FITTING IN PROTECTED BIKE LANES

Creating a transferable tool that matches particular existing street conditions with the most suitable Protected Bike Lane type

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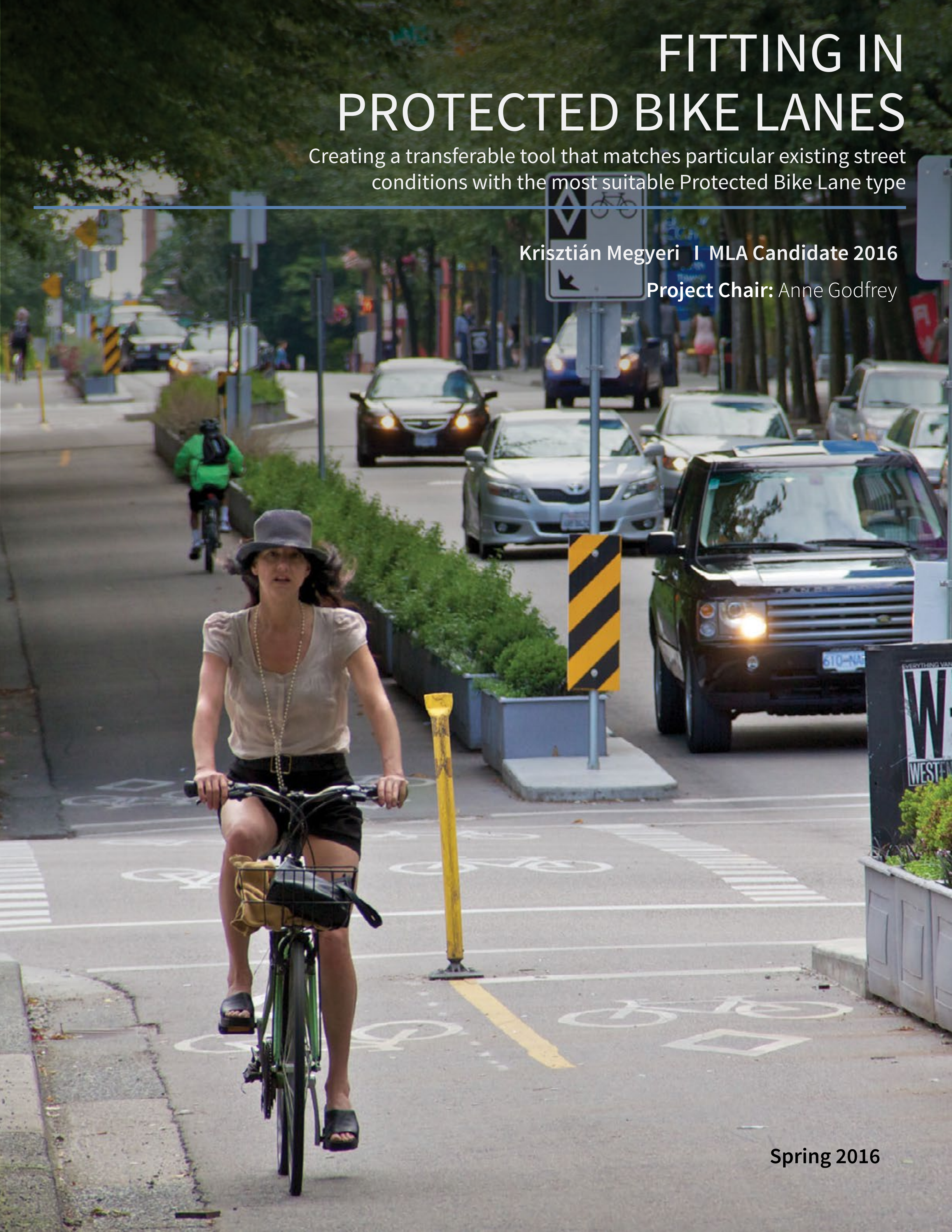

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It’s great to know that we will continue to be colleagues for years to come!

Abstract

While bicycling is growing in the U.S., only 1% of all trips are made by bike. Surveys reveal that up to 60% of the U.S. population is interested in biking as a legitimate mode of transportation, but they are concerned about their safety. Thus, in order to make significant impact, cities must go beyond the bare minimum and invest in a complete bicycle network that prioritizes bike safety. In terms of infrastructure, this means going beyond conventional bike lanes that separate bikes from cars with a mere stripe on the road. Instead, bikes have to be physically protected from vehicles with the use of Protected Bike Lane (PBL) facilities. Because there are numerous PBL types with unique characteristics, and because the employment of PBLs is still new within the U.S., there is a lack of consensus on specific design standards and a lack of guidance on choosing the appropriate PBL type. Additionally, as most PBL installations will be retrofit projects, the existing street conditions (dimensions, traffic configurations, street trees) have to be considered.

Thus, the objective of this project is to create a transferable tool that matches particular existing street conditions with the most suitable Protected Bike Lane type. To demonstrate its efficacy, flexibility and transferability, the tool is applied to three case study streets in Eugene, OR. It is hoped that this tool can contribute to the planning process by aiding in the Protected Bike Lane selection process.

Table of Contents

Definitions and Acronyms

PBL	Protected Bike Lane. There are two main PBL
PBL-DIM	Protected Bike Lane Dimension: This number represents the dimension that is available for a Protected Bike Lane. The number is produced through using the Excel Matrix.
Facility	A term used to refer to bicycle infrastructure from bike lanes to bike parking areas. In this document, it only refers to bike lanes and Protected Bike Lanes.

Street Components

R.O.W	In the transportation field, and in this document, Right of Way refers to the piece of land containing the elements used in public transportation (streets, sidewalks, and planting strips).
Roadway	The actual roadway of travel lanes, parking spaces, and bicycle facilities that exist between the curbs.
LANES-EXIST	The combined width of existing travel lanes
LANES-MIN	The minimum combined width that the lanes can be narrowed to
Shy	The area between the curb face and the actual travel lane striping. It is designed to provide extra ‘room for error’ for vehicles before they contact the actual curb.
PLT	Planting Strip
SW	Sidewalk

NACTO	National Association of City Transportation Officials
FHWA	Federal Highway Administration
Minor Arterial	Major Arterials are the primary “arteries” for intra-urban travel. They provide for through travel movements and for travel from the city to outside destinations.
Major Arterial	Minor Arterials provide the next level of urban connectivity below major arterials and in most cases their main role tends to be serving intra- city mobility.

CHAPTER 1
INTRODUCTION

CH.1

FIGURE 1: Bike infrastructure made for everyone. (https://departmentfortransport.wordpress.com/2014/02/)

Overview

The over arching goal of this project is to increase the number of people who choose to bike instead of drive. There is a significant body of knowledge regarding the negative impacts of motor vehicles on the environment and society, and this project argues that an effective way to mitigate those impacts is by getting more people out of their cars and onto their bikes.

There are numerous ways to increase bicycle numbers such as addressing cultural issues, expanding infrastructure, marketing the benefits of cycling, and introducing car-related fees or taxes. While the whole range of these approaches is necessary, studies suggest that on of the key elements that increases biking is cyclist safety.

