadway Street Retrofit.

Conflict	Resolution
Protection techniques for minimal buffer space (Continued)  Source: http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/	
Ignoring cycle precautions  Source: http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/  Source: https://altaplanning.com/projects/seattle-broadway-first-hill-streetcar/	-Enforcement is necessary due to the newness of bicycle safety protocol. Safety measures such as signs, colored markings, and intersection signals are sometimes either not taken seriously or are unintentionally ignored by drivers. -drivers and law enforcement officials should understand and respect bicycle markings as they would traffic markings.[100]

Data Source: https://altaplanning.com/projects/seattle-broadway-first-hill-streetcar/ and http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/.

[100] Anderson, "7 Lessons."

Chapter 6. Enhancing Comfort and Pleasure

6.1 About Enhancing Comfort and Pleasure

Choosing the best bicycle facility type for a street is essential in creating a solid foundation that results in a pleasant riding experience. After choosing the right facility design, it is important to design an inviting environment that is low-stress, comfortable and pleasurable. This type of environment will be not only safe for the "Interested but Concerned," but also be enticing.[101]

If these cyclists feel a sense of safety, ease, efficiency, and pleasure, then a low-stress and comfortable cycling environment has been created. People are not having to sit in traffic looking at other cars. They can be out moving and enjoying the outdoor environment.

Fusing nature and art with safety and comfort is key to designing effective bicycle facilities. I have not seen bicycle lanes that have shading or many design features. Most of my inspiration for the design features come from pedestrian paths and some innovative bike lane design.

Why not put as much time and effort into bicycle lanes as designers do with a park or pedestrian walkway? It is important to welcome cycling into the city streets so that this alternative form of transportation can be effective. Bicycling can be good for the city as well as inhabitants' well-being. If designed well, they will come.

[101] Jennifer Dill, "Four Types of Cyclists," published August 10, 2012, 16, http://web.pdx.edu/~jdill/Types_of_Cyclists_PSUWorkingPaper.pdf.

The table (Table 20) below shows a list of the physical and personal factors that contribute to the wariness of the “Interested but Concerned” and how to implement the design solutions. The designs in the guideline (Figure 42) can help to increase the physical and personal sense of comfort and pleasure when riding through a typical high-stress street.

6.1.1 Guidelines

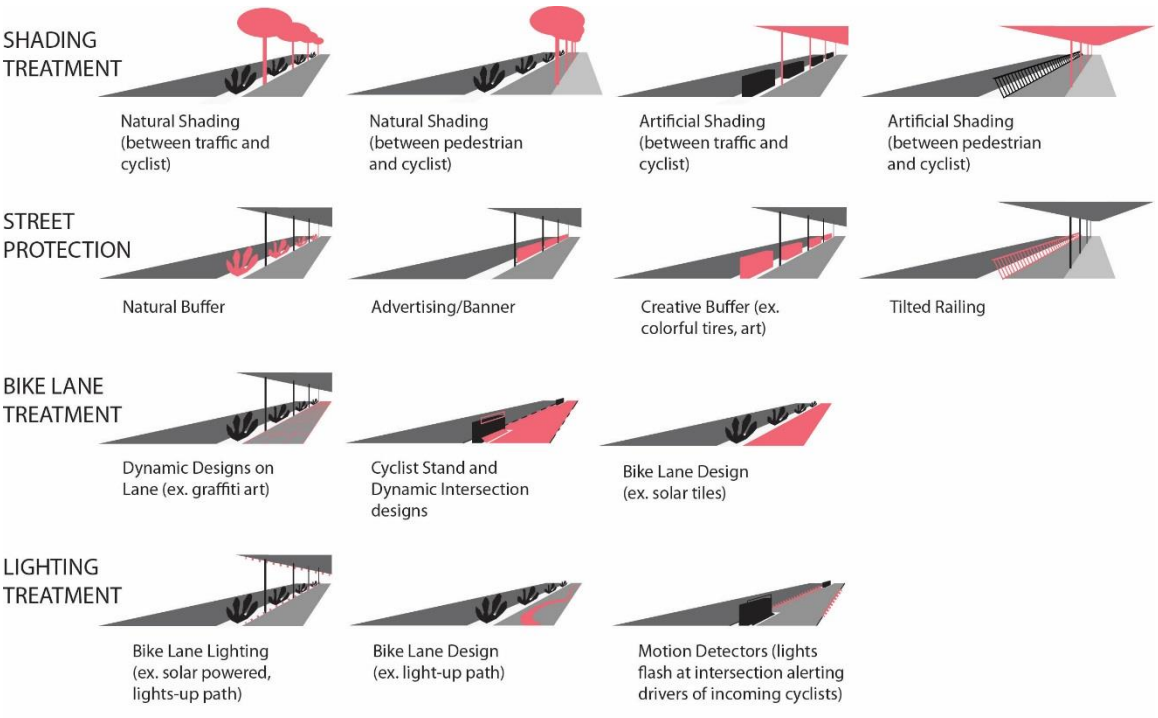


Figure 45: Design Solutions for “Interested but Concerned.”
Graphics by: Author.

Table 19. Design Solutions for the "Interested, but Concerned."

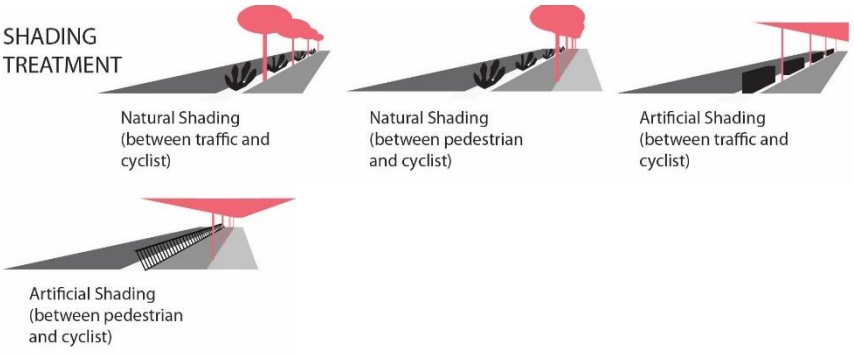
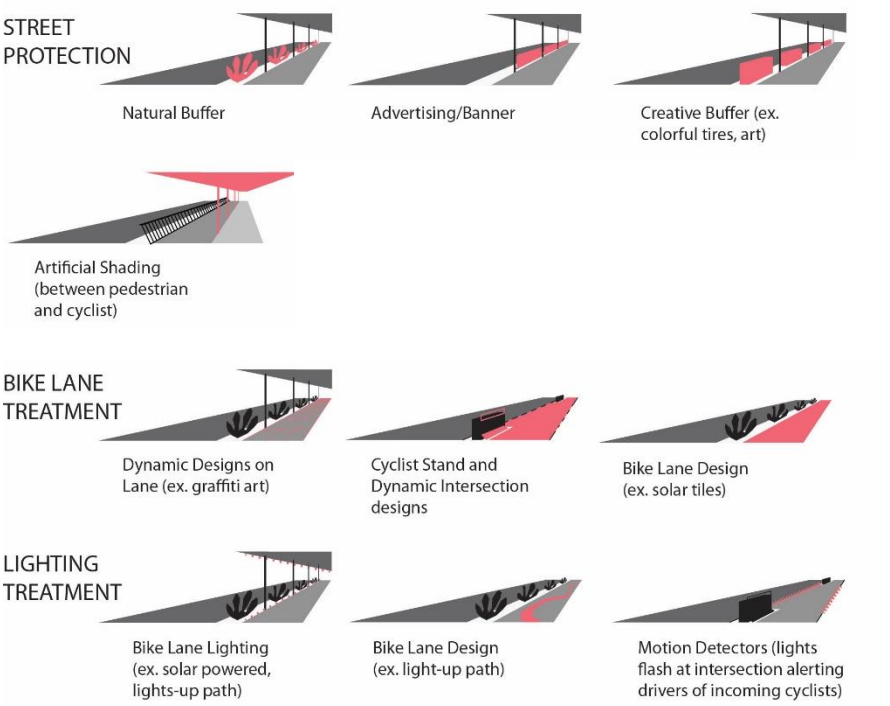
Interested, but Concerned Worries	**Suggested Solutions**
-Prevent falling off their bike	 -max. width bicycle lanes -minimum width lanes have protection from falling into roadway/parked cars/bus stops -sturdy poles or waist-high buffer to protect from alarm and allow visible boundary when a car passes by or opens their door
-Riding in the dark	 -add night-time lighting powered by solar panels -add motion detectors that send a stream of light into intersection, so cars know there in an incoming cyclist crossing the intersection -motion detecting flashing lights at intersection crosswalk communicating incoming cyclist to driver/pedestrians at intersections/heavily used driveways -wider bike lanes and more protection from traffic on winding streets
-Riding in rain -Feeling sweaty	 -shelter from rain -shelter over bike lane to protect from elements -wider bike lanes and more protection from traffic on winding streets -low-intensity streets to reduce sweating, -shelter over bike lane to protect from elements -rest stops with shower and locker

Table 20. (Continued) Design Solutions for the "Interested, but Concerned."

Interested, but Concerned Worries	Suggested Solutions
-Getting hit by a vehicle -Drivers speed in the streets -Traffic makes riding unpleasant	 -physical barriers only as high as bicycle wheels -vertical elements as physical barriers have to have adequate spacing between them to allow for visibility into bike lane by drivers -add motion detectors that send a stream of light into intersection/heavily used driveways so cars know there in an incoming cyclist crossing -bike signals at intersections -"protected intersections" that force drivers far out into intersection before making a turn then crossing the bike lane at 90 degrees -narrow lanes -display advertisements -lower bike lane speed limit to limit alarm from fast passing cyclists -colorful paint that delineates cycle lane from pedestrian or car lane to reduce cyclist alarm and interruption -wider bike lanes and more protection from traffic on winding streets -add vegetation and bright colors to distract from traffic and make riding pleasant

Source: Dill, Jennifer. "Four Types of Cyclists." http://web.pdx.edu/~jdill/Types_of_Cyclists_PSUWorkingPaper.pdf.

6.1.2.1 Precedents

The precedents below offer design inspiration to the treatments in the toolkit above (Figure 45). Communities with unique design features contribute to the idea of place-making.

Place-making involves reinventing public spaces to strengthen the bond between people and their community. This creates a sense of pride and ownership in a shared space making it high-value. This can positively contribute to people's health, happiness, and well-being.[102]

Currently, there are very few bicycle facilities designed with place-enhancing design features. Hopefully, these quick examples can be an inspiration for planners and designers.

If the dedication and creativity is present within the designer, these installations can be simple to create. It would be ideal for bicycling environments to feel as comfortable and beautiful as many pedestrian areas.

[102] "What is Placemaking?," pps.org, accessed February 22, 2017, https://www.pps.org/article/what-is-placemaking.

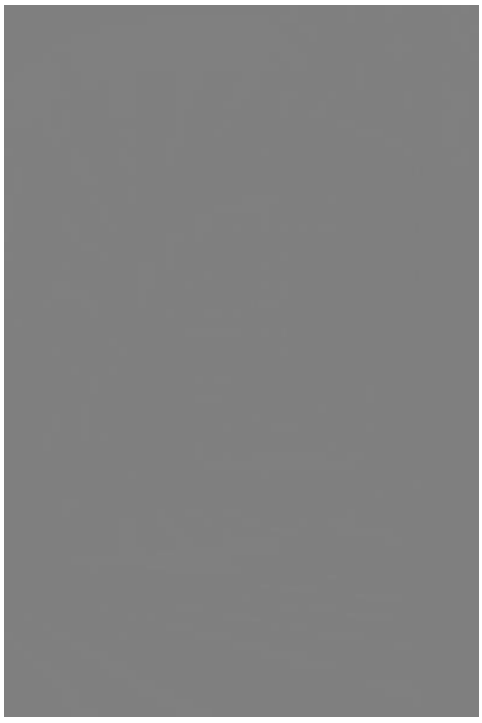
Shading

1.

This type of design treatment is simple and can be a fun project in which the community can engage. Sometimes the simplest things can have the greatest impact.

Figure 46: Floating Umbrellas, Portugal.
Source: http://enpundit.com/hundreds-of-floating-umbrellas-cover-the-streets-of-agueda-portugal/.

2.



Shading can be artificial with a natural feeling. This low-maintenance shade offers a natural and organic aesthetic without the high maintenance of natural vegetation.

The designer could also use solar panels for the solid portions facing the sunlight to generate energy for surrounding businesses or to gain energy credits.

Figure 47: Shading at Arizona Center, Phoenix, Arizona.
Source: https://www.pinterest.com/pin/481885228872318072/

3.

Figure 48: Solar Panel Shelter.
Source: http://www.utraderv.com/UT6798AD_solar-panel-shaded-rv-spaces-for-rent-55.html.

This type of shelter is heavy and industrial but can be an effective tool to gain energy. Electronic technology can be powered by the amount of energy these shade produce. Lighting systems, motion activated sensors or other types of bike-safety technology can be powered using solar energy.

If solar power could cover the cost of electricity, then the business could buy into electrically powered lighting systems or motion-detecting technology to reduce potential liabilities.

The city could also gain energy credits to help the island with its energy needs. New technologies can be tools that help to provide a safe space for cyclists, pedestrians, business owners, and the whole city.

Street Protection

1.

Colorful and creative physical barriers can help to make the riding experience both safe and enjoyable. These features can encourage community participation and promote bicycle lane use.

Figure 49: One-Way Protected Bike Lane, Seattle, Washington.
Source: http://www.capitolhillseattle.com/2015/02/broadway-bikeway-bollard-braces/.

2.

Figure 50: Natural Additions to Protected Bike Lane, Vancouver, Canada.
Source: https://www.cycleto.ca/sites/default/files/AccessibilityBikeLanes.pdf.

Natural Buffers can be a great addition to bicycle lanes. As long as they are low-lying and they can be maintained they make for a pleasant environment. The addition of nature can be good for the environment as well as people's psychological well-being.

They can also provide a sense of calm to drivers to help them to be more mindful of their surroundings. Business owners also have less dust and grit from the road blowing into their storefronts because the plants can act as a filter or buffer from the street's debris.

3.

Figure 51: Recycled Plastic Lane Dividers, Useful if Buffer is Narrow but Necessary.
Source: https://inhabitat.com/armadillo-cool-recycled-plastic-bike-lane-dividers-keep-cyclists-safe-on-roads/.

These small but impactful buffers can be used for bicycle lanes where the buffers are narrow, but physical protection is necessary to keep cars from drifting into the lane. These features are visually noticeable with bright colors and physically noticeable because they are raised enough to be felt by drivers.

Bike Lane Treatment

1.

Figure 52: Solar Panel Bike Path, Netherlands.
Source: https://www.citylab.com/transportation/2014/11/the-netherlands-gets-the-worlds-first-solar-powered-bike-lane/382480/.

Similar to solar powered shading, these solar panels can also help to create energy. The panels can be placed on the riding surface of the bike lane. They can be used in places where shelter is not necessary or provided.

2.

Pavement artwork can be visually stimulating for cyclists and help to emphasize the presence of bicycle facilities to motorists and pedestrians. Different colors and patterns can be used as a way to separate adjacent pedestrian and cycling zones. Bicycle markings will still need to be noticeable to communicate that the lane is designated for bicycle riding.

Figure 53: Pavement Artwork, Boston, Massachusetts.
Source: https://www.bostonglobe.com/business/2017/09/07/boston-gets-artsy-new-public-space-former-man-land/q2AVuEQS3o5riiN878HcEK/story.html.

3.

Pedrails enhance comfort for cyclists waiting at crossings. These rails can help cyclists who are worried about falling off their bicycles or ones who would like to stay on their bikes at the stop.

Figure 54: Ped Rail for Resting at Crossings.
Source: https://www.dero.com/news/protected-bikeway-and-pedestrian-solutions/.

Lighting Treatment

1.

Figure 55: Solar Bike Path, Netherlands.
Source: https://www.atlasobscura.com/places/van-gogh-bicycle-path.

Figure 56: Solar Path, Poland.
Source: http://www.thisiscolossal.com/2016/10/a-mesmerizing-glow-in-the-dark-bike-path-unveiled-in-poland/.

Coated rocks absorb sun energy and allow them to glow in the dark. The illumination allows the path to be lit. This low-cost technique allows for the lane to stand out providing the bike rider with a sense of comfort, safety, and adventure.

2.

Figure 57: LED Illuminated Crossing, Catalonia, Spain.
Source: http://www.lucenews.it/luce-led-smart-anche-la-sicurezza-del-pedone/.

This crosswalk lights up as pedestrians cross. A good idea for intersections and areas where cyclists and automobiles might cross paths.

3.

Figure 58: Umbrella-Style Urban Lighting, New York City.
Source: https://inhabitat.com/urban-umbrellas-to-replace-nyc-sidewalk-sheds/.

Street lighting does not have to be standard street lamp posts. It can be something that not only lights but adds shade. This intervention has a natural and organic feel that makes the city look and feel more inviting.

6.2 About Innovative Design Examples

This last portion of ideas showcases creative infrastructure design that gives thought and respect to the everyday person who is not the most confident on the roads. It is important to not just think about stamping a “safe facility” into a street. It needs to be molded and designed to fit the context.

Urban forms that work well are designed. They are designed for the user. Since the user is surrounded by “other factors,” the “other factors” have to be taken into account as well.

6.2.1 European Inspiration

Looking outside of the US to Europe can help to inspire planners and engineers to take more risks and advocate for bicycle infrastructure that is not only pleasurable and comfortable but also safe and efficient.

In Copenhagen, Denmark their success is proven because over 62% of Copenhageners feel safe to cycle in their city.[103] Copenhagen’s success has come from having clear goals. Their goals highlight the importance of target travel times, sense of security, comfort, lifestyle and image, and experiences. Over 67% of Copenhageners believe that cycling positively affects the city’s atmosphere, supports the transportation infrastructure. They also believe their city provides facilities that are safe when traveling in traffic. The 67% percent is about the same as the as the number of commuters that

[103] Camilla Peterson Weihe, "Copenhagen City of Cyclists - Facts and Figures 2017," Cycling Embassy of Denmark, last modified July 4, 2017, http://www.cycling-embassy.dk/2017/07/04/copenhagen-city-cyclists-facts-figures-2017/.

cycle to work, so it goes to show that a large majority of people who do cycle in the city feel good about doing it. To better serve cyclists in The US it is a good idea to look at what already works for Copenhagen's cyclists. Below is Copenhagen's Bicycle Strategy for 2011-2025.[104]

Table 20. Copenhagen's Bicycle Strategy: 2011-2025.