Increasing safety in terms of infrastructure means that we must go beyond conventional bike lanes that separate bikes from cars with a mere stripe on the road. Instead, bikes have to be physically protected from vehicles with the use of Protected Bike Lane (PBL) facilities.

Protected Bike Lanes are essentially conventional bike lanes that are separated from motor vehicle traffic using a buffer area and a variety of barrier types like bollards, planters or even parked cars.
Because there are numerous PBL types with unique characteristics, and because the employment of PBLs is still new within the U.S., there is a lack of consensus on specific design standards and a lack of guidance on choosing the appropriate PBL type. Choosing a suitable PBL type is further complicated by the fact that street conditions (dimensions, traffic configurations, street trees etc.) vary continuously even along one particular street. For instance, lane widths and configurations change, on-street parking is intermittent, and the specific planting strip dimensions and characteristics (presence of trees and utilities) change. Because most PBL installations will be retrofit projects as opposed to new construction, these existing street conditions have to be considered.

Thus, the main goal of this project is to create a transferable tool that matches the existing conditions of any particular street with the most suitable Protected Bike Lane type.

Throuhout this document, this will be referred to as the Protected Bike Lane Suitability Tool.

The necessary design standards for streets and PBLs are described and established in chapter 2. The PBL suitability tool is then created and demonstrated in a step-by-step process in chapter 3. Then, to demonstrate its efficacy, flexibility and transferability, the tool is applied to three Eugene case study streets in chapter 4. Finally, the limitations and future potential of PBL Suitability Tool is discussed in chapter 5.

Before these steps, however, it is necessary to set the stage.

The Introduction Includes:

1) Significance
2) The State of Bicycling
3) Protected Bike Lanes
4) Related Work by Others
5) How This Project Contributes
6) Goals and Objectives
7) Project Scope

1.1 Significance

The Impacts of Cars

Due to the many negative environmental and social impacts of automobiles, and because of their large share of fossil fuel use, feasible alternatives to driving will have significant impact on our society (FIGURE 1.1). Transportation accounts for nearly 25% of global CO^2 emissions and in the US, car travel (as opposed to freight) accounts for 91% of all vehicle miles traveled.(1) A few of the documented environmental impacts of cars are CO^2 emissions, water and air pollution, and heavy metal pollution.(2) Automobiles are also associated with a number of external costs relating to congestion, accidents, air pollution, noise, climate change, water pollution, soil pollution and energy dependency.(2) The rise of automobiles in the US resembled a positive feedback loop as it paved the way for American suburban development, which in turn, increased further dependence on cars due to longer travel distances to employment and shopping areas.(3)

In the planning and design fields, there is great emphasis on reversing suburban sprawl by suggesting that people live at higher density. But it all comes down to transportation, proximity, safety, convenience, and *habit*. That density alone is not enough is illustrated by the staggering statistic that 60% of trips made by personal vehicles are to destinations within one mile or less.(4) It is apparent that there needs to be a viable alternative to driving, especially for short distance trips.

Why Bikes Are a Great Alternative

While motorcycles, walking and public transit are all possible alternatives for cars, this project focuses on bicycling for several reasons. Bicycles do not require any external energy input to move, require much less infrastructure than motorized vehicles, are affordable and accessible to the majority of people, and are much faster than walking (15mph vs. 2.5mph). Additionally, while public transit is an integral part of minimizing car use, bicycles are preferable for several reasons. Public transportation vehicles are only efficient (in terms of energy use) when they are carrying a full load of passengers, which typically only happens during commuter rush hours in densely populated areas. For instance, a bus averages 5.5 mpg, and while a full bus (with 60) passengers can result in 330 Person Miles Per Gallon (PMPG)[1], at average busloads they only achieve 38.3 PMPG. In contrast, bicycles have an average PMPG of 984, which is 25 times as efficient.(5)

Furthermore, most if not all transit networks in US cities are inadequate; it is difficult to get from point A to point B unless those points are directly on the

[1] PMPG (Person Miles Per Gallon) is a fuel consumption measurement that takes the average number of passengers into consideration. For instance, the PMPG of personal vehicles is about 35.7, which is higher than conventional MPG estimates because the average number of passengers is 1.58.
For human-powered activities, one gallon of gasoline is converted to 31,500 kcal, and the energy expended is in terms of calories used.

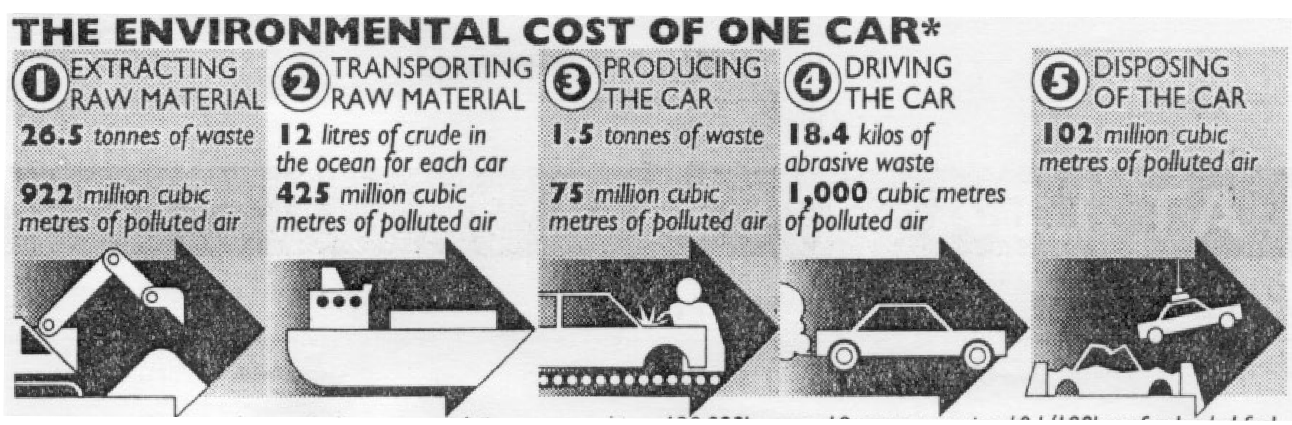

FIGURE 1.1: Environmental Cost of One Car. Based on medium sized car with three-way catalytic converter, driven 130,000 km over 10 years averaging 10L/100km of unleaded fuel. Sources: Environmental and Forecasting Institue, Heidelberg, Germany (http://www.lead.org.au/lanv3n2/lanv3n2-4.html)

transit route. For instance, if someone has to walk 6 blocks to catch one bus, go to the transfer station where s/he waits 15min to take another bus, and then has to walk 5 more blocks to get to a destination, it is likely that s/he will choose to drive instead.

In contrast, biking is direct and usually as fast if not faster than driving and transit for shorter trips in urban areas. The Social Computing Group at MIT[6] developed an interactive map of selected cities that shows which mode of transportation is fastest between two points. As an example, the map of Portland, OR (FIGURE 1.2) shows the result of placing the trip origin point in the center of the green box. As expected, walking (green) is the fastest way to get within a couple of blocks. Beyond the adjacent blocks, however, biking (orange) is faster than any other mode (including driving (red)) for up to about 5 miles away, and there is only one particular place that transit (blue) was the fastest mode. Moving the origin point to numerous areas returned similar results. In fact most origin points resulted in an absence of transit, meaning it was slower than any other option.[7]

Benefits of Bicycling

The bicycle is still the single most efficient vehicle in the world[8] and their increased use in favor of driving will have numerous social and environmental benefits. For instance, an increase in active transportation (walking + biking) would have greater impact on reducing global CO^2 emissions than increasing the use of lower-emission (hybrid) vehicles.[9] One report estimates that if 20% of schoolchildren living within 2 miles of school were to walk or bike to school (instead of being driven), it would save 4.3 million miles of driving every day, which amounts to 356,000 tons of CO^2 each year.[10]

Biking is also beneficial to general human fitness and health. Studies suggest that even low-intensity commuter cycling can increase physical performance as much as specific physical training programs.[11] This is fairly important as there are a lot of people who do not seek out formal exercise, but most people could start biking for their daily commutes.

Bikes are also significantly more economical than cars, and thus more accessible to a greater range of people from different socio-economic backgrounds. The average annual operating cost of a bicycle is $308, which is only 2.25% of that of an average car ($13,646).[12][13] Even that $308 is skewed as it would include abnormally large numbers of expensive ($3,000+) racing bikes, instead of just the modest, commuter bikes which require significantly less investment and annual costs. It is no wonder than

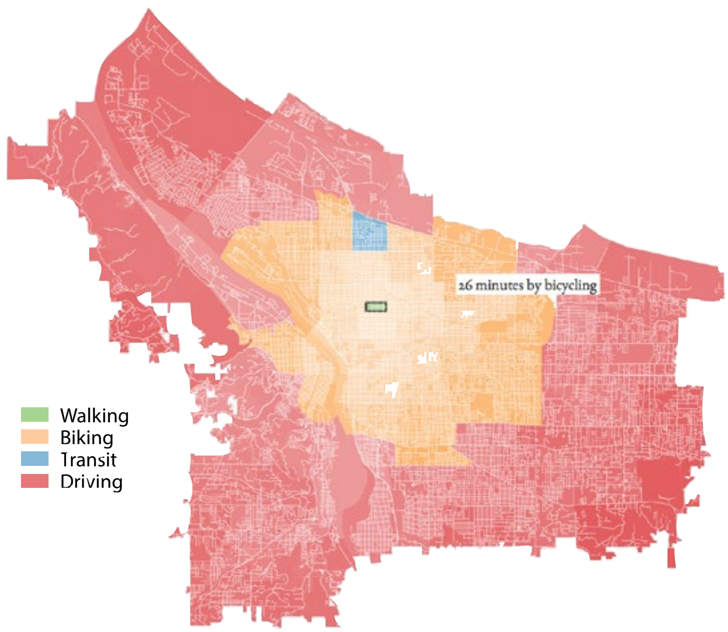

FIGURE 1.2: Fastest route from green origin by mode of transport

that the general demand and popularity of biking (including commuter bikers) is increasing,[14] and 71% of Americans say they would be interested in bicycling more often than they do now.[15]

1.2 The State of Bicycling

Bicycling Trends

While biking is gaining popularity in the U.S., only 1% of all trips are made by bicycle[16] compared to nations like the Netherlands (27%), and Denmark (18%),[17] (FIGURE 1.3). To put these numbers into perspective, anyone who has been to Portland, Oregon was likely impressed by the number of people on bikes, and indeed it has the highest percentage of trips made by bicycle in the U.S. Yet at 3.5%, it still pales in comparison to Dutch cities like Groningen (38%) or

Danish cities like Copenhagen (29%).(17) The University of Oregon has been designated a silver-level Bike Friendly University since 2011 by the League of American Bicyclists(18). Yet the overall bike modal share numbers in Eugene are only between 1-3% +/-, depending on the source.(19)(20)(21) The good news is that these low numbers actually reflect a significant growth within the last decade. Since 2005, there has been an average national increase in bike commuting of 46% and within the top 50 cities the rate of growth ranged from 44% to 403% (306% in Portland, OR) [2].(22)

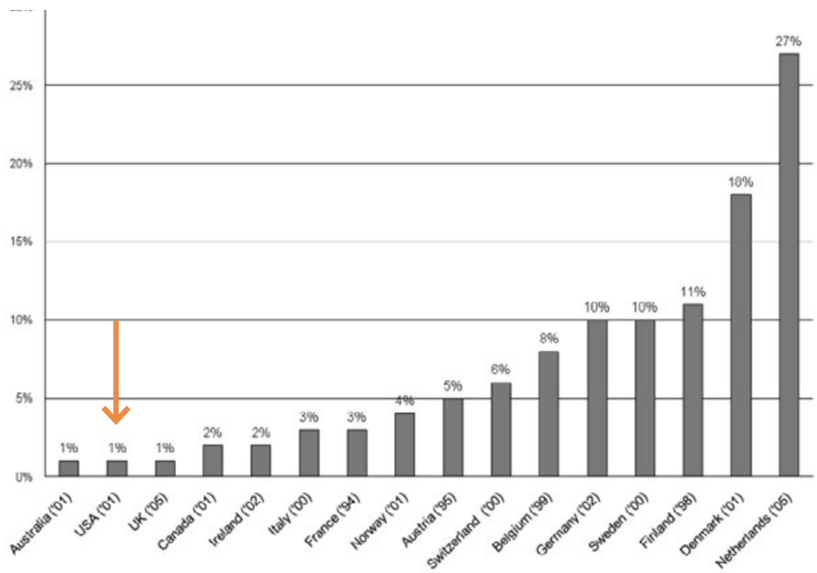

FIGURE 1.3: Percent of all trips taken by bicycle

Factors affecting ridership

So why are there still so few people biking in the U.S.? Dr. John Pucher of Rutgers University, known for his continuous contributions to active transportation research, addresses this issue in one of his articles. According to Pucher, some of the factors affecting bicycle use include cultural issues (public image and the general acceptance of biking), city planning (sprawling cites are difficult to bike in), cost of cars (cost and convenience of cars discourage other transportation modes), income, climate, danger, and cycling infrastructure. He continues by proposing a number of steps to increase bicycle use: increase the cost of car use (he states that this may be the most effective way, but also the most politically unrealistic way in the U.S. where car-related fees or taxes would be rejected), clarify cyclists' rights, expand bicycle facilities, make all roads bikeable, hold special promotions, link cycling to wellness, and broaden and intensify political action(16). While all of these factors are important, in another paper Pucher states that the provision of separate cycling facilities (synonymous to Protected Bike Lanes) is undoubtedly the cornerstone of Dutch, Danish and German policies to make cycling irresistible.(17)

Safer bikeways = more cyclists

Pucher and others have found that one of the main reasons biking is prevalent in so many of the aforementioned European countries is that the bicycle facilities are designed to be safe enough for children. As the cross-cultural adage "it's like riding a bike" suggests, people who grew up riding bikes are more likely to bike as adults. But it's difficult to become a confident bike rider as a child in the U.S. when the only streets safe enough to ride on are the quiet neighborhood streets. Just as the safety of car passengers is a top priority and selling point for motor vehicles, the desire for cyclists' safety should, be accepted without the need for justification and confirmation.