Improvements	**Goals**
Travel time	-Bicycle superhighways that create routes around the region -Small and large shortcuts to increase connectivity. These include many small shortcuts like contraflow lanes and a few larger shortcuts such as bridges or underpasses -Use Information Technology Services (ITS), such as green waves, or driveway flashing -Route information including signage and GPS -Slowing traffic around places like schools and playgrounds -More partnership between buses, metro, trains, and bicycles. Increase bicycle parking and bike share program -Community outreach about safe cycling and driving -Communication with law enforcement about new laws and practices
Sense of Security	-Green painted bicycle routes-even on wide tracks and especially busy cycle tracks -Intersection re-design -Increase cycle track widths at bottlenecks and in general -Implementation of new cycle tracks and lanes -Design bus/bicycle interaction better

[104] "Good, Better, Best," eltis.org, accessed November 24, 2017, 16, http://www.eltis.org/sites/eltis/files/case-studies/documents/copenhagens_cycling_strategy.pdf.

Table 21. (Continued) Copenhagen's Bicycle Strategy: 2011-2025.	
Improvements	**Goals**
	-Community awareness of appropriate cycling, driving, and enforcement behavior -Safer school routes
Comfort	-Smooth riding surface on the cycle track -Better bicycle parking -Bike services such as air, water fountains, weather reports, 'bicycle buddy' apps -Awareness in workplaces to support cycling -Create incentives for cyclists in the city
Lifestyle and Image	-Marketing the positivity of cycling -Campaign to increase ridership among target groups who may have thought biking was out of their league once upon a time -Create community pride with slogans that make cyclists feel a sense of pride -Online presence for easy information
Experiences	-Designing with weather and unique factors in mind -Increasing communication about best routes and favorite places to bike

Source: Eltis.org. "Good, Better, Best." Accessed November 24, 2017, 16. http://www.eltis.org/sites/eltis/files/case-studies/documents/copenhagens_cycling_strategy.pdf.

The Urban Street has many conflicts that create discomfort for cyclists. Design solutions for the treatments of Intersections, Driveways/Loading Zones, Bus Stops, and Street Parking are found below.

6.2.2 Intersections

Intersections and driveways are major conflict areas for cyclists. They are one of the more tricky problems to solve. Whether the biker is approaching a busy driveway or stoplight, they need to be clearly visible to the driver. One way to mitigate the dangers is to reduce turning conflicts, provided safe connections throughout the bicycle routes,

and design techniques to make cyclists more visible to other street users. Since intersections are so complex, I will show a few examples of intersection designs. There are a variety of ways to accomplish safer intersections.

One example is to make cyclists visible to drivers who are approaching an intersection and may turn across the cycle track. Reducing visual barriers also means that there is less protection between them and automobiles. It does, however, help to make them visible to drivers who may be turning left. The image below is an example of an instance where they limit parking as much as 50 feet back from the intersection so that cyclists can be clearly seen. Adding a left turn only lane as well as a “chicane” slows the driver’s speed.

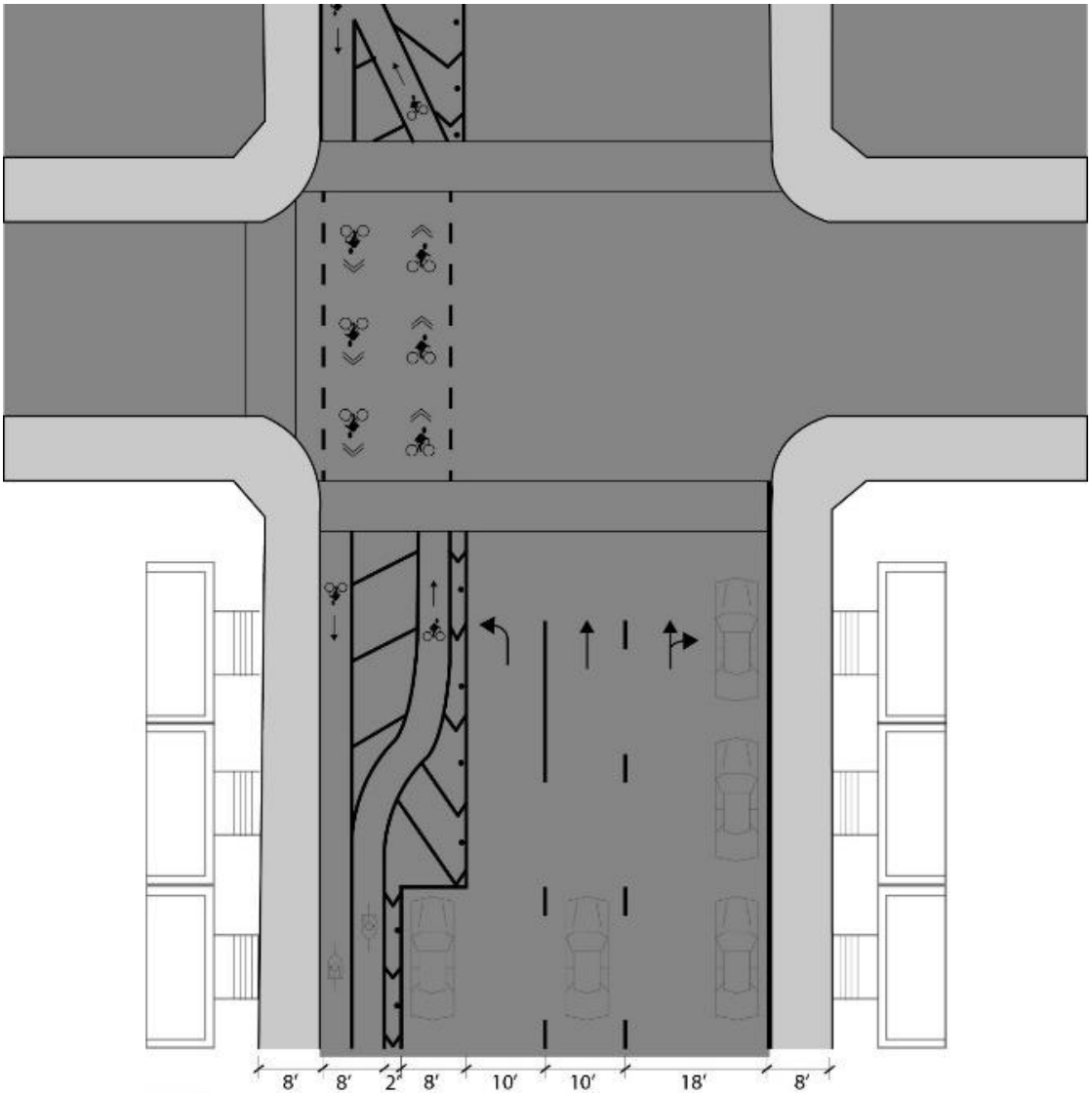


Figure 59:15th Street, Washington D.C. Intersection.
Source: Goodno, Mike. “Cycle Tracks and Green Lanes in Washington DC,” District Department of Transportation. Last modified, March 19, 2013.
file:///C:/Users/Jayna/Downloads/COG%20Cycle%20Track%20Presentation_031913.pdf.
Graphic by: Author.

With this example, the cyclists may feel more vulnerable without the parked cars buffering them from the cars, but they also become more visible to the motor vehicle driver at the intersection. Part of this solution could be solved by raising the buffer to create a curb that drivers cannot encroach.

In other instances, when approaching the intersection, the protected bicycle lane may changeover to a conventional bike lane or a combined bike lane/turn lane to increase visibility. Bike boxes have also been known to give cyclists priority at the intersection. Turning lanes may also have an automobile stop line further back to allow cyclists a head start when turning left at an intersection.

The right turning lane can also be a high-conflict zone. One innovative solution is to have traffic signals. The driver is signaled to stop and let the cyclist cross in front of them to get to their dedicated lane on the opposite side of the right turn only lane. This prevents the cyclist from getting sandwiched between or clipped by the car or the edge of the road. There is one signal for the motorist and one signal for the cyclist.

Figure 60: Atwater Avenue and Saint Antoine, Montreal Street Intersection.
Source: Lukas, Stevens. “From Copenhagen with Love, Dispatches from a Montreal Intersection.” The Blog. Last modified, September 29, 2017. http://www.copenhagenize.com/2017/09/from-copenhagen-with-love-dispatches.html.

Bicycle signal phases can decrease conflicting movements between drivers and cyclists. Adding green painting at street crossings in intersections mark conflict zones, so it makes cyclists and drivers more aware of each other.[105] In the Image below you can see the left turn lane traffic signal is red, and the cyclist’s signal is green, allowing cyclists to move freely through the intersection.

[105] Anderson, “7 Lessons.”

Figure 61: 9th Avenue on-Street Protected Bike Path.
Source: National Association of City Transportation Officials. "9th Avenue on-Street Protected Bike Path, New York, NY." Accessed November 19, 2017. https://nacto.org/case-study/ninth-avenue-complete-street-new-york-city/.

This last design “protected intersections” is one that the Europeans have been using to create safer intersections for cyclists. Protected bike lanes are safe until they have to confront an intersection. The protection disappears, and they cyclist becomes vulnerable to getting hit by vehicles. The protected intersection uses curbs to protect the cyclist and brings the drivers further into the intersection. The curb also causes the driver to make a sharper turn into the bicycle lane so that they have better visibility of the cyclist.

Figure 62: Protected Intersection, Portland, Oregon.
Source: Michael Anderson, “Protected Bike Lanes of East Powel? Monday Meeting Could Sway Plan,” published June 5, 2015, https://bikeportland.org/2015/06/05/protected-bike-lanes-east-powell-meeting-monday-sway-plan-144064.

6.2.3 Driveways/Loading Zones

These minor crossings can be no-big-deal, except when a street sees three within 100 feet—which is something seen in commercial districts around the city. For situations like these, more needs to be done.

Lane markings may suffice for streets that have limited curb cuts, but for these busier streets with frequent curb cuts or loading zones, flashing lights or motion detector may be the next big thing. Pedestrian crossings on busy streets have flashing lights signaling pedestrian crossing. This type of technology could work for cycle lanes as well.

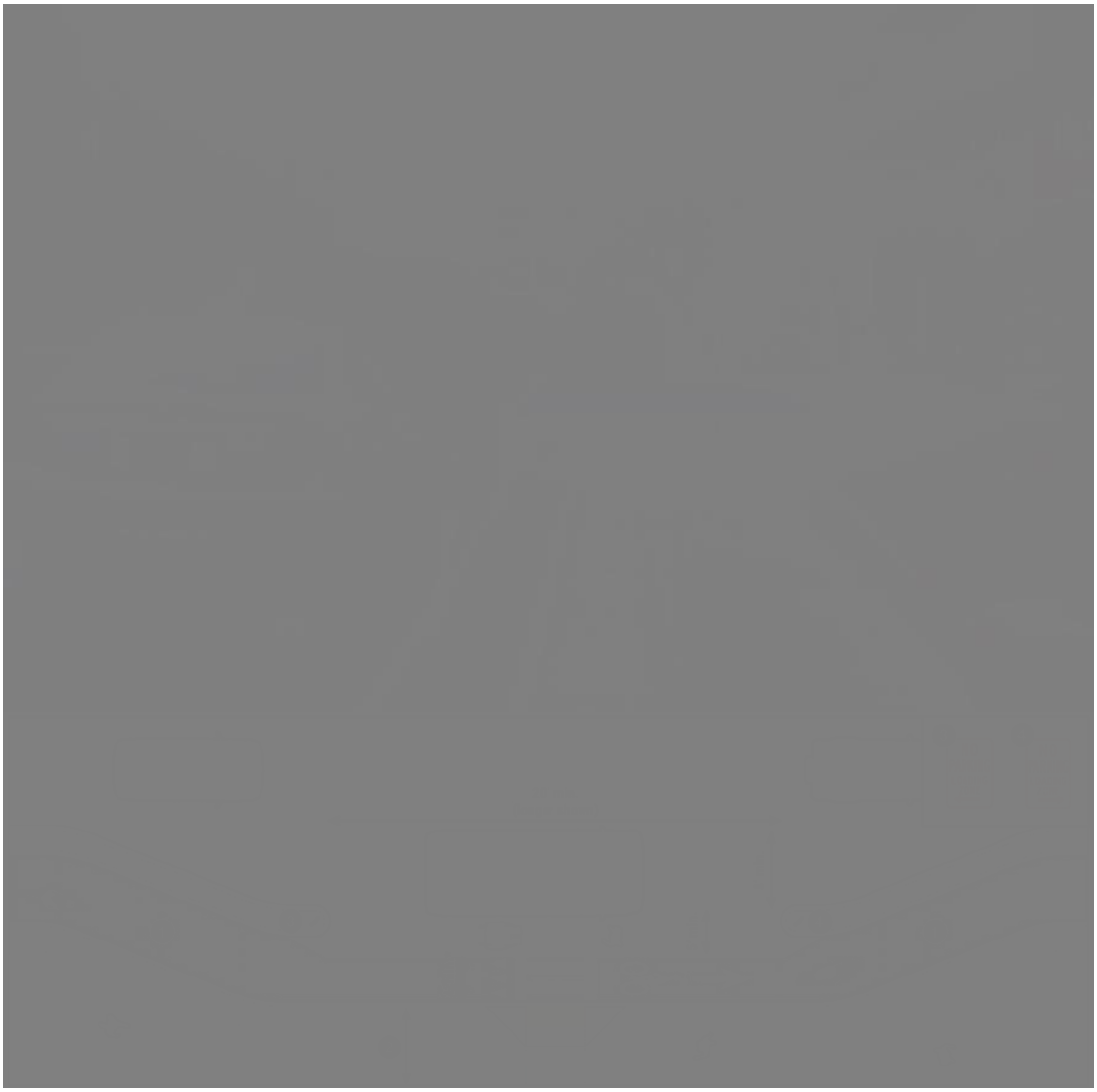


Figure 63: Mid-Block Chicane Design for Loading Zone, Massachusetts.
Source: https://www.cycleto.ca/sites/default/files/AccessibilityBikeLanes.pdf.

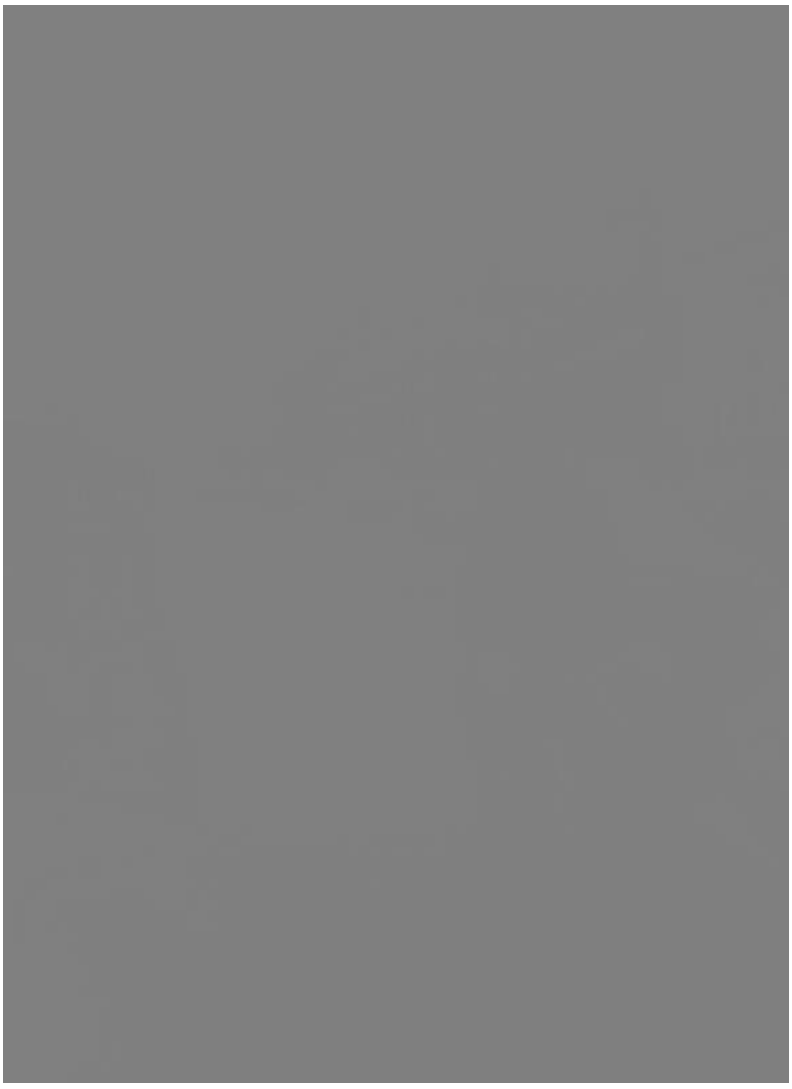


Figure 64: Warning Lights to Signal Approaching Cyclist.
Source: http://www.xwalk.com/images/application-buttons/bike-path-in-road-lights-HR.jpg.

6.2.4 Street Parking

Street-Parking Lanes and high parking-turnover can cause two major problems- vehicles encroaching on the bike lane and "dooring." Dooring is when parked cars open their car doors into the bicycle lane causing cyclists to collide with the door. If the cyclist sees the door, then they may swerve to avoid it, making them encroach into the driving lane. Both of these hazards can be remedied by placing the bicycle lane between the

parked car lane and the sidewalk or creating suitable buffer spaces or wide lanes that anticipate conflicts.

Figure 65: Protected Bike Lane With Wide Buffer To Minimize 'Dooring', Manhattan, New York. Source: http://www.streetfilms.org/a-bike-parking-protected-protected-bike-lane-grows-in-manhattan/.