That said, there are numerous studies showing the same demand for bicycle safety in American cities. For instance, a Portland, OR study(23) classified people into four different types of cyclists (FIGURE 1.4). The "strong and fearless" represent about 1% of people who will bike on any road with or without any bike facilities present. The "enthused & confident" are the 7% of people who really want to bike and do so on roads that have at least bike lanes or shared lane

[2] Bicycle use data is difficult to find and compare as the means of measuring varies depending on the country and method of data collection. For instance some percentages reflect people who bike in general regardless of frequency. The U.S. census reflects responses from "Bike to Work" surveys, which only takes commuting into consideration. Thus, these percentages will be higher than if all trips are taken into consideration since commuting account for only 20% of all trips taken. To keep my numbers consistent this document will only use numbers that reflect the % all trips taken by bike from here on out. A multiplier of 0.20 is used where commuter numbers need to be converted, and these will be indicated via a subscript (+/-).

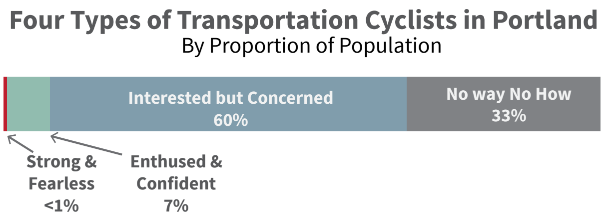

FIGURE 1.4: 4 Types of Cyclists

markings. The largest part of the population at 60% are people who are interested in riding bikes, but are highly concerned about their safety. When considering that 33% of people are unable to or completely unwilling to ride, this interested but concerned population really represents closer to 90% of potential cyclists.

Indeed, Americans have good reason to be concerned; in 2013, 14,000 bicyclists were injured and 743 lost their lives in bicycle/motor vehicle crashes.[(23)] FIGURE 1.8 illustrates the dramatic difference between bicycle injuries and fatalities in the U.S. and countries like the Netherlands and Germany. Injury rates in the U.S. are 6 times higher than in the U.K., and 26 times higher than in the Netherlands.

While roads with conventional bike lanes reduce crashes by 50% from roads with no bike markings,[(25)] the majority of people are reluctant to ride on a road that only separates them from moving cars with a stripe on the road (FIGURES 1.5-1.7)

Existing Bike Infrastructure / Facility types

So if safety is the key to increase ridership, and if safety depends on the bike facility type, what types of bike facilities exist in the US? The two most common facility types are 1) Shared lane markings that can be seen on low traffic neighborhood streets commonly referred to as bicycle boulevards or neighborhood greenways, and 2) conventional bike lanes that are typically seen on roads with higher traffic volume. Where space allows, conventional bike lanes are sometimes converted to buffered bike lanes by simply adding a painted 1.5' – 5' buffer between the bike lane and the travel lanes.

Protected Bike Lanes, the subject of this document, are bike lanes that are somehow physically separated from traffic. In addition to these on-street bike facilities, there are also Multi-Use Paths, which are often found in parks or along rivers and can be used by pedestrians as well as bicyclists. FIGURE 1.9 shows these bike lane types on a gradient from least to most protected. It should be noted, that while shared use markings provide the least protection,

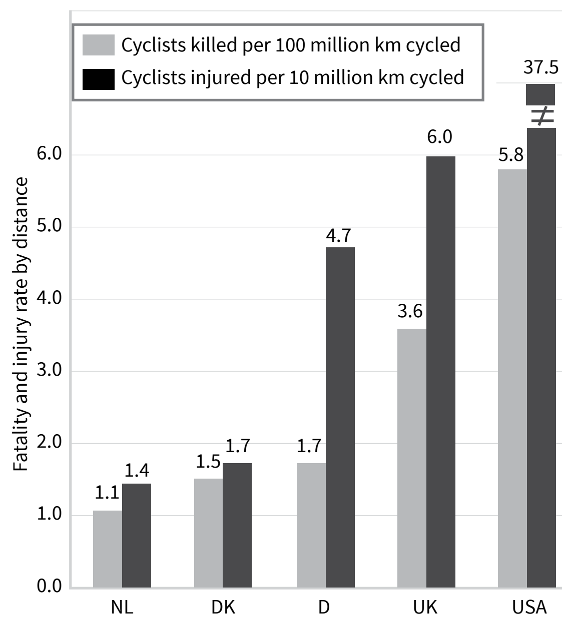

FIGURE 1.8: Fatality rates and non-fatal injury rates in selected countries (2004-2005) Adapted from Pucher. [(17)]

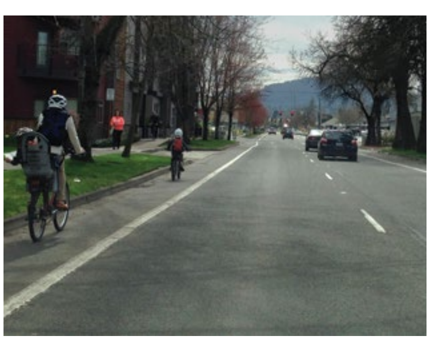

FIGURE 1.5: Family riding on Pearl St. Eugne

FIGURE 1.6: Dangerous bike lane in Boston, MA (https://www.bostonglobe.com/metro/2015/09/30/bike-crash-records-show-commonwealth-avenue-can-dangerous-ride/Fx6JPtQxdh0MfzKULbIQwN/story.html)

FIGURE 1.7: Dangerous bike lane is Cambridge, MA. (http://www.metro.us/boston/dangerous-allston-street-to-get-new-bike-lanes-road-stripes/zsJnkq---JHyPxMcWl21E/)

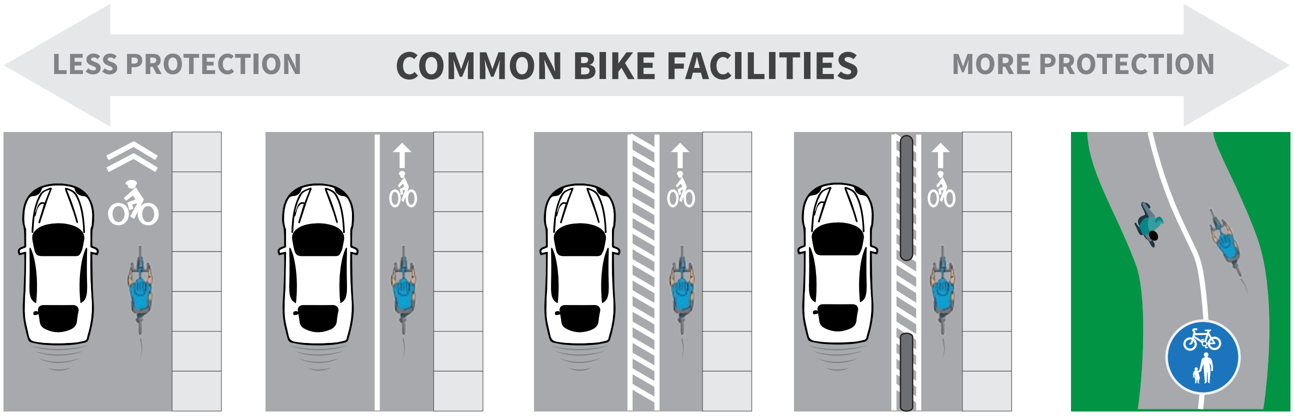

FIGURE 1.9: Common bicycle facility types on a gradient from least to most protected from motor vehicle traffic.

they are predominantly used on neighborhood streets with low speeds and traffic volumes. In many cases it could be argued that those streets are safer for cyclists than even buffered bike lanes found on higher speed arterial streets.

Beyond Bike Lanes

While all of the facility types in FIGURE 1.9 have a place within a bicycle system, the presented research suggests that in order to reach the majority of the population, we must create bicycle infrastructure that is first and foremost safe. There are three common ways to achieve this:

1) Bikes and vehicles can share certain streets known as neighborhood greenways that have low traffic volumes and speed (FIGURE 1.10).

2) Multi-Use Paths are also safe as they are completely removed from vehicular traffic. Instead of running along streets, Multi-Use Paths are typically found along natural features and in parks (FIGURE 1.11).

3) Finally, for the majority of routes that follow the existing road system, there needs to be space for bicycles. Instead of just bike lanes, these corridors need to have Protected Bike Lanes (PBL) that are somehow physically protected from vehicular traffic (FIGURE 1.12).

This project focuses on PBLs for several reasons. While Multi-Use Paths are the safest due to their complete separation from roads, they typically only

FIGURE 1.10: Neighborhood Greenway with Sharrows

FIGURE 1.11: Multi-Use Path (Ruth Bascom in Eugene)

FIGURE 1.12: Parked Car Protected Bike Lane

exist within parks or along rivers, railroad tracks, and other areas where other uses do not interfere with their construction. In cities fortunate enough to have several Multi-Use Paths like Eugene, these routes are invaluable and very popular. However, since these routes are typically restricted to the natural area that they exist within, they do not create any sort of network and thus are mainly used for recreation.

Neighborhood Greenways *do* exist within the regular city grid and they are an essential part of a bicycle system, but they are restricted to local, low traffic-residential streets. For these Neighborhood Greenways to be fully functional within a system, they rely on equally safe bike facilities on the collector and arterial roads that they connect to and intersect.

1.3 Protected Bike Lanes

What are Protected Bike Lanes?

Protected Bike Lanes (PBLs) are bike lanes that are somehow physically protected from motor vehicle traffic.

Protected Bike Lanes are also referred to as cycle tracks, separated bikes lane, green lanes, and protected bike paths. The term used in this document is the more recently accepted one, and it is the term used by the advocacy group People For Bikes.[26]

The specific characteristics that constitute a Protected Bike Lane are:[26]

1) Physical Separation: Protected bike lanes have some sort of physical, stationary, vertical separation between moving motor vehicle traffic and the bike lane.
2) Exclusively for people on bikes: Protected bike lanes must define and allocate space exclusively for people on bikes, not shared with pedestrians or motorized traffic except for brief mixing zones where necessary and at intersections. If the designs are sidewalk level, there must be separate, identified space for people on bikes and people on foot in order for the facility to be considered a protected bike lane.
3) On or adjacent to the roadway: Protected bike lanes are part of the street grid. In some instances, a protected lane may be separated from the road by landscaping or other features, but it runs parallel and proximate to the roadway. This distinguishes protected bike lanes from off-street pathways that follow waterways or rail corridors.

Protected Bike Lane Safety

People for Bikes provides an extensive list of studies showing increased cyclist and pedestrian safety after PBL installation projects.[27] For instance, one study found that streets with PBLs had 90% fewer cyclist injuries per mile than those with no bike infrastructure.[28] A specific report on 9th Avenue in New York City found a decrease of 57% and 29% to cyclists and pedestrians respectively, after PBL installation.[29]

Another study looking specifically at U.S. cities found that PBL significantly reduce injuries, increase ridership, decrease motor vehicle speeds and generally improve the perceived safety of riders.[30] It has also been shown that creating safer infrastructure has a positive feedback effect in that the more people start biking in general, the safer biking is for everyone; in other words, safety in numbers.[31] It is no wonder then that bicycle fatality and injury rates are so much lower in countries with extensive PBLs than in the U.S. (FIGURE 1.8).

Types of Protected Bike Lanes

There are many types of Protected Bike Lanes all around the world, distinguished by the specific mode of physical separation from vehicular traffic. The images from People for Bikes show some of the

FIGURE 1.13: Protected Bike Lane Examples
(People For BIkes)[26]

PBL configuration possibilities (FIGURE 1.13). The specific design standards and components of PBLs are detailed in Chapter 2 of this document, and FIGURE 2.4 shows the PBLs that were selected for the purpose of this project.

Given the vast variety of PBLs, determining the most suitable type given a particular street can be challenging, and is the focus of this project.

1.4 Related Work by Others

Implementing any bicycle infrastructure project requires a number of methods. At the very least ,and in simplified terms, planners and designers have to answer two main questions:

- Where should bicycle infrastructure be installed within a city
- What kind of specific bicycle infrastructure is best suited for each street

While both questions are important to a system planning process, this document is mostly concerned with how others have addressed the matching of particular streets with the most suitable PBL types. The following is a brief review of recent organizations and/or guides related to PBL planning and design.

Bicycle Master Planning

While planning itself is not new, the methodology of bicycle planning has been an evolving field. Traditionally, city transportation planning projects have been conducted within city departments, and a lot of cities still do take on this task. However, there are a number of private firms that contract with cities to complete these projects from start to finish. For example, Alta Planning + Design in Portland, OR is one of the major active transportation and planning firms in the U.S., producing bicycle master plans for numerous U.S. cities including the 2012 Pedestrian and Bicycle Master Plan for Eugene.[32]

While these planning documents have a high level of detail concerning the planning stages of a bicycle system plan, there is not much regarding the selection of PBLs.

Bicycle Facility Selection

NACTO

The National Association of Transportation Officials (NACTO) has released a number of city-specific transportation guides with the intent to provide transportation-related design solutions that are not currently referenced in traditional, government-issued documents. For instance, the Urban Bikeway Design Guide includes state-of-the-art solutions used worldwide, and provides guidance on the design standards of bike lanes, cycle tracks (same as Protected Bike Lanes), intersections, and signals.[33] While the guide includes treatment options that were initially not referenced by any government agency, it has since gained official support from the Federal Highway Administration (FHWA), and is widely referenced in the field.

NACTO is an invaluable guide for general design standards of a number of world-class facilities. However, there is no specific guidance on the selection of a PBL type.