6.2.5 Bus Stops

Bus stops create a challenge because the bus and the bus riders must cross over the bicycle lane. If the bicycle lane is protected, buses cannot pull over to the curb to pick up riders. This is troublesome for planners who want to place a protected bike lane on a potentially less conflicting side of the street but cannot.

One way to design around this is for the bicycle lane and sidewalk to essentially switch places. In this scenario, the bicycle lane must swerve around the bus stop, and the pedestrian must cross the bicycle lane to get to their bust stop "island." An example is shown below. The bike lane can even become raised to ensure easy access for bus riders and also, so cyclists know that they are sharing space with pedestrians.

Figure 66: Protected Bike Lane at Bus Stop
Source: http://peopleforbikes.org/blog/7-lessons-from-seattles-spectacular-broadway-protected-bike-lanes/.

6.2.6 High Traffic-Speed

High traffic speeds tend to make cyclists uncomfortable because drivers are more likely to not notice cyclists on the roads. Also, injuring in a higher speed crash may be more severe. In the urban street, most roads are 25-35mph. Speeds above 25 mph tend to be riskier because the higher speed is usually coupled with high-traffic volumes. To lower road speeds, planners tend to make car lanes narrower, forcing drivers to use more caution.

6.2.7 High Traffic-Volume

High-Traffic Volumes cause cyclists and cars to feel too close together, and sudden small shifts can startle a nearby cyclist. There is also more of a chance of lane encroachments which cause disturbances and collisions. It is ideal to have protected

bike lanes in these situations because in tighter spaces adequate physical separation is necessary between the motorized vehicles and the cyclists.

6.2.8 One-Way Streets

One-way streets without the option to travel in opposite direction can be stressful for cyclists. They may resort to wrong-direction travel. This can be dangerous to cyclists traveling in the bike lane going the correct direction, causing a head-on collision. Also, riding on the sidewalk is dangerous for pedestrians, many of whom are not expecting cyclists, especially elderly who cannot move as swiftly as most.

Some cyclists will choose to break the law if the action will save them time or if the alternative route means encountering more conflicts. These issues are commonly solved by adding a contra-flow lane or a two-way protected bicycle lane.

All in all, one-way streets with limited bicycle infrastructure run an increased risk of out-of-direction travel. Improving bicycle facilities by creating bike lanes that allow for two-way travel on one-way streets can make it easier to travel. This can potentially reduce the length of trips and lessen the conflicts between cyclists and drivers.

Part 3: Design Project

South Street Design

In this final chapter, I use my guidelines to design an urban street in Hawaii that is low-stress for the "Interested, but Concerned." This design also showcases the steps a designer must go through to analyze a site to determine the most fitting design. The guidelines are important to follow, but since every site is different, there may be modifications and additions required to make the bike lane fit into the site safely and effectively.

Chapter 7. Designing Ideal Facility Types for South Street in Honolulu, Hawaii

7.1 Honolulu's Urban Environment

Honolulu is a city like no other. It is surrounded by and entangled with nature. The mild climate and terrain create an ideal place to live and visit all year round. Over the years, the city has become increasingly dense. Many local people fight to keep the "Hawaii Sense of Place" amid fast-paced modern changes. The natural environment coupled with modern-day luxuries and comforts are what bring tourists to this concrete jungle.

Some of the best places in the city cannot be experienced by quickly passing through with an automobile. The driver of the vehicle passes by too fast and misses too much. When it comes to discovering the city, the streets are best traversed slowly.

Visiting and living in urban areas of Hawaii has its advantages. There is little need for a car because most destinations are within a five-mile radius. Many tourists and locals walk or bike within that five-mile radius.

With the implementation of Biki, Honolulu's bike-share program, many users have been utilizing it. The more people utilizing the Biki bikes, the more cyclists there are on roads that are underequipped to handle cyclists of all ages and skill levels. With the city's traffic and lack of continuous bicycle infrastructure, people either choose not to bike or they ride on the sidewalks endangering pedestrians.

With the Biki stations being seen throughout Honolulu's urban core it is essential that we have the infrastructure to protect the safety of pedestrians, drivers, and cyclists. In addition to the rise of the Biki population, O'ahu is anticipating high-capacity rail transit stations. These rail stations will weave in and around O'ahu's 132 miles of existing bicycle network.[106] The city of Honolulu is predicting and preparing for the increase in the volume of motor vehicles, pedestrians, and cyclists.

It is important to predict and prepare for this especially in areas where the rail stations will operate. It is also vital to create an infrastructure that can provide safe and efficient routes to main areas of the city.

The transportation infrastructure and layout of the streets need to be able to safely accommodate the users. Currently, there is a space for pedestrians on the sidewalk, a space for cars on the street, but cyclists lie somewhere in between with little to no designated zone. With the increased prevalence of cyclists in urban streets, it is important to have bicycle facilities that are appropriate and safe for the majority of riders, especially the "interested but concerned."

7.2 Honolulu's Cycling Environment

Honolulu's increasing urbanization is resulting in narrower and more densely packed streets. This environment is not an ideal place to ride or walk-through for many people. Honolulu has many of the same issues as other US cities. The infrastructure is in need of upgrades due to rising cyclist populations in the urban core's high-stress streets.

[106] "Oahu Bike Plan: A Bicycle Master Plan," honolulu.gov, last modified August 2012, 9, https://www.honolulu.gov/rep/site/dts/bike_docs/Bicycle-OahuBikePlan-8G-August2012.pdf.

With the introduction of Hawaii's first protected bicycle lane in 2012, there has been major progress with bike infrastructure in Honolulu. The City and County is enthusiastic about making Honolulu more bicycle friendly.

The Department of Transportation Services published the Oahu Bike Plan in 2012, which was an update to the 1999 Honolulu Bicycle Master Plan supporting holistic and safer street design. The goal is to put people before cars. With Honolulu's mild weather and dense urban core, designing the city for biking and walking has become the logical consensus.

Implementing an effective bicycle network supports the symbiosis of the city, and enhances the idea of continuous flow through the city with limited conflicts. Safe bicycle facilities are key to producing an effective bicycle network that can be used by a broad range of users.

During the summer of 2017, about 500 bicycles were installed in the Biki bike stations. Currently, the stretch of the city from Chinatown to Diamond Head is not made for bicyclists. Implementing the Biki without existing bicycle infrastructure is increasing the risk of accidents, but hopefully, the popularity will make a case for more bike facilities in a quicker time frame.[107]

7.2.1 Honolulu's Bicycle Facilities

Hawaii's first protected bike lane on King Street will certainly be seeing higher cyclist volumes because of its future connection to the South Street transit station and

[107] Mark Terry, "Be Careful with Biki, Bike Lanes," Honolulu Star Advertiser, published June 30, 2017, https://www.pressreader.com/usa/honolulu-star-advertiser/20170630/281668254993320.

planned connections to McCully Street. South Street will be bringing people toward the University of Hawaii at Manoa from the rail station, and McCully will be bringing people to the University from Waikiki.[108]

As of October 2017, Oahu had around two miles of protected bike lanes counting King St. and South St., 46 miles of bike paths, 59 miles of regular bike lanes, and 40 miles of bike routes (Figure 66).[109]

Figure 67: Honolulu's Bicycle Facility Types.
Source: https://www.hbl.org.

[108] Terry, "Be Careful with Biki, Bike Lanes"
[109] "Bicycle Program," City and County of Honolulu, accessed February 20, 2017, https://www.honolulu.gov/bicycle.

These facilities have been supporting the 360,000 trips that have been taken due to the Biki in its first six months of implementation as well as the regular populations of riders in the urban streets.[110] The city buses and future rail cars that feature bike racks show that the City and County of Honolulu is committed to finding better ways to integrate bicycling into Honolulu's transportation network.

Overall, in Hawaii, there are unique challenges, but progress is taking place. The state's first protected bike lane was implemented in 2014, and many successful facilities have been and are currently being implemented.

7.2.2 Types of Cyclists in Honolulu

A 2003 Hawaii based survey published by the Department of Transportation separated cyclists into three separate categories similar to the studies done by Portland's Roger Geller and Jennifer Dill. They are broken up into three categories, the Advanced Bicyclists, Basic Bicyclists, and Children.

"Advanced Bicyclists." can ride in almost any condition. They are prepared to handle high-traffic volume streets with minimal bicycle facilities. Most of the current bicycle facilities in Hawaii are geared toward the advanced cyclist. These categories are comparable to Geller and Dill's "Strong and Fearless" and the "Enthused and Confident."

The majority of people who ride their bikes in Hawaii fall under the "Basic Bicyclist," comparable to the "Interested but Concerned." This audience would include

[110] "Popularity of Biki bikes is booming — and not just with visitors," hawaiinewsnow.com, last modified January 17, 2018, http://www.hawaiinewsnow.com/story/37290418/popularity-of-biki-bikes-is-booming-and-not-just-with-visitors.

new adults and young riders who are less sure of themselves on roadways with minimal bicycle facilities.

The lowest rider group category is “Children,” which includes pre-teens whose parent’s monitor their roadway use.[111] This category would be similar to the “No Way No How” rider group mentioned in my research.

7.2.3 Benefits of Better Bicycle Planning and Investment in Honolulu

Bicycling in Honolulu has the potential to be a popular choice for tourists and residents. With the mild weather and close-proximity to many attractions and services, there is a demand for this way of living and getting around. It is no more evident than in the city’s bike-share program, which is what has generated 360,000 trips in six months.[112]

The facilities that are currently employed in the high-stress corridors are inviting to only the confident and skilled cyclists. The “Interested but Concerned” are riding on sidewalks or choosing not to ride at all. It is exciting to think that with the right bicycle infrastructure, we could make Honolulu a cycle-friendly city.

As I mentioned in my research, many tourists in Honolulu choose to bike or walk along the streets, allowing for businesses to have more foot traffic. With the use of buses and bike-share programs, the streets would be less dense, riders would be healthier, and the air would be cleaner. Some incentives particular to Honolulu include

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[111] “Hawaii Department of Transportation. Highways: Bike Plan Hawaii Master Plan,” (Kimura International, Inc., 2003), http://hidot.hawaii.gov/highways/bike-plan-hawaii-master-plan/.
[112] “Popularity of Biki bikes is booming — and not just with visitors,” hawaiinewsnow.com, last modified January 17, 2018, http://www.hawaiinewsnow.com/story/37290418/popularity-of-biki-bikes-is-booming-and-not-just-with-visitors.

tourism and alternative transportation. These are two big factors that drive Honolulu's economy and impact the urban way of life.

7.2.3.1 Tourism

Tourism is the main source of income for the state of Hawaii. In 2010 the Hawaii Tourism Authority (HTA) reported that tourism provided over 152,864 jobs statewide earning 11.6 billion dollars from visitor spending and one-billion dollars in tax revenue.[113] For tourists staying in Waikiki or urban Honolulu, improved biking facilities would make getting around to different destinations faster and easier. The ease of getting around would give visitors the opportunity to visit more places, spend more money, and increase urban Honolulu's overall appeal. Ease of mobility is important to creating cities that run efficiently.

[113] "Tourism Helps Provide for Hawaii's Economy," Hawaii Tourism Authority, accessed January 25, 2018, http://www.hawaiitourismauthority.org/news/articles/tourism-helps-provide-for-hawaiie28099s-economy/

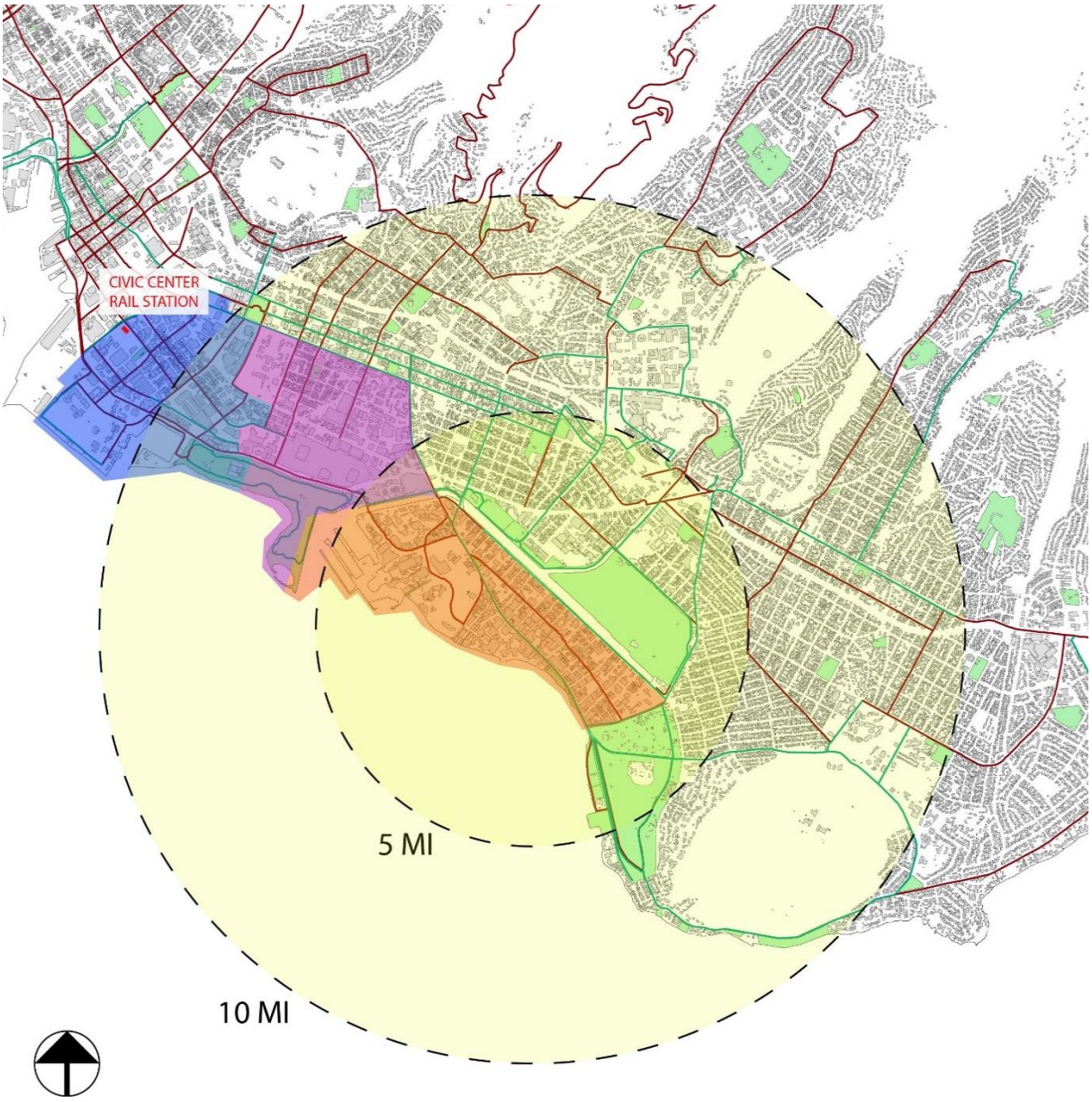

Figure 68: Kaka'ako Context, 5 & 10 Mile Radius Map From Waikiki Through To Kaka'ako Civic Center Rail Station.
Source:
Graphics by: Author.
Information from: ArcGIS, City, and County of Honolulu.

7.2.3.2 Alternative Transportation

The rail stations are predicted to bring a large population of people into one small area of the city. People will then disperse from this area. Honolulu needs to provide comfortable and enticing bike facilities that provide low-stress routes that move people around the city efficiently. This involves thinking about multi-modal transportation which incorporates, the rail, buses, and bikes.

The Biki bike-share program is very popular in Hawaii with two-thirds of its 360,000 riders being Oahu residents. It is turning out to be a realistic form of transportation for both visitors and locals.[114] In Honolulu's urban core some of the Biki bike-share stations are placed in areas where there are minimal to no bicycle lanes. Less-confident bicyclists are forced to ride on the sidewalks.

Currently, places in Honolulu's urban core have bicycle facilities for the confident cyclist, but you will likely not see a father and child riding together in the high-stress streets. With the implementation of the bike-share programs in the urban core, it is in the best interest of the bike-share program and the city to implement bike lanes that can be used by a broad range of people who ride bikes—especially in places where people connect to buses and rail stations.

[114] Hawaiinewsnow.com, "Popularity of Biki bikes is booming — and not just with visitors."

Figure 69: Kapi'olani Blvd. In Honolulu Has Bike Share Station With No Bicycle Lanes In Or Around This High-Stress Urban Street.
Source: Author.

7.3 Introduction to Kaka'ako

Kaka'ako is a district in Honolulu, Hawaii. It is the between Ala Moana and Downtown Honolulu. This area is going to be the location of one of Oahu's rail stations and has seen major development within a short period. The once industrial district is seeing more residential and retail development.

Kaka'ako is managed by the State agency, Hawai'i Community Development Authority (HCDA). The HCDA promotes and organizes public and private community development in Kaka'ako. The streets are managed by the City and County of Honolulu.

The rail station will sit at the corner of South Street and Halekauila Street. I chose South Street in Kaka'ako as my site because, in addition to it being the site of the rail station, it is a typical high traffic-stress street that anticipates an increase in pedestrian, traffic, and bicycle volume when rail begins operation.

The Honolulu Authority for Rapid Transit (HART) manages the stations and aims to create a user-friendly area for rail users. South Street and will be one of the main access ways to and from the rail station.

As noted in my case study, the street is a high-stress multi-lane roadway with street parking and both conventional bicycle lanes and a two-way protected bicycle lane running from mauka to makai (mountain to ocean). This street-condition and street-type are typical of many dense urban cities.

The goal is to analyze the surrounding context and choose a bike facility and design a bicycling environment that will provide low-stress travel. The strategies and conclusions from this analysis and redesign can help other cities with similar streets achieve their goals of having safer bicycle facilities for the "Interested but Concerned."