Federal Highways Administration

In 2015, the FHA released it's own guide specific to Separated Bike Lanes (same as Protected Bike Lanes). The "Separated Bike Lane Planning and Design Guide" is an extensive document encompassing everything from the reasoning for PBL use, to planning where they should go, to specific design considerations. Design recommendations include: establishing directional and width criteria, selecting forms of separation, midblock challenges and solutions, and intersection design.[34]

The only guidance this document offers in terms of selecting specific PBL types is that the decision should be based on "the presence of on-street parking, overall street and buffer width, cost, durability, aesthetics, traffic speeds, emergency vehicle and service access, and maintenance". [34]

People For Bikes

The bicycle advocacy group, People for Bikes, offers a guide to 14 different PBL types. Created by Nathan Wiles (City of Austin), the guide provides some estimates on required dimensions, protection level, installation cost, durability and aesthetics of each PBL types (APPENDIX 1). The graphic guide is accompanied by an excel worksheet that includes more detail and information on how metrics like “cost” were determined.

This is perhaps the most useful guide found regarding PBL selection. The ‘score card’ associated with each PBL type is used along with the width requirements to make a specific selection. As described in the following section, the current project intends to build on this guide to make it more robust, and interactive.

1.5 How This Project Contributes

The preceding documents are remarkably detailed and helpful regarding the general process of bicycle master planning. What is missing in the documents is a clear method of selecting the most suitable PBL type for a particular street. This is not surprising as the use of PBLs is still very limited in the U.S., and there is no clear consensus on their design standards. Additionally, as the FHA’s guide stated, PBL selection would have to be based on the variety of existing street conditions of each potential route.

The PBL guide from People For Bikes is a useful start, but is missing some necessary components that will be addressed with this project. For instance, the provided width requirements seem to only account for the actual barrier; it does no include the width needed for the buffer in which the barrier is located. In the case of the “Precast Curb PBL” in APPENDIX 1, the 1.5' “additional width “only accounts for the actual curb barrier; it does not consider the required shy (or buffer) distances, or the width of the bike lane. And while it provides useful information and effective visualizations of different PBL types in the world, it cannot be used to match a particular street with one of the given PBL types.

Indeed, it seems that this question of how different PBL types can be paired with different street types has not been adequately addressed in the literature. With the rise in PBL popularity and the variety of design types, it is important to create a guide or tool that will address this question.

The heart of this project is to create a transferable tool that can be used to match existing street conditions to the most suitable Protected Bike Lane (PBL) types.

1.6 Goals and Objectives

The key goals and objectives of this project are shown in FIGURE 1.14 and detailed below:

1 **Establishing design standards**
What are “street conditions”, and what are the possible types of PBLs? Because the PBL Suitability Tool is the intermediary decision-making tool between existing street conditions and the number of PBL types, these questions have to be answered before creating the actual tool.

- Streets
    - Define all relevant street components
    - Establish design standards to use for this project using state and federal road standard guides
- Protected Bike Lanes
    - Choose a set of PBLs for the project
    - Establish design standards for the barrier types
    - Establish design standards for the bike lanes

2 **Creating the PBL Suitability Tool**
Once the design standards of both streets and PBLs are established for the project, the PBL Suitability Tool is created and demonstrated using a conceptual street cross section.

- Create the PBL Chart of all PBL types and their attributes
- Create the PBL Excel Matrix
- Demonstrate the PBL Suitability Tool on a conceptual street

3 **Applying the Suitability Tool to Case Study Streets**
To demonstrate its efficacy and flexibility, the Suitability tool is applied to three case study streets in Eugene, OR.

- 1) Case study street selection criteria is determined
- 2) Three case study streets selected from Eugene, OR
- 3) Applying the PBL Suitability Tool to case study streets

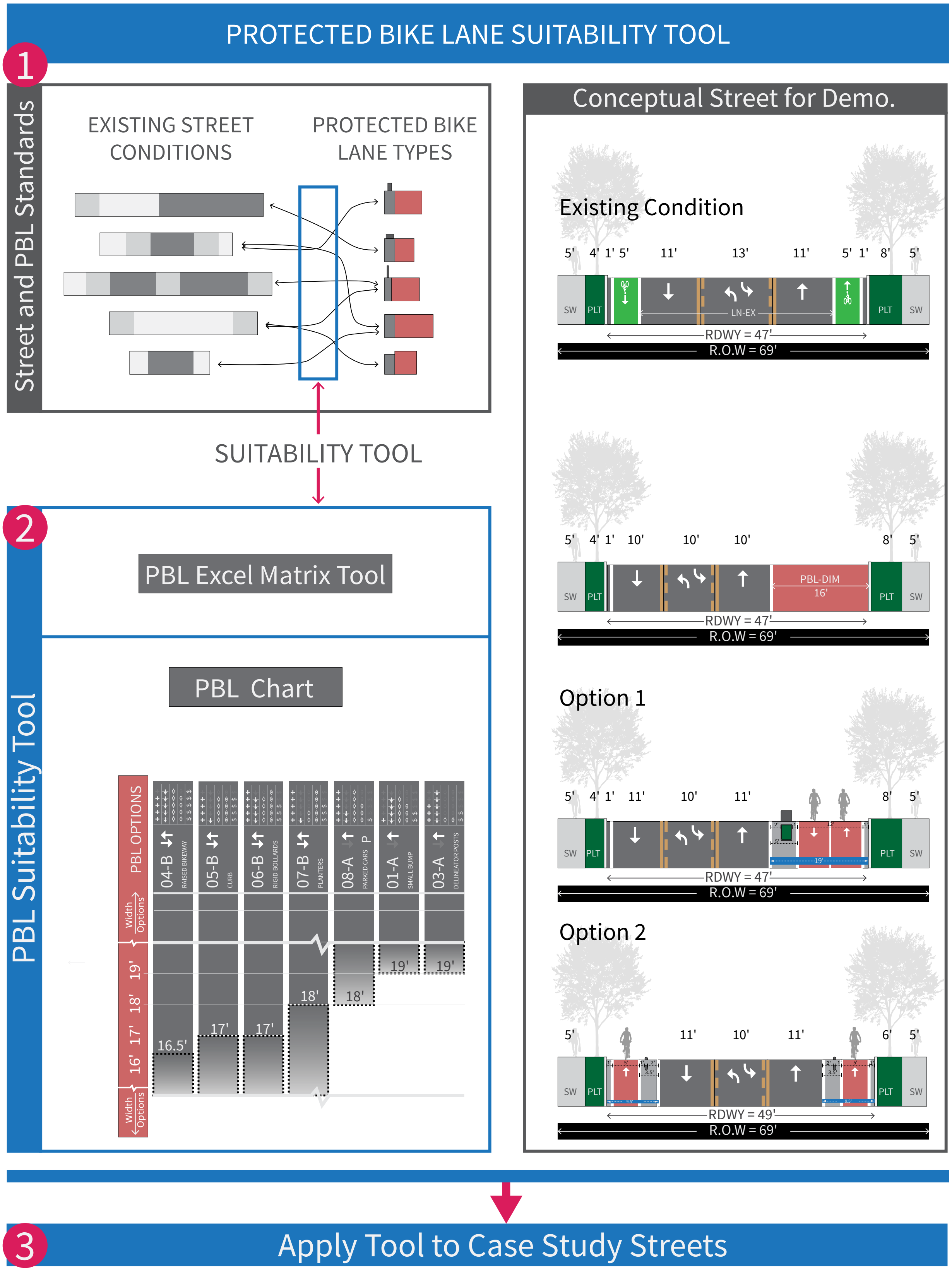

FIGURE 1.14: Project process diagram of key goals and objectives

1.7 Project Scope

Any city-wide infrastructure project is tremendously complex. It often involves a number of private and government agencies, and has to address issues such as: budget, politics, social/cultural issues, and a whole range of construction issues. With transportation projects, there are additional considerations such as: moving of/or altering utilities, potential land acquisitions, and mitigating traffic impact.