7.3.1 Bicycle Mobility and Access through Kaka'ako

In 2013, The City and County's Transit Development (TOD) and The Department of Business, Economic Development & Tourism (DBEDT), HART were responsible for coming up with a plan to create context-sensitive street designs for Kaka'ako. The plan

shows that their first priority is pedestrians, second is transit, third is bicycles, and fourth is automobiles. Safe and efficient multi-modal streets are their goal. [115]

In regards to bicycles, the plan emphasizes bicycle connectivity, storage, and direct access to and from transit facilities. Better facilities are desired along the mauka-makai directions and the Ewa-Diamond Head (West to East) directions. Increased cycle volumes are predicted-especially with the rail stop in Kaka'ako. Low-stress bicycling with a focus on better facility design and public education are two things that desired to increase ridership. [116]

The increase in ridership will support the multi-modal transportation system, improving efficiency and sustainable practices in Honolulu. With the potential of increased rider volumes, it is important for pedestrians, drivers, and cyclists to understand the signage, symbols, and other accessories that go along with the street design. These efforts help to support the urban city's symbiotic relationships. [117]

7.4 South Street Site Analysis

South Street is an ideal site to implement my design strategies that make streets lower-stress to attract the "Interested, but Concerned." South St. has a number of conflicts that are common to most urban cities. These include; high traffic-volume, bus stops, loading zones, street parking, large intersections, and frequent driveway openings.

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[115] "TOD Overlay: Draft Plan," dbedt.hawaii.gov, published May, 2014, slide 7-10, https://dbedt.hawaii.gov/hcda/files/2013/05/Transit-Oriented-Development-Presentation.pdf
[116] "TOD Overlay: Draft Plan," dbedt.hawaii.gov
[117] "TOD Overlay: Draft Plan," dbedt.hawaii.gov

I hope that planners, engineers, and designers will be able to solve some of their street conflicts by looking at how these common conflicts are resolved.

7.4.1 South Street Site Analysis

South Street in Kaka'ako is the main makai-mauka corridor that will connect the city to the Civic Center rail transit station. The Transit Oriented Development (TOD) Overlay Plan defines South Street as a Commercial Avenue (Figure 69). This avenue typically contains offices, goods/services and residential.[118]

[118] "TOD Overlay: Draft Plan," dbedt.hawaii.gov, accessed January 17, 2018, slide 6-14, http://dbedt.hawaii.gov/hcda/files/2013/05/kakaako-tod-overlay-draft_6-complete-streets-in-kakaako.pdf

Figure 70: Complete Street Typology for Kaka'ako.
Source: http://dbedt.hawaii.gov/hcda/files/2013/05/kakaako-tod-overlay-draft_6-complete-streets-in-kakaako.pdf.
Graphics by: Author

Originally, a part of South St. was a four-lane one-way street until 2015, when a two-way protected bike lane reduced the street from four-lanes to three-lanes. The in-house staff at the Department of Facility maintenance removed 28 parking stalls and overall the project cost around $80,000.[119]

The makai end of the South St. stretch is four-lanes with two-lanes devoted to each traffic direction. Along with this stretch, there are conventional bicycle lanes going in both directions. Based on my research of "Level of traffic-stress," this street portion would currently be a level two, which is tolerable for the "interested, but concerned." The road layout is one which does not cause a high level of stress to the "interested, but concerned."

South Street approaching the rail station is a three-lane one-way street heading mauka with a two-way protected bicycle lane. Continuing through South St. going mauka, the street turns into a four-lane one-way street with one lane partially dedicated to street parking opposite of the two-way protected bicycle lane.

The lane breaks at the S. King St. and South St. intersection before the King St. bike path begins. The "Level of Traffic Stress" for this portion of the street would be the high end of the spectrum at level 3 or 4, which is more comfortable for the "enthused and confident" and "strong and fearless." Our target group, the "Interested but Concerned" would need protected bicycle lanes on this street to feel a lower level of stress.

[119] "South Street Protected Bike Lane Opens to Bicyclists," khon2.com, published May 3, 2017, http://khon2.com/2017/05/03/south-street-protected-bike-lane-opens-to-bicyclists/.

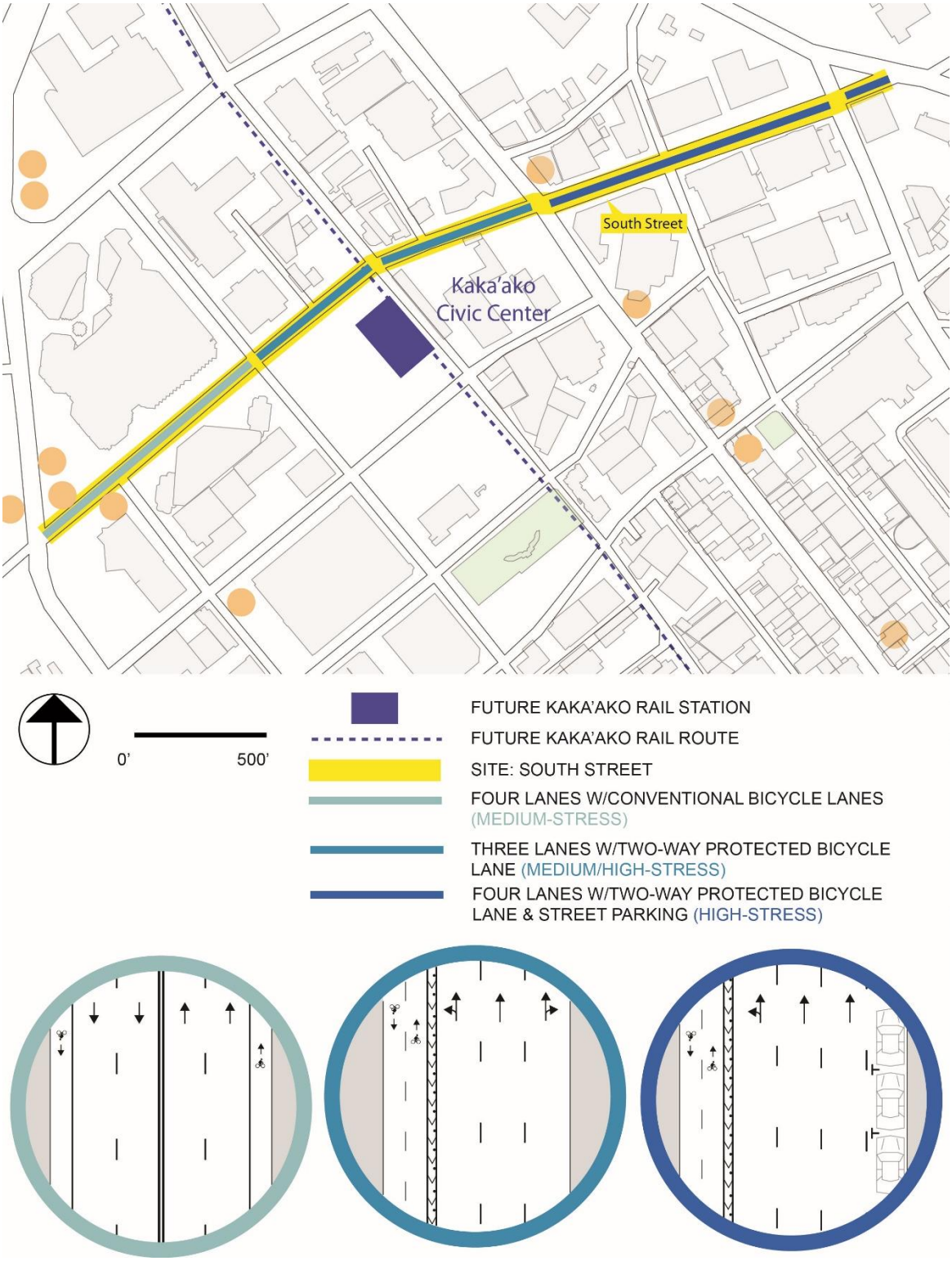


Figure 71: South Street Lane and Stress Map.
Source:
Base Map and Rail Information from: City and County of Honolulu
http://www2.honolulu.gov/honolulumyway/?bike.
Graphics and Conflict Data by: Author.

Currently, the bicycle lanes on this street are adequate, but the connection from the conventional bicycle lanes and the protected lanes could be improved. With South St. being the location of the rail arrivals and departures, the increasing volumes of traffic, pedestrians, and cyclists will require a rethinking of this urban corridor so that bike lanes that can be used by bike users of all ages and skill levels.

7.4.2 Existing Bicycle Routes

Presently, there are no bicycle lanes that feed directly into South Street. In Honolulu, there are only two protected bicycle lanes, South Street and King Street. The two streets feed into each other, but their lanes do not safely lead into each other. The bicycle connectivity in and around Kaka'ako is not strong, but there is a proposal for better bicycle connectivity around the Civic Center Rail station and through Kaka'ako in the future.

7.4.3 Existing and Proposed Bicycle Facilities

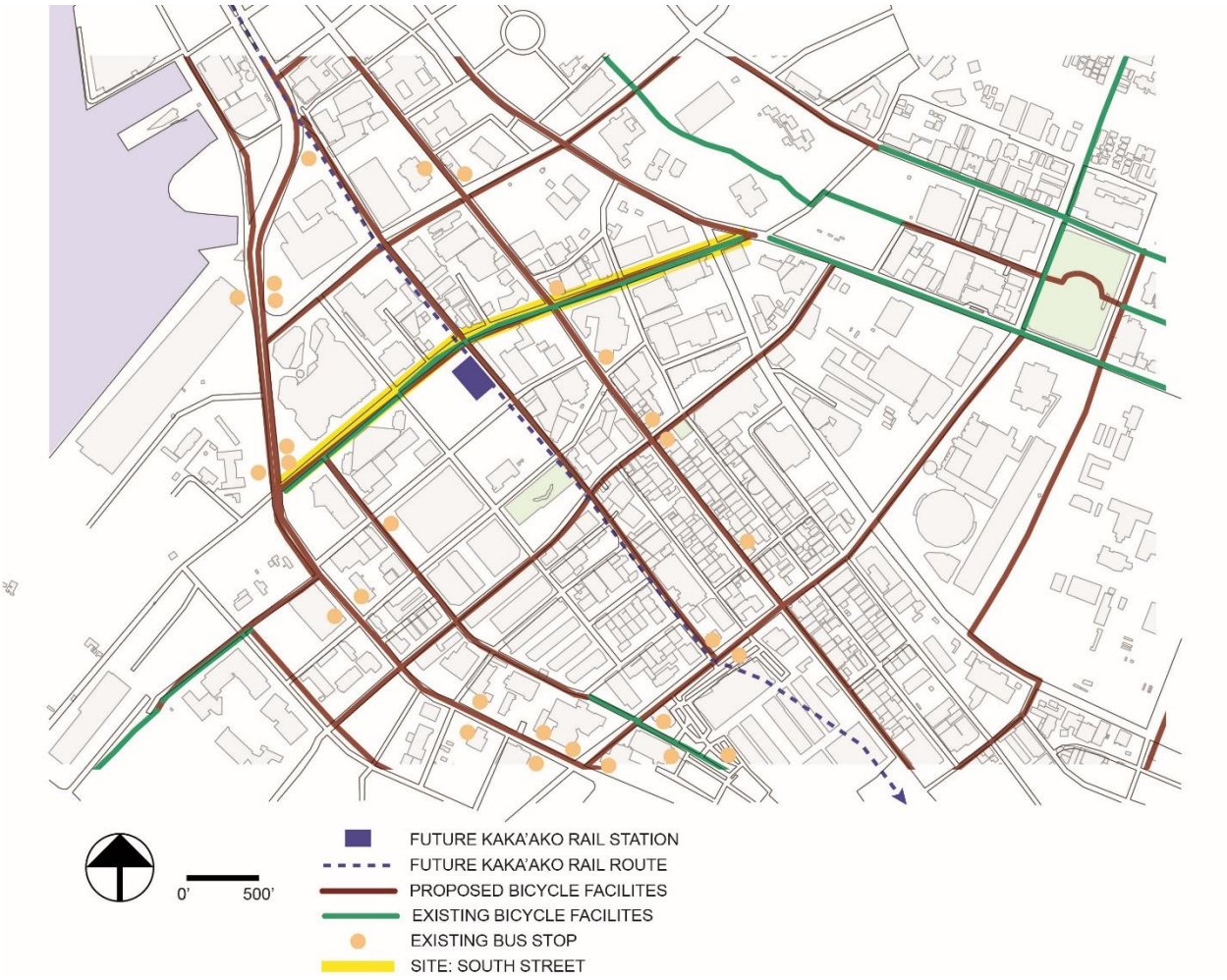


Figure 72: Existing and Proposed Bicycle Lanes Only.
Source:
Information from: ArcGIS, City and County of Honolulu
http://cchnl.maps.arcgis.com/home/item.html?id=bc24f3eb50f94f698d830aed9c428548
http://dbedt.hawaii.gov/hcda/files/2013/06/KS-Master-Plan-SM-Kaiaulu-o-Kakaako-Master-Plan-11-26-08-including-revised-pages-2-5-and-5-12.pdf (slide 54).
Graphics by: Author.

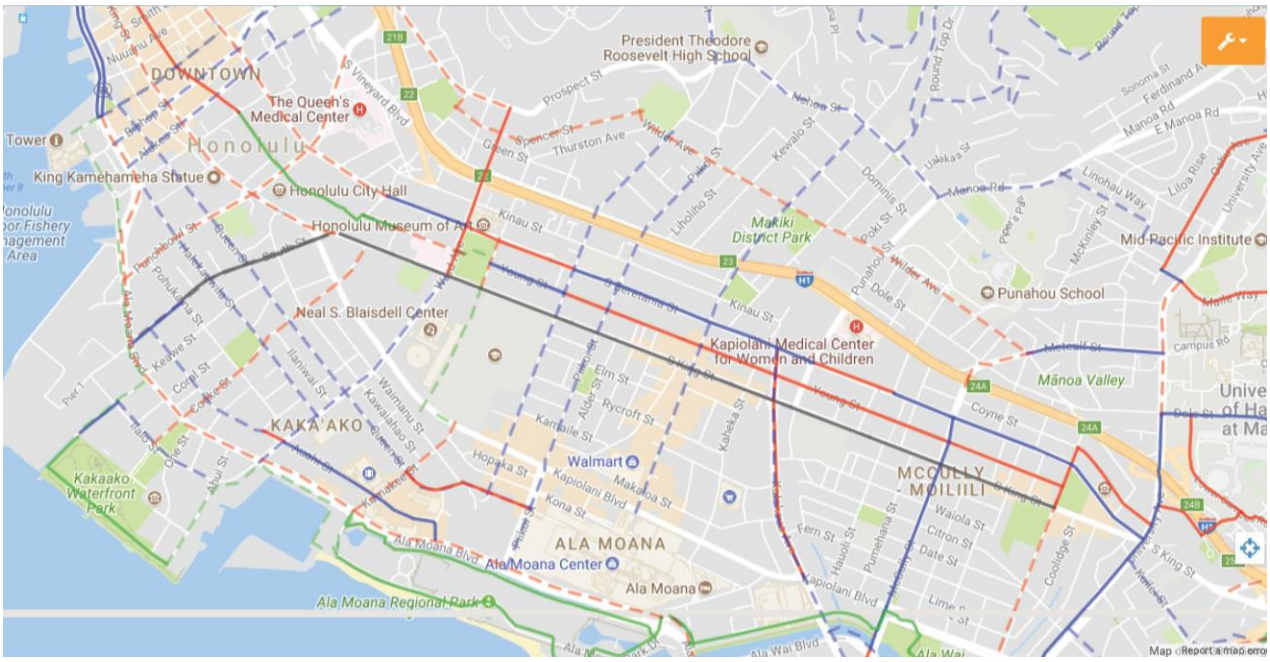


Figure 73: Existing and Proposed Bicycle Facilities—All Facility Types.
Source: City and County of Honolulu http://www2.honolulu.gov/honolulumyway/?bike.
Data Collected by: Author.

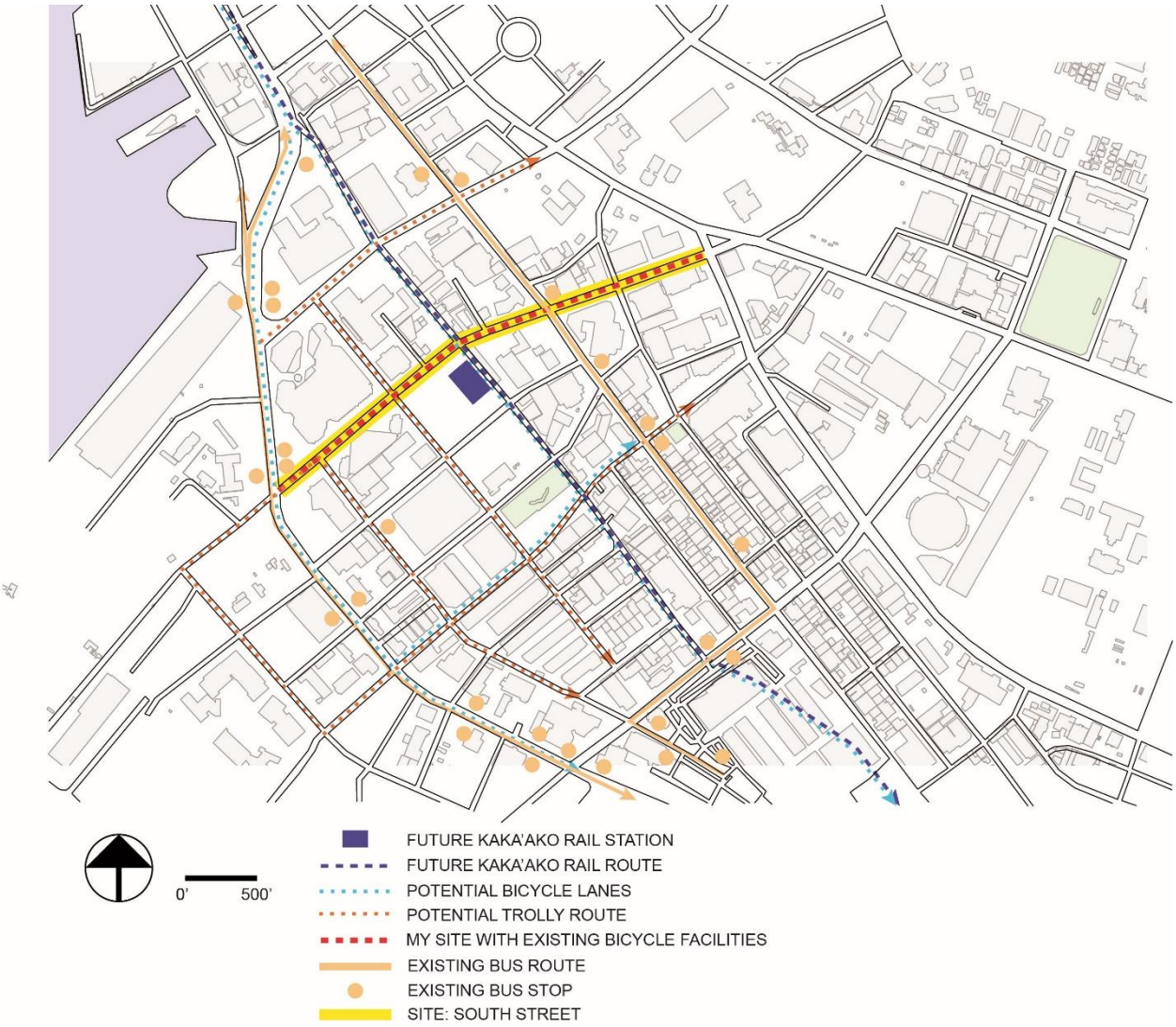


Figure 74: Existing and Proposed Existing and Proposed Bike Lanes Relating to Existing and Proposed Transportation Routes.
Source: .
Information from: ArcGIS, City and County of Honolulu
http://cchnl.maps.arcgis.com/home/item.html?id=bc24f3eb50f94f698d830aed9c428548
http://dbedt.hawaii.gov/hcda/files/2013/06/KS-Master-Plan-SM-Kaiaulu-o-Kakaako-Master-Plan-11-26-08-including-revised-pages-2-5-and-5-12.pdf (slide 54).
Graphics by: Author.

7.4.4 Conflicts on South Street

These conflicts make cyclists vulnerable to vehicle contact throughout the street. South Street acts as a perfect example of a high-stress urban street with its high traffic-volume and frequent occurrence of intersections, street parking, loading zones and driveways. It is important to consider these conflicts to design the facility to fit the site and increase safety and comfort for cyclists.

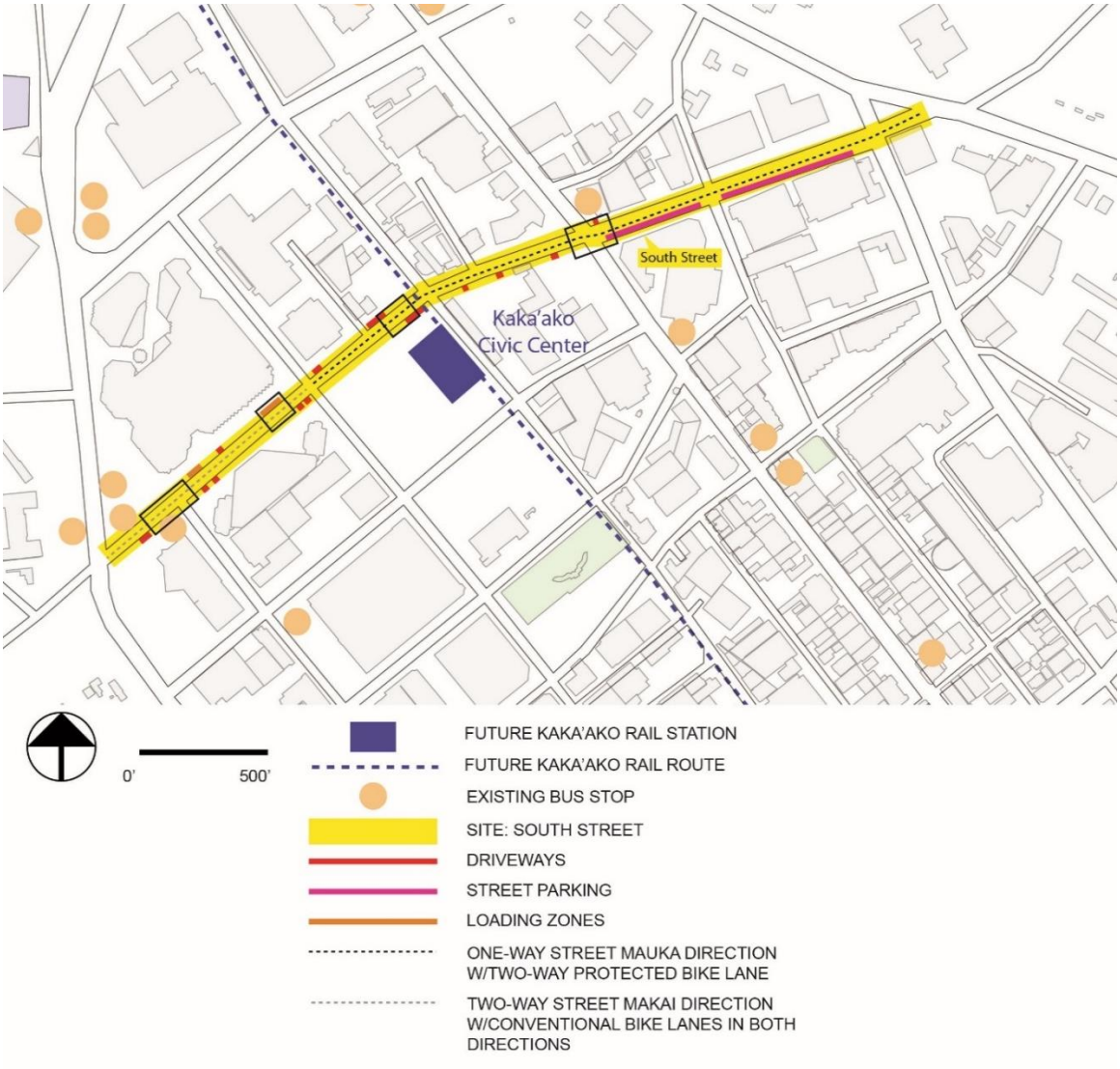


Figure 75: Conflicts on South Street.
Source:
Base Map and Rail Information from: City and County of Honolulu, http://www2.honolulu.gov.
Graphics and Conflict Data by: Author.

Table 21. South Street Existing Conflicts.

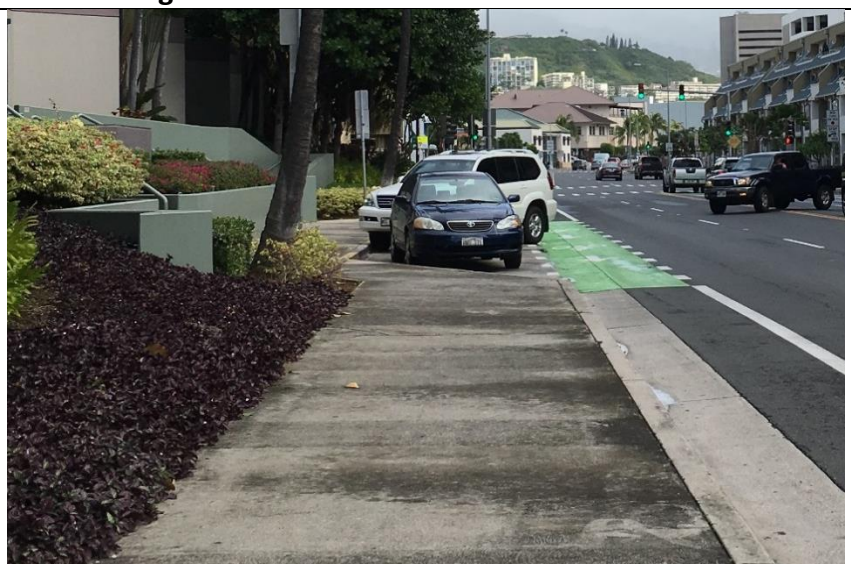
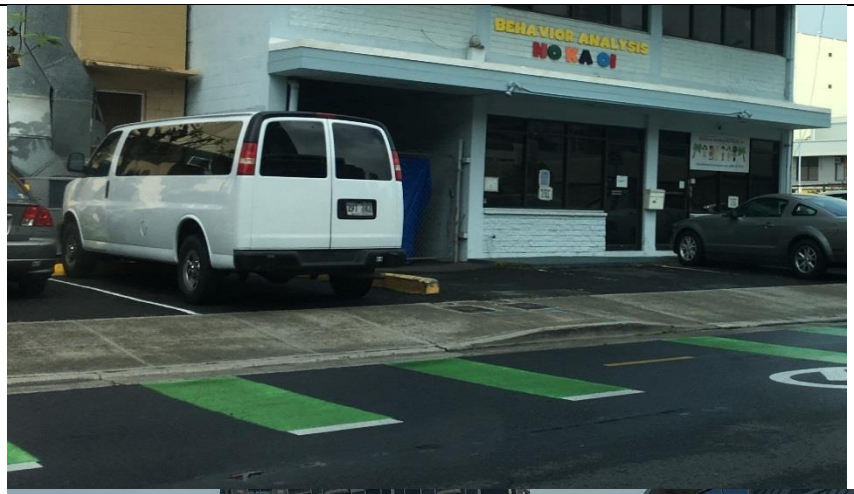
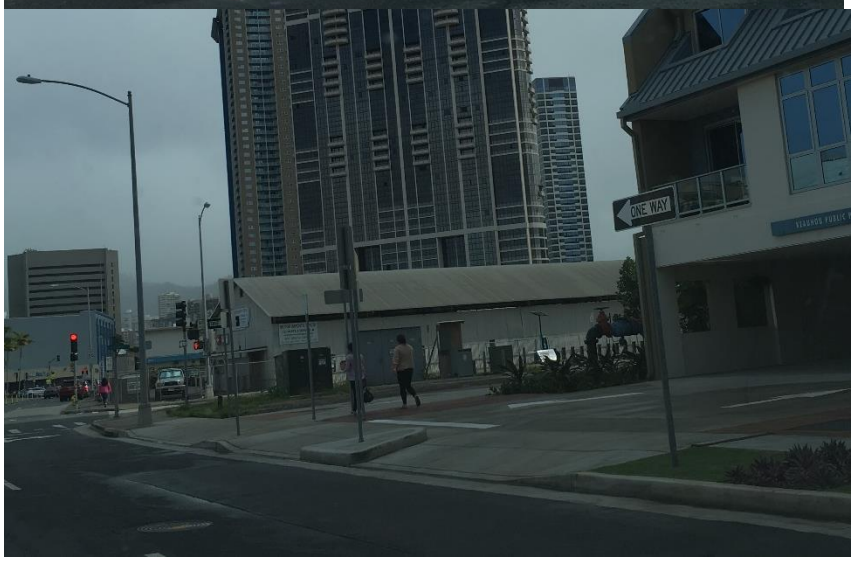
Major Conflicts	Confict Images
Loading Zones- cars encroach into bicycle lane	
Driveways- cars pass through cycle lane	 

Table 21. (Continued) South Street Existing Conflicts.

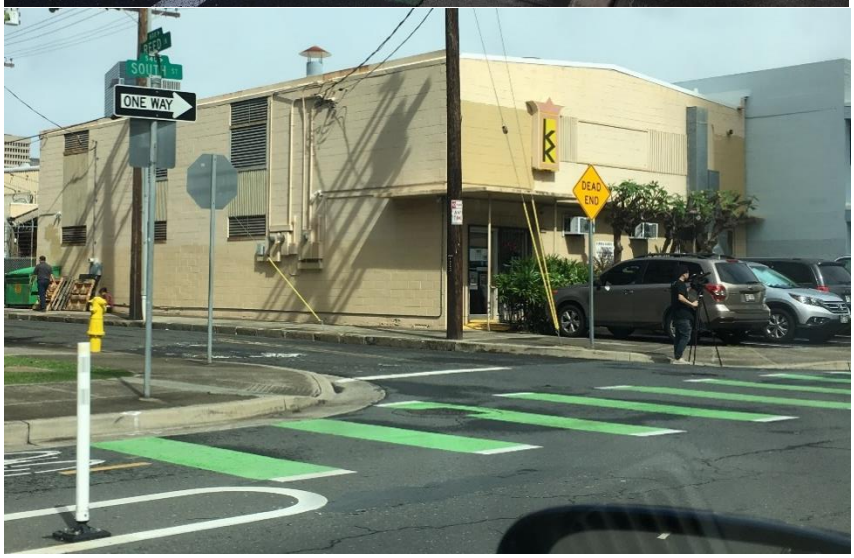
Major Conflicts	Confict Images
Intersections- cyclists become vulnerable when traveling through intersection	 

Table 21. (Continued) South Street Existing Conflicts.

Major Conflicts	Confict Images
Street Parking- vulnerable to dooring and cars cross cyclists travel path	
Bus Stops- buses block bike lane	

Source: Author.

7.4.5 Current Traffic Volumes

Traffic Volumes reported in 2013 report:

-South Street sees 6,214 average daily traffic (ADT)

-maximum volume during typical weekday peak hours of 7:30am-8: 30 am to be 477 vehicles per hour (VPH)

-the two-directional section gets an afternoon peak at 4pm-5pm of 542 vehicles per hour and at 6 pm the traffic drops to 300 VPH then at 6:30 pm to 100 VPH.[120]

Figure 76: South Street 24-Hour Traffic Volumes.
Source: DBET.hawaii.gov. "Draft: Traffic Evaluation." Last modified, June 2013, 11. https://dbedt.hawaii.gov/hcda/files/2014/01/16532A-AB-600-Ala-Moana-Draft-TIS.pdf.

[120] "Draft: Traffic Evaluation," DBET.hawaii.gov, last modified, June 2013, 11, https://dbedt.hawaii.gov/hcda/files/2014/01/16532A-AB-600-Ala-Moana-Draft-TIS.pdf.

7.4.6 Civic Center Rail Station Impacts

The station will connect the island in the Ewa-Diamond head directions. The rail will transport the public to work, school, or recreation. The access point to the station will be on the corner of South Street and Halekauila Street.

HART predicts that 80% of the riders will be pedestrians, cyclists, or bus users. The TOD's goal is to maximize pedestrian connectivity, and safety while creating an efficient environment for operational and functional duties. The area around the station needs to have sufficient infrastructure to handle the high volumes of automobiles, transit vehicles, cyclists, and pedestrians. The area around the stations should integrate transit-friendly development and provide high levels of comfort for pedestrians, cyclists, and neighboring residents to make the compact and high-volume desirable to users.[121]

Based on the HART Access Report, South Street will prioritize people on foot, people on bicycles, people riding transit, and drop-offs/automobiles in that order. It is projected that with the city's current growth rate there will be a ridership of about 3,320-3930 on opening day and a 500% increase within 20 years. [122]

[121] "Seven HART Stations and Access," dbedt.hawaii.gov, published May, 2014, slide 4-5, http://dbedt.hawaii.gov/hcda/files/2013/05/kakaako-tod-overlay-draft_7-hart-stations-and-access.pdf
[122] "Seven HART Stations and Access." dbedt.hawaii.gov.

7.5 Designing South St. for the “Interested but Concerned”

What to Consider When Designing Low-Stress Bike Facilities for High-Stress Urban Streets		
Step 1	**Step 2**	**Step 3**
Street Conflicts to Address	Options for Bicycle Lanes in Urban Streets	Requests of the Interested but Concerned
intersections	buffered bike lanes	shade
loading zones	two-way protected bike lanes	protection from adjacent traffic flow
driveways	one-way protected bike lanes	protection in intersection
parked cars		needs visibility
bus stops		needs to be visible
winding roads		space to ride
traffic speed		clean air
traffic, pedestrian, cyclist volume		adequate lighting
street typology		
surrounding community		

Figure 77: Checklist of How to Design Bike Facilities for the "Interested but Concerned."
Graphic by: Author.

According to my guidelines for designing streets for all ages and skill levels, South Street currently has an average daily traffic volume that should not allow for any facilities with less protection than a protected bicycle facility. It would also benefit from environmental design features highlighting cyclists and enhancing the bicycling experience.

Currently, the two-way protected bike lane that is installed on a majority of South Street is sufficient for the existing traffic volume. However, because of the predicted increase in traffic, pedestrians, and cyclist volumes after the rail station opens South Street will need one-way protected bike lanes-making the conflicts less severe.

7.5.1 Selected Design Patterns for South Street

The three design patterns listed below are taken from my research. These are the design facilities most appropriate for urban streets. It is known that not all streets in the urban core are created equal. Factors such how many conflicts the street has to the

average daily volume of traffic (ADT) that runs through the street contributes to the measure of efficiency and safety when choosing the most appropriate facility layout.

Of the three facilities I mentioned, one-way protected bicycle lanes are the most suitable for South Street. This will be comfortable enough for the “Interested but Concerned” based on NACTO guidelines, LTS guidelines, and testimony from the category above about what they find comfortable.

With the growing traffic volume in this area because of the future rail station and the amount of driveway and intersection conflicts, one-way protected bicycle lanes will provide more protection than the two-way protected bicycle lane. The existing buffered bike lane does not provide a low enough level of stress for the “Interested but Concerned” population.