The Protected Bike Lane Suitability Tool is not designed to address all of the necessary challenges involved in an actual implementation project, and the results are not meant to be conclusive. It simply allows a user to determine which PBL types are best suited for particular street, based on:

1) The dimensional cross section of the particular street
2) The desired PBL characteristics
3) Situation specific details such as: can the roadway be expanded (presence/absence of trees), and context (traffic volume, urban vs. non-urban setting)

The following is a list of issues this project will and will not address:

Will not be addressed:

- Policy, Funding and Social/Cultural
    - While all infrastructure projects require funding, political support and at least the acceptance of the community, this project will not address those issues.
- Construction challenges (costs, utilities, trees, traffic impact)
    - There are a number of construction issues that are not addressed in this project. The assumption is that if the budget and political support exists, all of the specific construction and traffic challenges can be resolved. For instance, it is likely that some trees as well as utilities (electric post, sewer lines, traffic signals) would have to be altered, removed or added. This would almost certainly be the case if the roadway were to be expanded.

Will be addressed:

While the PBL Suitability Tool is not designed to solve all of the following issues, they will be addressed throughout the document and in the discussion chapter.

- Lane configurations (Widths, numbers, directions)
    - Reconfiguring the specific dimensions of the street components is the main function of the PBL Suitability Tool. One of the key interventions that most Protected Bike Lane installations will require is the reconfiguration of the roadway. Sometimes this can be a re-allocation of space given to cars and bicyclists by restriping the roadway. In other cases, entire travel lanes or parking lanes have to be sacrificed in order to fit in the PBL.
- Expansion of Roadway
    - The PBL Suitability Tool gives the option to expand the Roadway (the area between the two existing curbs) in cases where it is not wide enough to accommodate a PBL. Since doing so takes space away from either the planting strips or the sidewalks, this decision has to be carefully considered, and depends on a number of factors. For instance if the planting strips are narrow (less than 6') and have mature trees, it is unlikely that an expansion would occur.
- PBL Conflicts
    - Although the scope and purpose of this project is not to create master plan document which resolves every possible challenge, some of the more common and relevant PBL design considerations will be addressed in the discussion chapter. The issues discussed include:
      Intersections
      Driveways
      Transit Stops
      Garbage Collection

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CHAPTER 2
DESIGN STANDARDS

CH.2

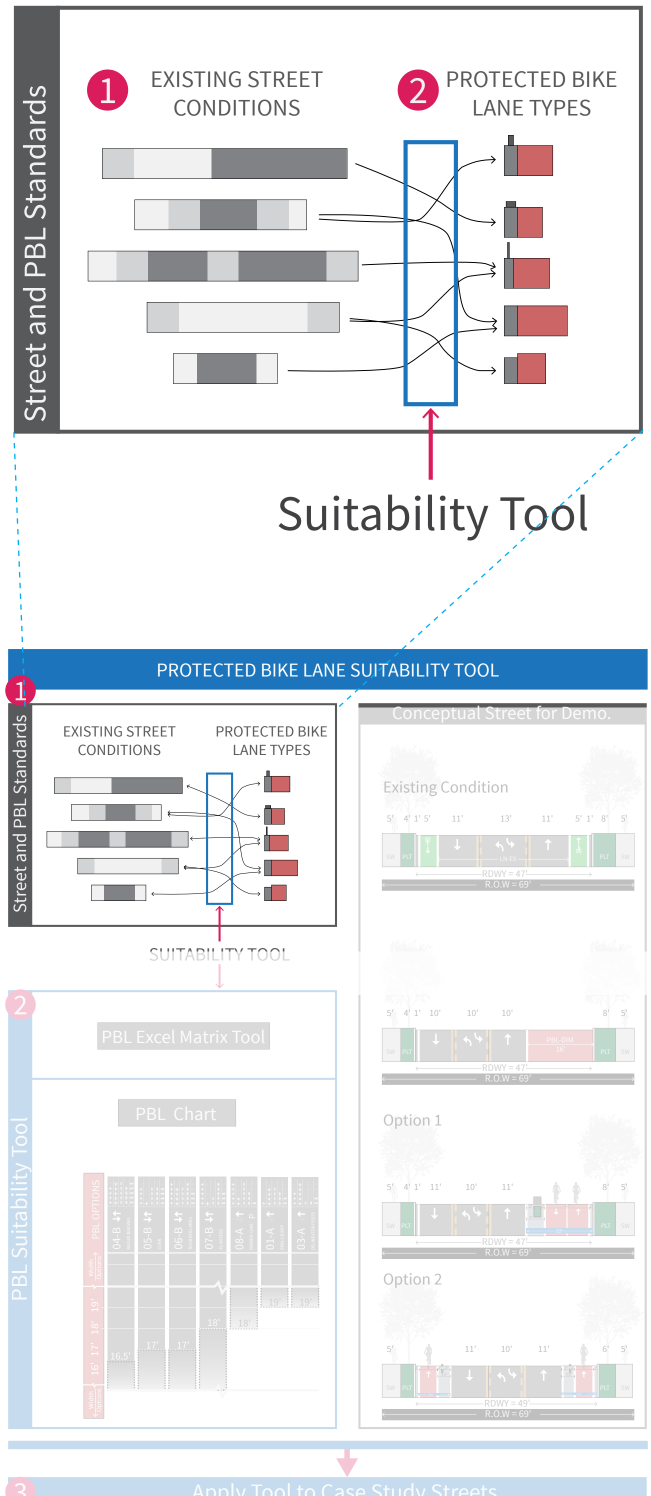
FIGURE 2: Father / son bike ride. (http://www.charlottebellamy.com)

OVERVIEW

The heart of this project is to create a tool that can be used to match existing street conditions to the most suitable Protected Bike Lane (PBL) types.

But what are "street conditions", and what are the possible types of Protected Bike Lanes (PBLs)?

While all streets share similar general characteristics, the specific existing conditions vary greatly even at difference sections of the same street. Lanes often change in width and number, sidewalk dimensions vary, and planting strips change in width and characteristic. Protected Bike Lanes (PBLs) are also generally similar, but each PBL type has different design standards as well as a unique user-experience characteristic. For instance, parking protected PBLs are quite different from planter protected PBLs in a number of ways such cost, aesthetics, and perceived safety.