7.5.1.1 Buffered Bicycle Lanes Street Configuration on South Street

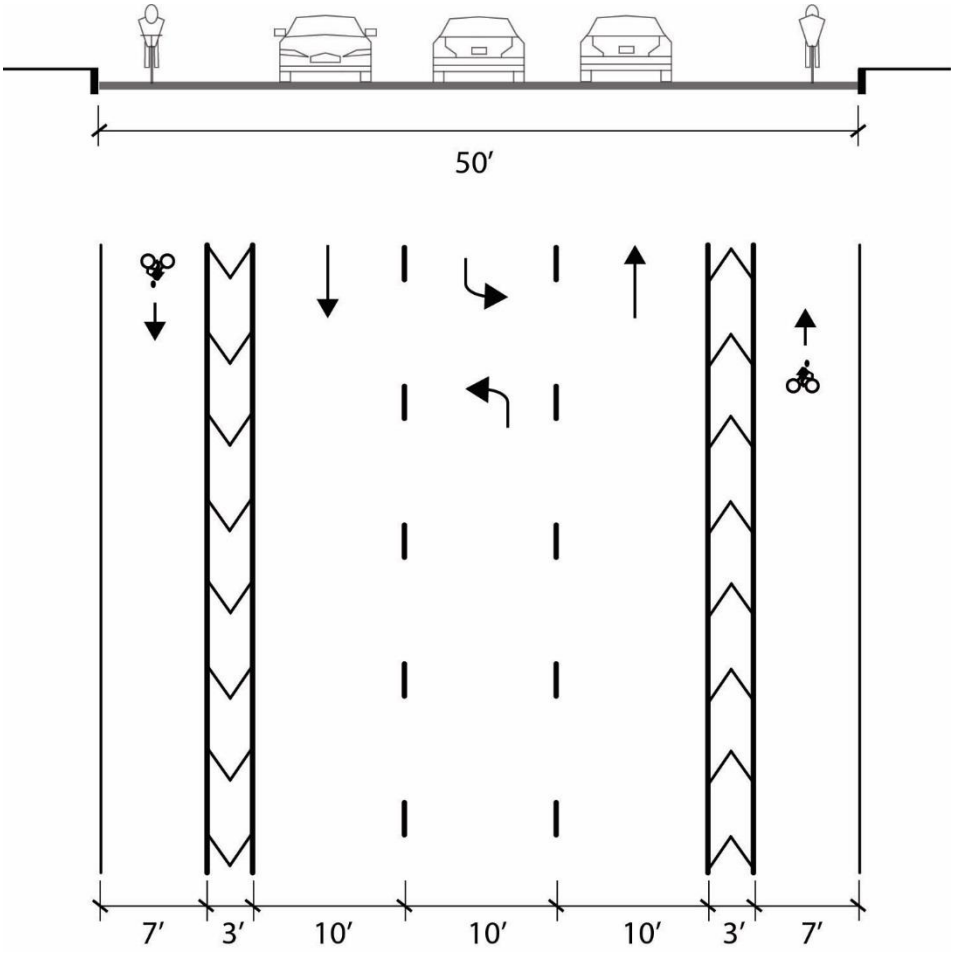


Figure 78: Buffered Bike Lane.
Graphic by: Author.

Although this type of facility would work for part of South Street currently, it is not the safest option for the street's growing cycling population and increased traffic from the rail station's presence. According to the new NACTO Design Guide, Buffered Bicycle Lanes are ideal for streets that see a traffic volume of less than or equal to 1,500-3000 average daily traffic (ADT). South Street sees, 6,214 ADT.

7.5.1.2 Two-Way Cycle Protected Bicycle Lane on South Street

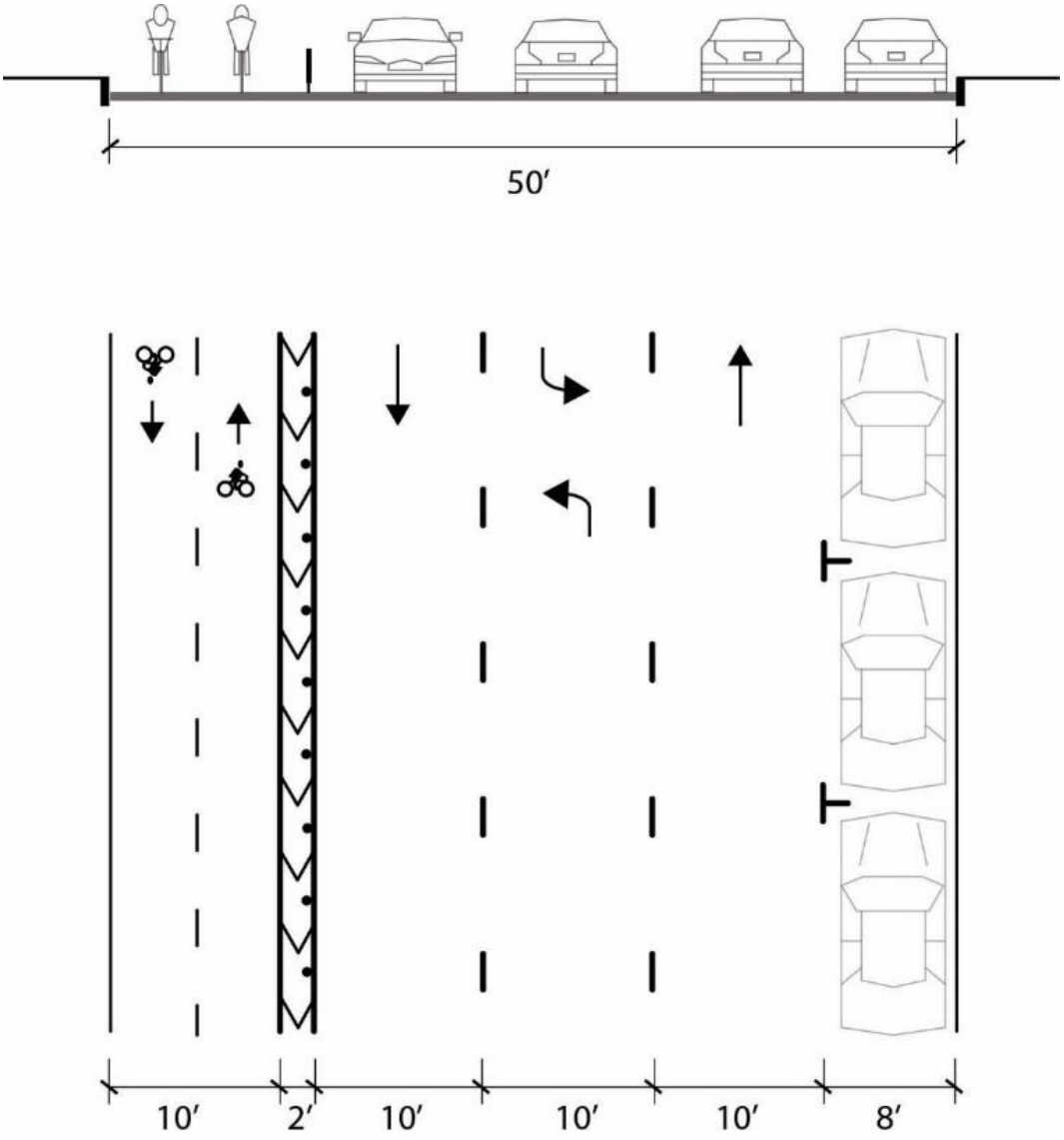


Figure 79: Two-Way Protected Bike Lane.
Graphic by: Author.

A two-way protected bicycle lane can be appropriate for a street that sees greater than 6,000 ADT. Currently South Street has a two-way protected lane from Pohukaina Street until it ends near the connection to South King Street's two-way protected bicycle lane.

The current two-way lane works to keep cyclists on one side of the street, freeing up the rest of the street for low-stress intersections, driveway access on one side of the street, as well as potentially more direct future connection to the King Street protected bicycle lane.

With the number of intersections and driveways, this two-way lane set-up makes it more difficult for drivers at the driveways adjacent to the two-way bicycle lanes to turn. It becomes necessary to not only look in two-directions of lanes but the street traffic as well. As I mentioned in my research, the “Interested but Concerned” tend to be nervous on the bi-directional lanes because of the smaller width of the lanes and the passing action that is done by potentially more experienced cyclists. Overall, two-way protected bicycle lanes are not as ideal in intersection and driveway-heavy streets because the “Interested but Concerned” feel congested and more vulnerable.

7.5.1.3 One-Way Cycle Protected Bicycle Lanes on South Street

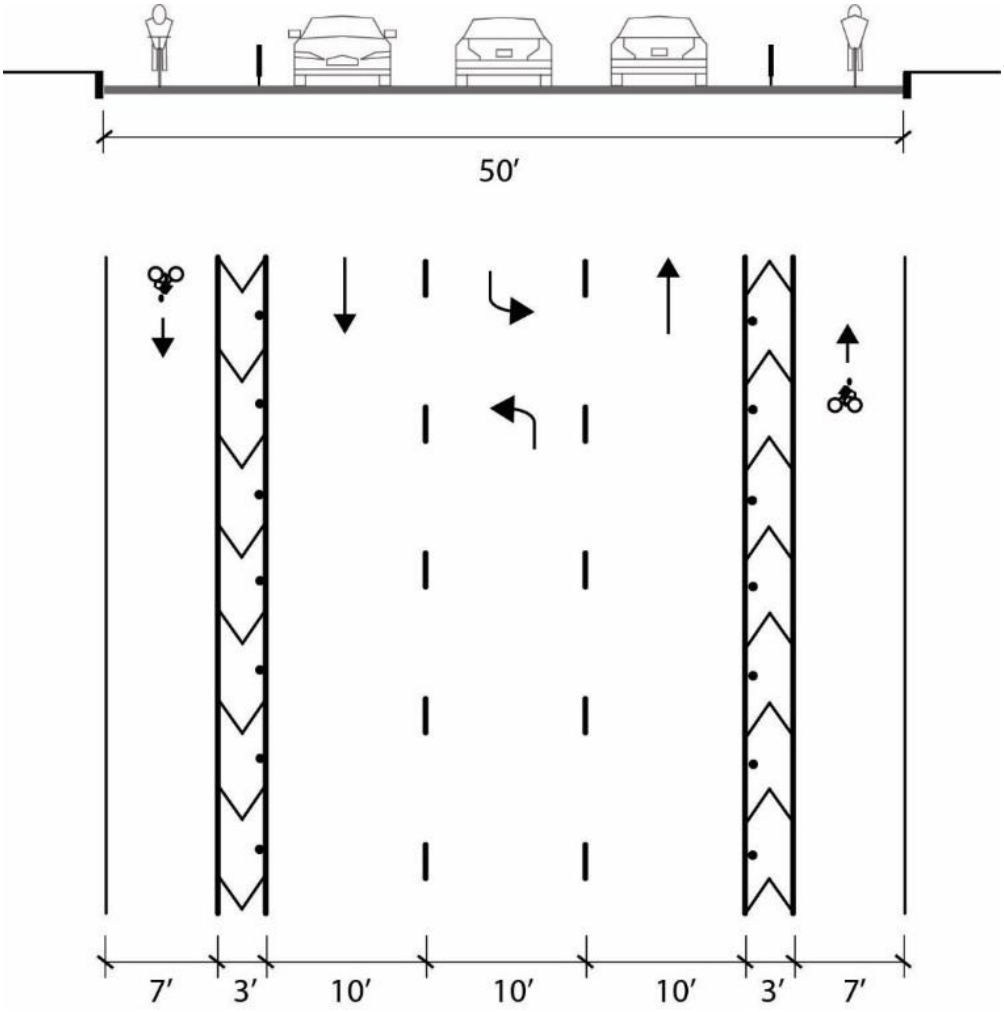


Figure 80: One-Way Protected Bike Lane.
Graphic by: Author.

One-way protected bicycle lanes can be appropriate for a street that sees greater than 6,000 ADT. This is the preferred facility by bicycle advocates in Copenhagen. The singular direction of the lanes allows for a simpler street condition when drivers are checking for cyclists.

Currently, the street is considered high-stress and will be even more so. The current facilities two-way protected bicycle lane is not wide enough for the anticipated cycling increase or fitting into the street's context in a way that make it the ideal and

most comfortable facility for large volumes of cyclists. Having the bi-directional one-way protected lanes will mean that another vehicular lane will need to be removed. This is a move that pushes the city to becoming less car-centric and more pedestrian and bicycle-focused. The future bike lanes feeding in and out of South St. will help the street be more accessible to more cyclists as well as the "Interested, but Concerned," if implemented according to best practice techniques.

The intersection at South Street and Kapi'olani Boulevard is a fitting location for cyclists to cross over to connect to the King Street's two-way protected bicycle lane. King Street could also potentially expand to bi-directional one-way protected bicycle lanes in the future as well.

7.5.2 Design Features for South Street

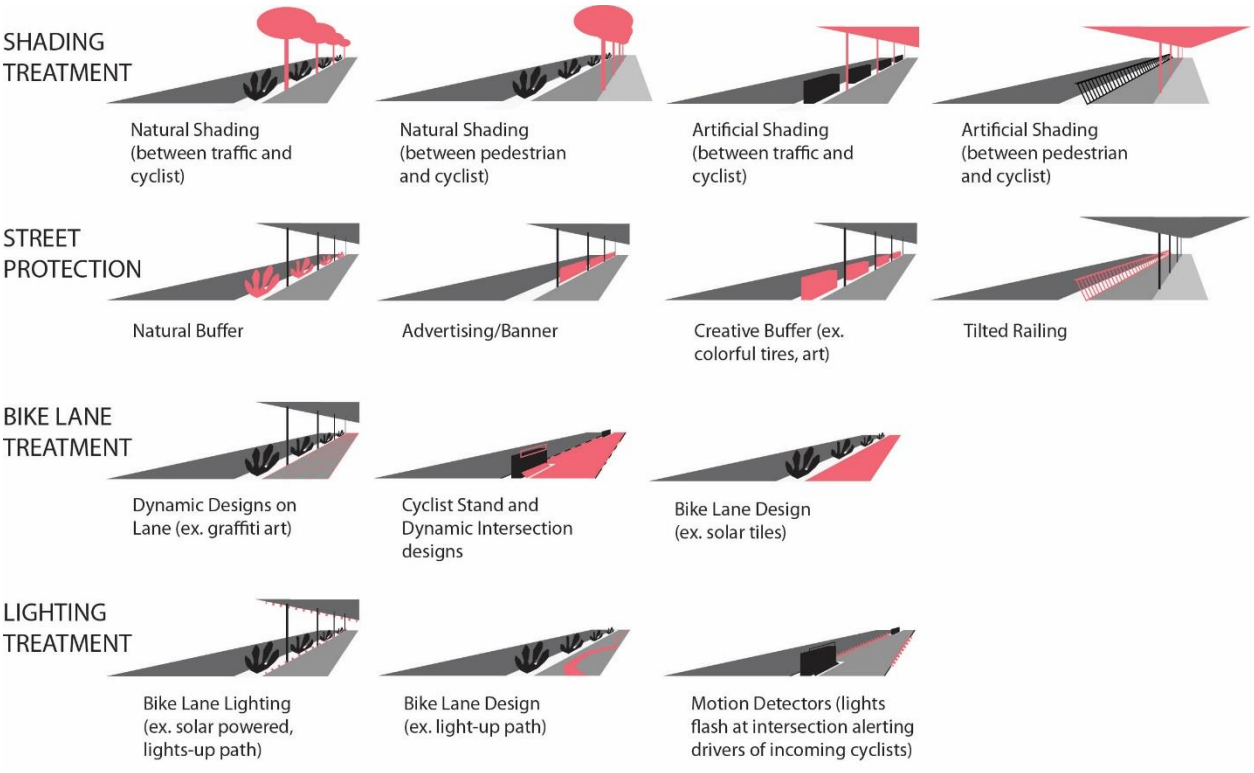


Figure 81: Design Solutions to Provide Comfort for the "Interested but Concerned." Graphic By: Author.

7.6 Design of Facilities on South Street

After a bicycle facility is chosen based on measured consideration, it is important to think of solutions to enhance the experience of the cyclist. Not only do they want a safe facility, but one that enhances their bicycling experience.

7.6.1 South Street Sun Study

Based on the amount of shade in the morning (Figure 82), noon (Figure 83) and evening (Figure 84) there is the most shade during the morning hours and least amount at noon. This yellow marks the parts of the street where the sun hits and the yellow circle represents the area where South St. sees the most sun all day. This is the area where shade would be most useful.

The unshaded portion of South St. has a large parking lot on the southern side of the street and the northern side has retail businesses. Businesses might have an issue with the shade blocking their front façade, but signage can be added to the bicycle facility if visibility becomes an issue.

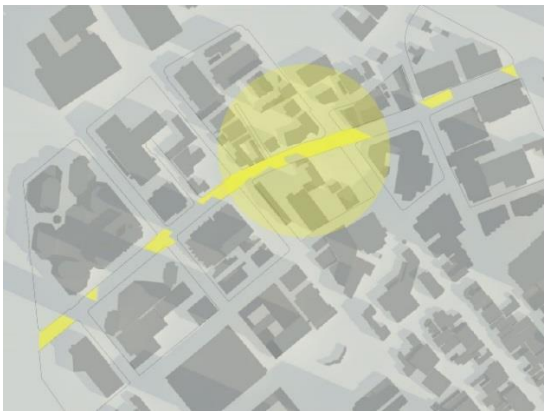


Figure 82: Sun Study, South St. at 9 am.
Source: Author.

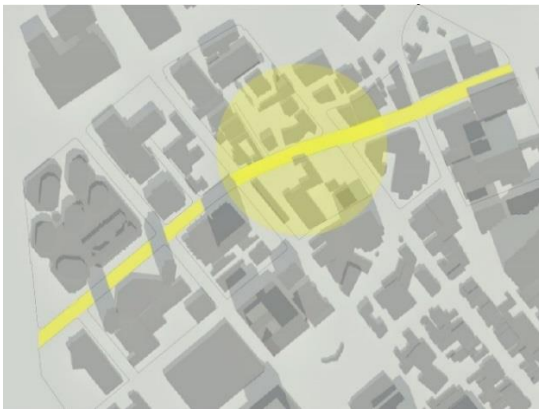


Figure 83: Sun Study, South St. at 12 pm.
Source: Author.

Figure 84: Sun Study, South St. at 5 pm.
Source: Author.

7.6.2 Realized Facility Design

Figure 85: Aerial View of South Street.
Graphic By: Author.

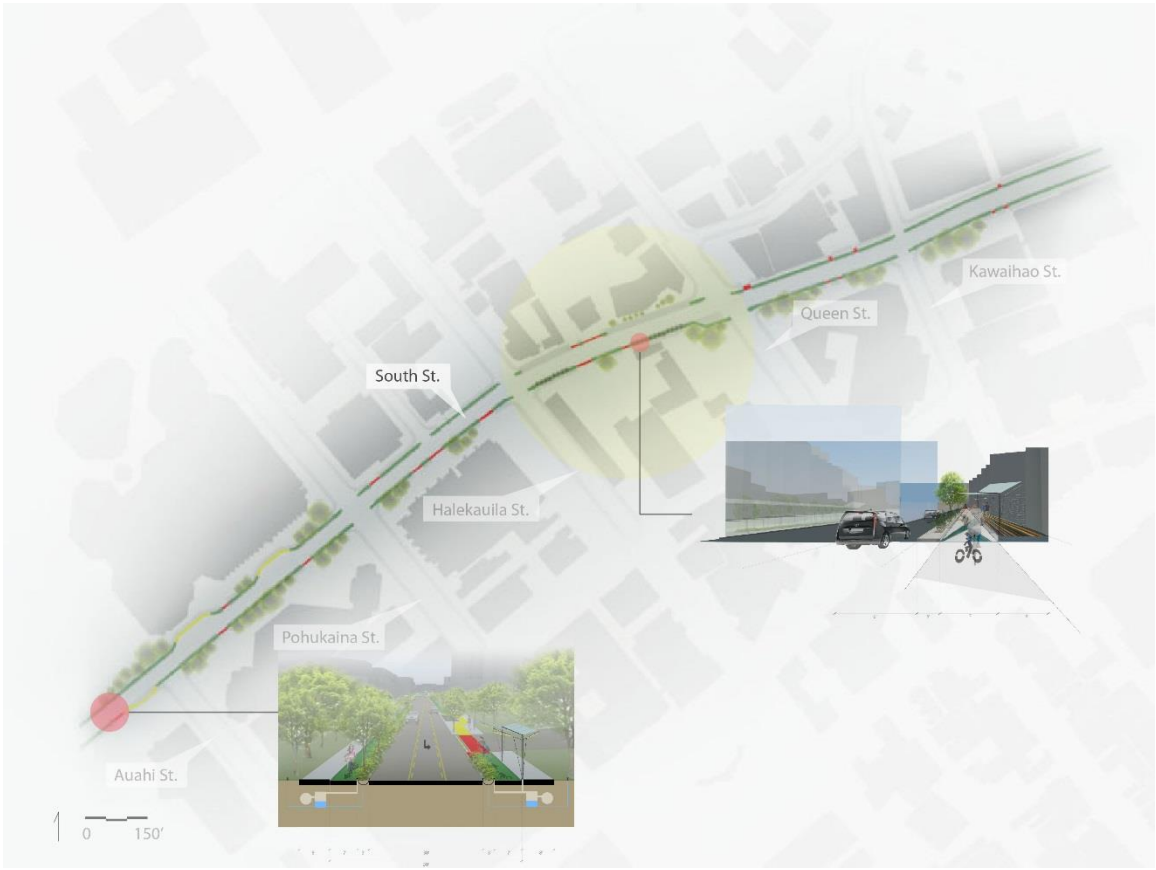


Figure 86: Plan View of South Street.
Graphic By: Author.

7.6.2.1 Street Design

Figure 87: Conflicts and Resolutions Using Bike Facility Design.
Graphic by: Author.

Table 22. South Street's Conflicts and Existing/Proposed Street Conditions.

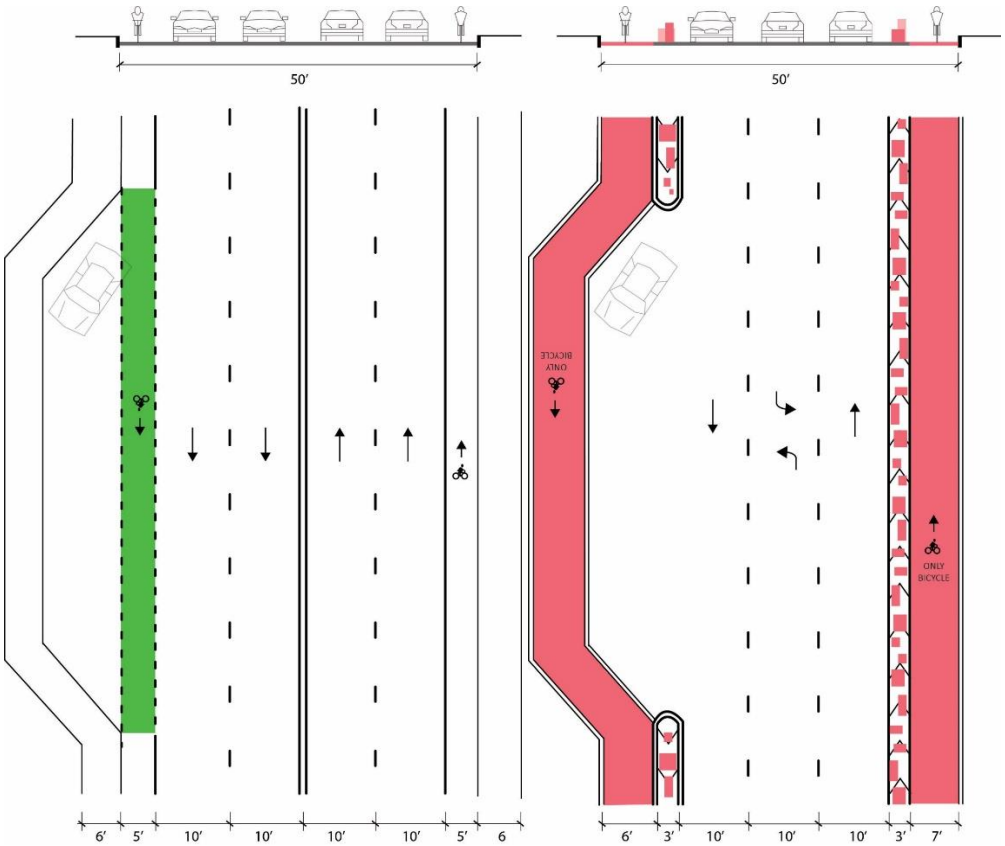
Conflict	Resolution with the One-Way Protected Bicycle Lane
Loading Zones w/ Diagonal Parking (Between Ala Moana Blvd. + South St. & Pohukaina St. + South St.)	 Before After **Guidelines** NACTO and LTS guidelines to comfort the "Interested but Concerned": --Wrap-around loading zone -eliminates vehicle encroachment into bicycle lane -buffer allows for three extra feet of loading zone space -cyclist are further from street traffic and have increased protection --Double lines in contra-flow bicycle lane -highlights to drivers and cyclists that the bicycle lane is going in the opposite direction of vehicle traffic --Green paint -marks cycle zone, so pedestrians and drivers are aware of bicyclists presence **Design Solution to Comfort the "Interested but Concerned"** -creative and artsy design features (fits in with Kaka'ako vibe) -physical barriers only about as high as bicycle wheels

Table 22. (Continued) South Street's Conflicts and Existing/Proposed Street Conditions.

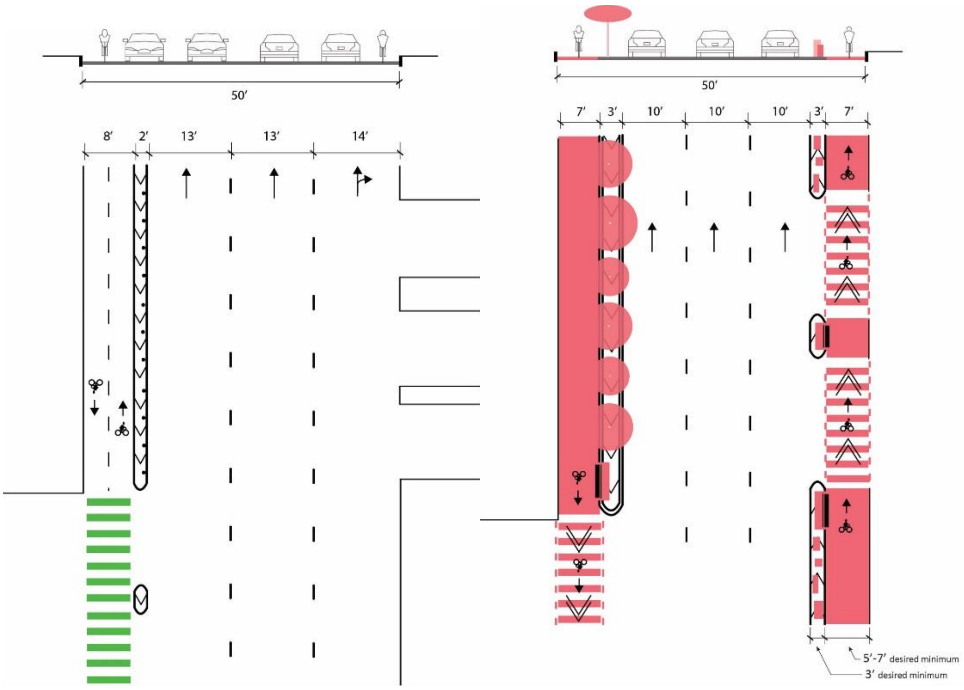
Conflict	Resolution with the One-Way Protected Bicycle Lane
Loading Zones w/ Diagonal Parking (Between Ala Moana Blvd. + South St. & Pohukaina St. + South St.) (Continued)	-tall vertical elements as physical barriers have to have adequate spacing between them to allow for visibility into bike lane by drivers -motion detecting flashing lights at intersection crosswalk communicating incoming cyclist to driver/pedestrians at intersections/heavily used driveways -bike signals at intersections -colored paint that delineates cycle lane from pedestrian or car lane to reduce cyclist alarm and interruption
Driveways	 Before After **Guidelines** NACTO and LTS guidelines to comfort the "Interested but Concerned": -30-50' sight distance with thin bollards or low barriers before turn into driveway for visibility of cyclists -green paint and markings at driveway -lighted sensors to notify drivers of incoming cyclist **Design Solution to Comfort the "Interested but Concerned"** -creative and artsy design features (fits in with Kaka'ako vibe) -add night-time lighting powered by solar panels -colorful paint that delineating cycle lane from pedestrian or car lane to

Table 22. (Continued) South Street's Conflicts and Existing/Proposed Street Conditions.

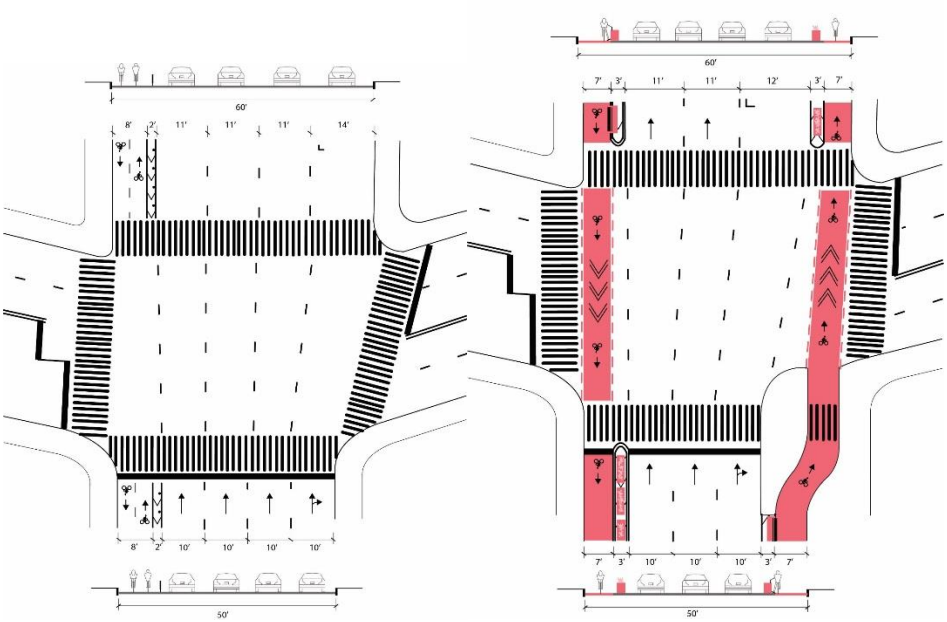
Conflict	Resolution with the One-Way Protected Bicycle Lane
Driveways (Continued)	reduce cyclist alarm and interruption -physical barriers only about as high as bicycle wheels -tall vertical elements as physical barriers have to have adequate spacing between them to allow for visibility into bike lane by drivers -motion detecting flashing lights at intersection crosswalk communicating incoming cyclist to driver/pedestrians at intersections/heavily used driveways -also, motion detectors that send a stream of light into intersection so cars know there in an incoming cyclist crossing the intersection
Intersections	 Before After **Guidelines** NACTO and LTS guidelines to comfort the "Interested but Concerned": --Bike traffic signals at intersection -"green wave" gives priority to cyclists by giving them a head start at the intersection --Double lines in contra-flow bicycle lane -highlights to drivers and cyclists that the bicycle lane is going in the opposite direction of vehicle traffic --Green paint -marks cycle zone so pedestrians and drivers are aware of bicyclists presence

Table 22. (Continued) South Street's Conflicts and Existing/Proposed Street Conditions.

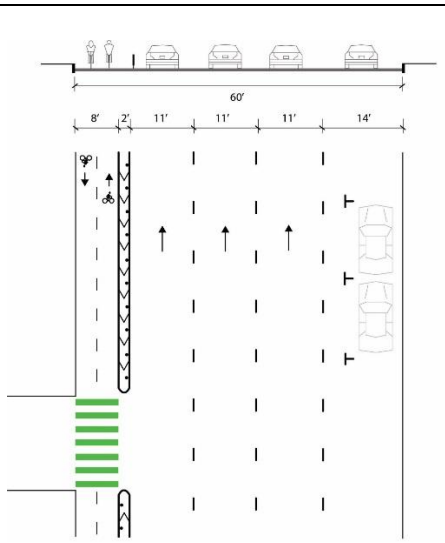
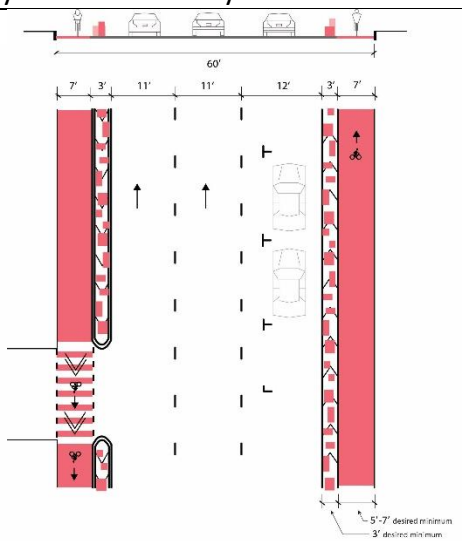
Conflict	Resolution with the One-Way Protected Bicycle Lane
Intersections (Continued)	**Design Solution to Comfort the "Interested but Concerned"** -creative and artsy design features (fits in with Kaka'ako vibe) -add night-time lighting powered by solar panels -motion detecting flashing lights at intersection crosswalk communicating incoming cyclist to driver/pedestrians at intersections/heavily used driveways -motion detectors that send a stream of light into intersection so cars know there in an incoming cyclist crossing the intersection -bike signals at intersections -"protected intersections" and "bend out bike lanes" force drivers far out into intersection before making a turn then crossing the bike lane at 90 degrees -"bend out bike lane" on this South St. Intersection allows for cyclists to have a smoother transition while crossing the intersection, causes drivers to slow down, and allows pedestrians to pause before crossing the bicycle lane -colored paint that delineates cycle lane from pedestrian or car lane to reduce cyclist alarm and interruption -physical barriers only about as high as bicycle wheels -tall vertical elements as physical barriers have to have adequate spacing between them to allow for visibility into bike lane by drivers
Street Parking (Between Queen + South St. & Kapi'olani Blvd. + South St.)	 Before  After **Guidelines** NACTO and LTS guidelines to comfort the "Interested but Concerned": --Driveway treatment -set cars at least 30' from start of driveway to maximize visibility

Table 22. (Continued) South Street's Conflicts and Existing/Proposed Street Conditions.

Conflict	Resolution with the One-Way Protected Bicycle Lane
Street Parking (Between Queen + South St. & Kapi'olani Blvd. + South St.) (Continued)	(see Chapter 2: "Loading Zones/Driveways" and "Intersections") --Wrap-around parking on sidewalk side -reduce dooring -higher sense of security for cyclist -flashing lights at edges of driveway signaling that a cyclist in approaching --Double lines in contra-flow bicycle lane -highlights to drivers and cyclists that the bicycle lane is going in the opposite direction of vehicle traffic --green paint -marks cycle zone so pedestrians and drivers are aware of bicyclists presence **Design Solution to Comfort the "Interested but Concerned"** -creative and artsy design features (fits in with Kaka'ako vibe) -maximum width lanes have protection from falling into roadway/parked cars -sturdy poles or waist-high buffer to protect from alarm and allow visible boundary when a car passes by or opens their door -lower bike lane speed limit to limit alarm from fast passing cyclists -colored paint that delineates cycle lane from pedestrian or car lane to reduce cyclist alarm and interruption -add night-time lighting powered by solar panels -motion detecting flashing lights at intersection crosswalk communicating incoming cyclist to driver/pedestrians at intersections/heavily used driveways -physical barriers only about as high as bicycle wheels -tall vertical elements as physical barriers have to have adequate spacing between them to allow for visibility into bike lane by drivers

Table 22. (Continued) South Street's Conflicts and Existing/Proposed Street Conditions.

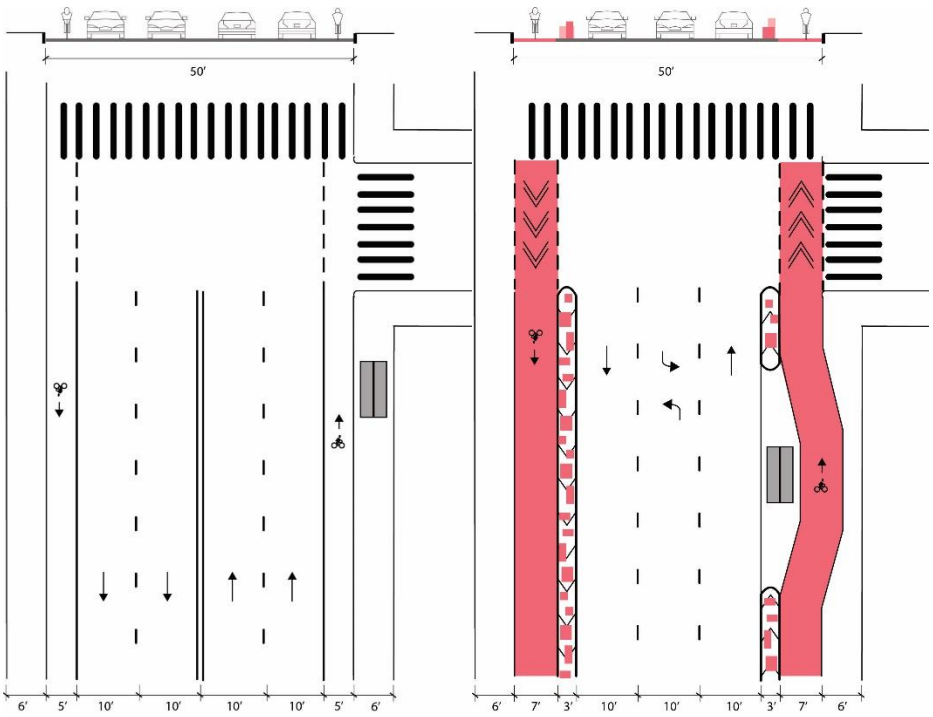
Conflict	Resolution with the One-Way Protected Bicycle Lane
Bus Stops	 Before After **Guidelines** NACTO and LTS guidelines to comfort the "Interested but Concerned" Best-Practice Techniques: --Wrap-around bicycle lane at transit stops: -creates a continuous path -decreases the stress of bus users crossing the bike path when the bus approaches --Green paint -marks cycle zone, so pedestrians and drivers are aware of bicyclists presence and potential pass-through **Design Solution to Comfort the "Interested but Concerned"** -creative and artsy design features (fits in with Kaka'ako vibe) -maximum width lanes have protection from falling into roadway/parked cars/bus stops -lower bike lane speed limit to limit alarm from fast passing cyclists -green paint that delineates cycle lane from pedestrian or car lane to reduce cyclist alarm and interruption -motion detecting flashing lights at intersection crosswalk communicating incoming cyclist to driver/pedestrians at bus stops

Table 22. (Continued) South Street's Conflicts and Existing/Proposed Street Conditions.	
Conflict	**Resolution with the One-Way Protected Bicycle Lane**
Bus Stops (Continued)	-sturdy poles or waist-high buffer to protect from alarm and allow visible boundary when a car passes by or opens their door -lower bike lane speed limit to limit alarm from fast passing cyclists -colored paint that delineates cycle lane from pedestrian or car lane to reduce cyclist alarm and interruption -add night-time lighting powered by solar panels -physical barriers only about as high as bicycle wheels -tall vertical elements as physical barriers have to have adequate spacing between them to allow for visibility into bike lane by drivers

Source: Images by Author.

7.6.2.2 Design Features

The design features in this one-way protected bike lane combine safety and artful design. Since South St. is in Kaka'ako, a very hip and artsy commercial and residential community I wanted the lanes to have a bright, fun, creative feel that can even involve the community's design and art installations. Some features of my design include;

-Lane that are painted and have varying colors emphasize the separation between bike lanes and pedestrian walkways. The lane pavement design and colors also let the cyclist know that there is a driveway or intersection approaching to increase their consciousness of the conflict.

-Artificial shading using solar panels can be a source of electric energy that can be used to sell electricity to the electric company or help to light any electronic devices that may be added to the bicycle facility. I chose two types of shading. One that is simple and allows for maximum use of solar panels since this portion of the street sees the most sunlight throughout the day. This structure gives full coverage of the bike lane and

sidewalk. It also increases in height, the columns spacing becomes further apart, and the colors change from green to red approaching or leading out of driveway crossings. The other shade I designed is directly across the street from the one previously mentioned. Solar panels can also be used with this shade, but less energy will be produced due to the tree-like covering design. This side of the street can have lighter shade because that portion of street sees less direct sunlight. This design is more open than the other shade and provides greater visibility in a heavy-driveway portion of the street. Artificial shading such as these are low-maintenance options if natural shade cannot be used and it can be quick to install.

-Plants that act as a road separation are a visually pleasing and the natural elements are more a psychological barrier than a functional. These plants are small and low-maintenance, yet add softness to the urban hardscape. The height of the trees and planters in the bike lanes are smaller in scale to make sure cyclists are visible (Figure 86).

-The three-foot raised curb adds separation and protection from motor vehicles drifting into the bicycle lane. This could be replaced with a more substantial barrier like the blue tie-knot barriers that I showed in my precedents.

-I chose to keep the bike lane on the street level for most of South Street so that cyclists do not have to change elevations at intersections. The different levels also create distinct separation from the sidewalk and lane so there less of a chance that pedestrians will drift into the cycle lane and vice versa. The lane also feels more protected if it is tucked between two elevated curbs.

-Raised bike lanes that are level with the sidewalk at the chicane for the loading zones and bus stops. This makes it easier for people to pass through and increases cyclists' awareness of pedestrian crossings.

-Driveway crossings have motion detecting lights that sense the cyclist approaching and start flashing. A lower maintenance solution could also be to add color-absorbing material to the pavement so that at night time these crossings stand out to drivers making a turn and crossing into the bike lane.

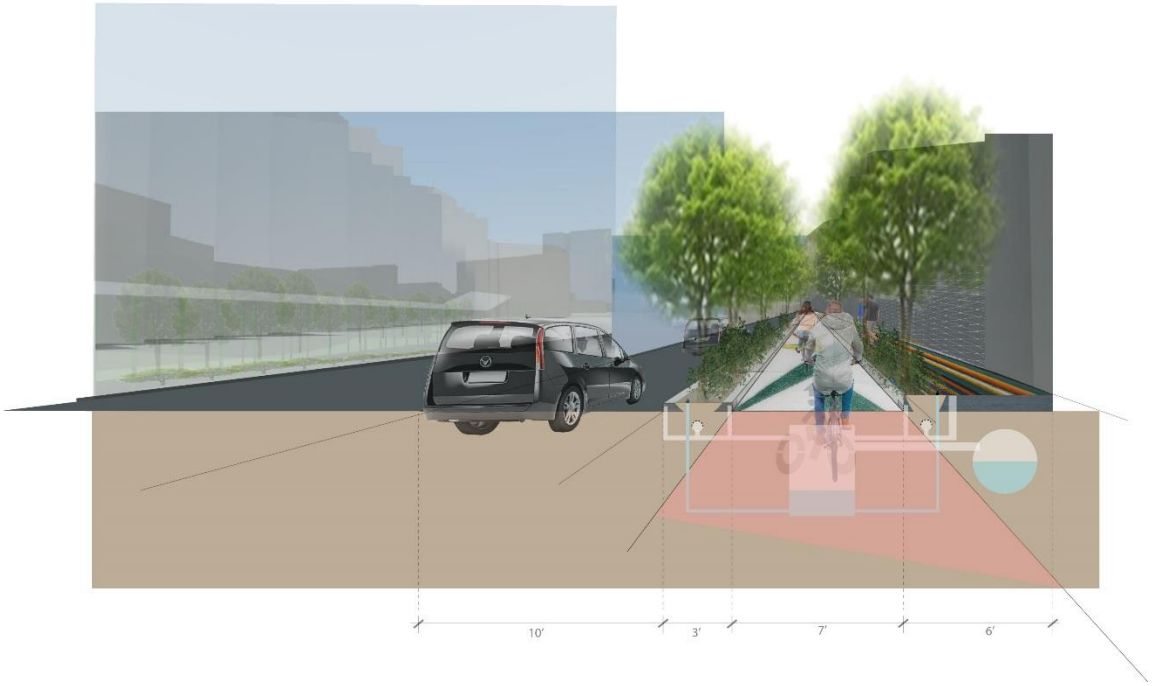


Figure 88: One-Way Protected Bike Lane Design for South St., Kaka'ako at Queen St. and South St., Looking North (mauka).
Graphic By: Author.

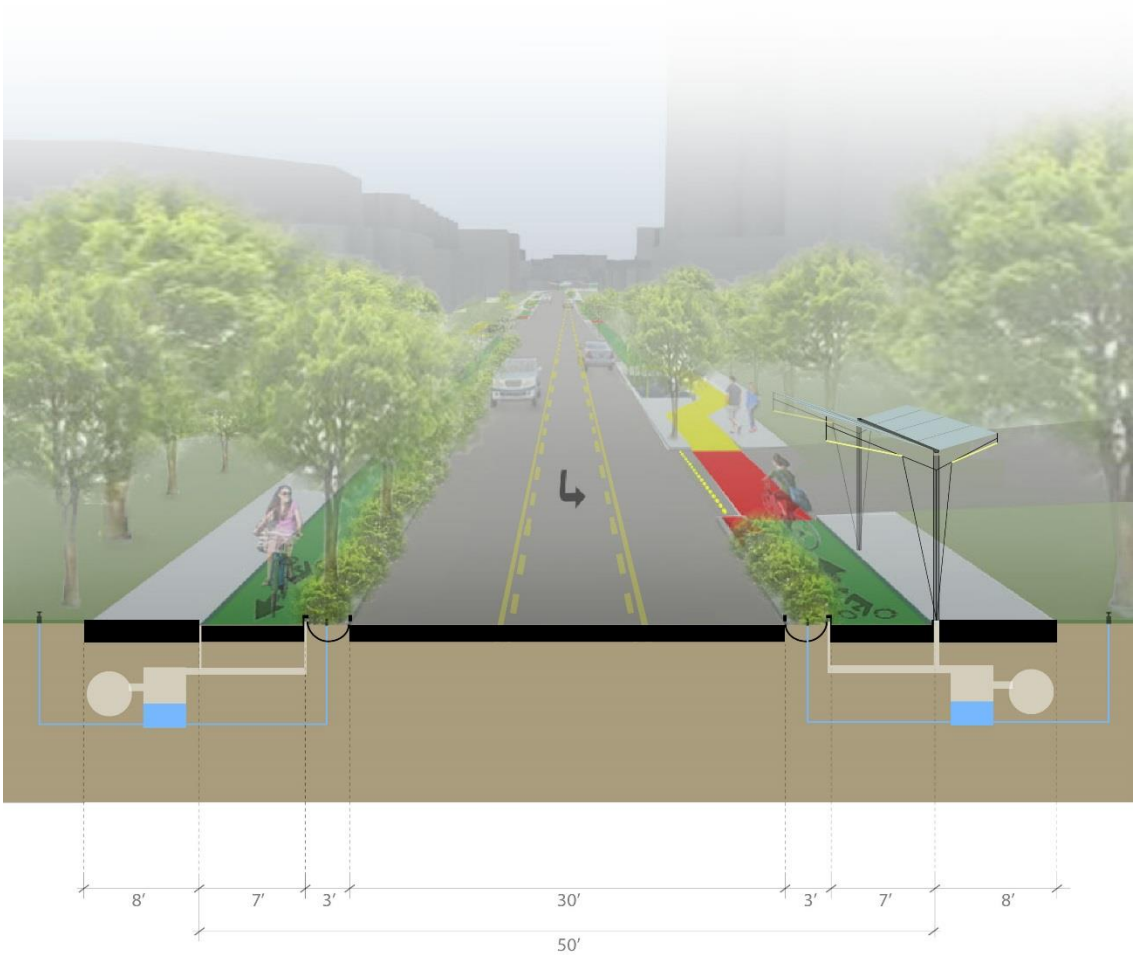


Figure 89: South Street Section Perspective at Ala Moana Blvd. and South St., Looking North (mauka). Graphic By: Author.

Design Features Shown:

-bioswale with natural vegetation as physical barrier

-bioswale for storm water retention and excess water runs into water catchment basins

-water catchment basins collect storm water and rain water from artificial shade for irrigation

-artificial shade with slim structure increases visibility at bike lane crossings in place of bulky trees and solar panels on roof create lighting for lane and sidewalk

-lighted driveway crossings

-street-level lane to allow for easy transition through driveway and intersection crossings

-raised bike and chicanes at loading zones and bus stops to allow for people and bikers to flow seamlessly together

-painted lanes communicating risk levels (red, yellow, green being lowest risk for cyclist)

-artfully painted lanes to add color and creative energy to the parts of South Street where there is bland pavement or lack of nature

-bicycle markings marking bike-only zone

-road diet, bi-directional street with turning lane

-large bus stop shelter

7.7 Results

Based on pedestrian volumes, traffic volumes, cyclist volumes, street type, and conflicts I concluded that a one-way protected bicycle facility on both sides of South Street would help the “Interested but Concerned” feel lower levels of stress in this previously high-stress urban street.

The current and predicted traffic volumes warrant a protected bicycle facility. The one-way protected bicycle facility will deal with conflicts on both sides of South St. Best-practice techniques will mitigate these conflicts and dangers. This has been researched in my previous chapters and proven as effective based on numerous American and International case studies from various Cities.

In addition to safe facility design, it is important to create holistic designs that not only make bicycling safe but also comfortable and pleasant. I hope that this dissertation can act as an inspiration to planners, engineers, and designers to create facilities that welcome all ages and skill levels of people who want to cycle in the urban core.

7.7.1 Trade-Offs

On South Street, there are changes that may require trade-offs. The major changes include eliminating traffic lanes and blocking the front facades of businesses in areas of South Street where shading elements are being implemented. These changes are deemed as necessary because of the predicted increase cyclists and traffic volumes coming with the start of the rail station.

Making bike facilities that are safe, accommodating, and pleasant for commuters and city-goers will increase the number of cyclists and prepare the community for this paradigm shift. The changes are inevitable so steps must be taken to prepare for what is coming and welcome the changes rather than resist them. The question many may ask is, how can we welcome these changes amid uncertainty?

There are solutions to these changes. This involves listening to the concerned parties. This audience may not be completely informed, or they may not know that some changes could benefit them in the future. It is important to acknowledge their concerns and come up with answers that are palatable, realistic, and positive. Working with a creative and open-mind is vital if one wants to come close to creating viable compromises. Some changes to South Street include:

-reducing traffic lanes to accommodate safe protected bicycle facilities- One traffic lane will be replaced with a one-way protected bicycle lane on the east side of South Street. The two-way bicycle lane that currently runs on the west side of South Street will stay the same width, but be modified to become a one-way protected bicycle lane. The bi-directional traffic lanes on the south end of South Street will be reduced from four car lanes to two-lane with a middle turning lane. One-way protected bicycle lanes will run through on both sides of the street continuing the path of protected bike lanes on this north-south direction street.

-adding shade and natural planning to areas on South Street- This feature will block cyclists from the road and provide shade, but can also block the street view of the storefronts. Most drivers do not even stop in these storefronts because their either pass

by too fast or there is not enough parking. The people who would stop into these businesses are pedestrians and cyclists. Allowing this population a safe, comfortable, and pleasant environment will encourage them to walk and bike in along this area and increase business pass-through. If advertising is a concern, implementing such as signage along the bike facility is one solution as long as it does not block the visibility of the cyclists as they approach an intersection or driveway crossing.

-one-way protected bike facilities- These are the safest and most efficient option when it comes to moving cyclists safely and comfortably through this urban street. Without the highest safety and comfortability, these bike facilities will not invite the majority of people who wish to switch from driving to cycling and will not be as effective as they could be. A sometimes enticing option for landowners is the city allowing them to extend their easement out to the street as long as they maintain the facilities and sidewalks as if it was their own. Businesses concerned about liability can enhance safety features to protect themselves from potential risks. The funding or source of energy could come from implementing solar panels in or along the bike lanes. These long-term investments can lead to encouraging people to have a presence on the street and participate more closely with and have more pride for their city's environment.

Supporting cycling as another major form of alternative transportation is vital to creating a more effective network for South Street as well as connecting streets throughout the urban core. The importance of encouraging cycling is important because stopping and parking a bike is much easier than a car in these dense and high-traffic

streets. The bike facilities need to be effective and usable by the majority of the population so that business can benefit from cyclist pass-through.

My research has shown that implementing safe, comfortable, and pleasant bicycle facilities for the “Interested but Concerned” will increase cycling and shift the current belief that driving is easier and more enjoyable than bicycling. It is important to work together with the community to look at ways to can become a whole rather than separately existing parts. What is best for the city is what is best for the people in the city. The entire city can benefit if planners and the community work with each other as a team.

Conclusion

Like a human body, no one street is exactly alike, so there is no “one size fits all” design. The streets must be closely examined and should be designed to be context-sensitive.

Designing safe streets not only decrease injuries but also increases rider populations because of the perceived safety. Increasing rider population is important now because bicycle riding is rapidly growing in popularity. The increase in popularity is fueled by increasing density in cities, a desire for ease of mobility through compact urban streets, biking’s positive effects on health, and fewer auto emissions.

This dissertation aims to support the use of both best-practice bicycle lane design and design features that make bicycling more enjoyable. Moreover, it sets the design standard at a level to attract people who are interested in riding their bicycles in the urban streets but do not yet feel like it is a safe or pleasant experience.

This method requires analyzing a street’s “Level of Traffic-Stress” and then designing facilities for people of all ages and skill levels, embracing “the Interested but Concerned” category of cyclists. With this information, the designer can come up with innovative guidelines and design features to create safer spaces that are also pleasant and efficient.

I hope that this document will help to inspire people in the public and private sectors to make bicycling an even more viable and popular form of alternative transportation in our cities.

Glossary

Average Daily Traffic Volume (ADT): the measure of the number of cars that goes through a street on average per day

Bike Facility: a space for cyclists

Interested but Concerned: defined by Roger Geller to be a category describing the majority of people who ride bicycles and is, therefore, the target audience who will benefit from bicycle facility improvement

Level of Traffic-Stress (LTS): measure of how stressful the street is based on the Interested but Concerned category of cyclists

Urban Core: dense setting has heavy development and shorter distances between destinations

Urban Street: dense street that has heavy traffic, multiple lanes, intersections, loading zones, driveways, etc. Provides access to residential, commercial, or industrial facilities.

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