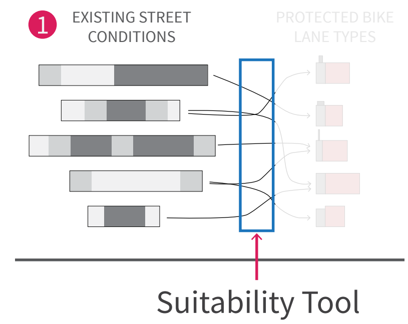


The Suitability Tool can be thought of as the intermediary decision-making tool between the varied existing street conditions and the number of PBL types. As previously explained, before the tool can be created and demonstrated, the design standards of streets and PBLs are defined and established in this chapter.

This Chapter Includes:

1) Design Standards for Streets
2) Design Standards for Protected Bike Lanes

2.1 Design Standards for Streets



Standards

Streets within the U.S. typically have to follow a certain set of design standards regarding dimensions, materials, and road striping. The PBL Suitability Tool is transferable to any street condition, but for the purposes of this project, street design standards will be referenced from either the NACTO Urban Street Design Guide,[4] or design guides specific to Eugene and/or Oregon. Additionally, since PBLs are almost exclusively installed on major and minor arterials, only these two road classifications will be addressed.[1] While no two street conditions are exactly alike, they are composed of similar components and this project is categorizing and defining those in the way illustrated by FIGURE 2.1.

The following section describes the main components of the street:

- Right of Way (R.O.W)
- Roadway (RDWY)
- Shy distance
- Planting strip (PLT)
- Sidewalk (SW)

***Note:** In the descriptions below, **[reconfiguration]** refers to the alteration of the existing condition often necessary to allow for the proposed addition of PBLs. Reconfiguration can be as simple as re-striping the roadway or as complex as a complete reconstruction of the R.O.W.*

R.O.W. (Right of Way)

In the transportation field, and in this document, Right of Way refers to the area containing the street elements used in public transportation (roadway, sidewalks, and planting strips), and is typically measured from outside sidewalk edge to outside sidewalk edge.

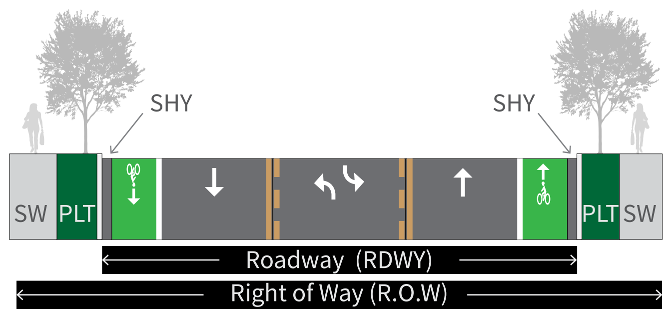


FIGURE 2.1: Typical components of a street

[Reconfiguration] of the R.O.W. can be accomplished through a legal process, but it is typically avoided due to political difficulties and the costs associated with land acquisition and construction. Therefore, in demonstrating the tool, this project will assume that the R.O.W. will not be altered.

The Roadway

The main component of the R.O.W. is the actual roadway of travel lanes, parking spaces, and bicycle facilities that exist between the curbs. Different states and cities have different design standards for these in terms of minimum dimensions, and the standards typically depend on the road classification, which in turn depends on speed limits and the amount of vehicular traffic. As the case study of this project is within Eugene, OR, it will use the standards shown inFIGURE 2.2.

[Reconfiguration] within the curbs can be relatively easy depending on the level of intervention. For instance, restriping the road to move the bike facility is much easier than constructing a raised protected bike lane. Expansion of the roadway, however, would involve higher costs associated with construction, utility relocation and having to reconfigure the planting strip and sidewalk.

1 Major Arterials are the primary "arteries" for intra-urban travel. They provide for through travel movements and for travel from the city to outside destinations. In Eugene, major arterials typically have four or more lanes, and raised median islands or two-way left turn lanes.[1]

Minor Arterials provide the next level of urban connectivity below major arterials and in most cases their main role tends to be serving intra- city mobility. In Eugene, a typical minor arterial contains two lanes plus a center turn lane.[1]

Shy distance
The shy distance is the area between the curb face and the actual travel lane striping. It is designed to provide extra 'room for error' for vehicles before they contact the actual curb, or run off the roadway. The width of this shy distance varies depending on the state, city, and the road classification as shown in FIGURE 2.2.

Planting Strip
The Planting Strip is the area between the roadway and the sidewalk that typically contains plants (lawn, shrubs, flowers, trees) as well as utility poles. As with travel lanes, the design standards of this area vary greatly between cities and states (FIGURE 2.2).
[Reconfiguration] of the planting strip depends on specific existing conditions as well as community values and city policies. For instance, planting strips that are only planted with sod, shrubs, or small/young trees would be easier to reconfigure than planting strips with mature trees and/or extensive utilities present.

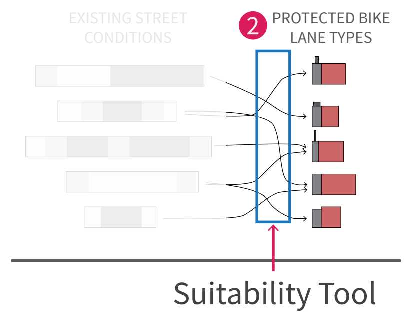
Sidewalk
The sidewalk is typically located at the boundary between private property and the R.O.W. and its width can vary greatly depending on location and city and state codes (FIGURE 2.2).
[Reconfiguration] of the sidewalk(s) is a relatively inexpensive part of a construction project. As the outside edges of sidewalks typically demarcate the R.O.W., any expansion has to come at the expense of cutting into the planting strip.

Street Type	Travel Lane*	Center Turn Lane	Parallel Parking	Shy*	Planting Strip	Sidewalk*
Major Arterial	11' - 12' (10' ok)*	10' – 12'	7'	1' – 2'	2@ 9'6" Min	2@ 6' Min
Minor Arterial	11' – 12' (10' ok)*	10' – 12'	7'	1' – 2'	2@ 8'6" Min	2@ 6' Min

FIGURE 2.2: Table of design standards and guidelines for Eugene streets, sidewalks, bikeways and accessways(1) *SHY(2) : Can be as little as 1' on both sides but typically preferred to be 2' on the right side of the road.
*Sidewalk : The 6' dimension includes 5' for the sidewalk and 1' for reserve strip behind the sidewalk(1)
*Travel Lane: Although the Eugene guide suggests a minimum of 11' for travel lanes, newer street design guides (such as the NACTO Urban Street Design Guide)(4) advocate for 10' widths in urban areas, so this project will use 10' as a minimum.

2.2 Design Standards for Protected Bike Lanes

Protected Bike Lanes
At the heart of the project is the suitability tool, which assists the user in choosing the most suitable PBL given a specific existing street condition. The need for this tool stems from the challenge that different PBL types vary both in terms of width and construction requirements, and in terms of user experience.



Standards
While bike lanes also have general design guidelines through city or state regulations, there is typically more flexibility than with motor vehicle travel lane standards. The following sections outline the standards for PBLs.

Protected Bike Lanes are composed of two major components:

1. The protective barrier type and
2. The bike lane.

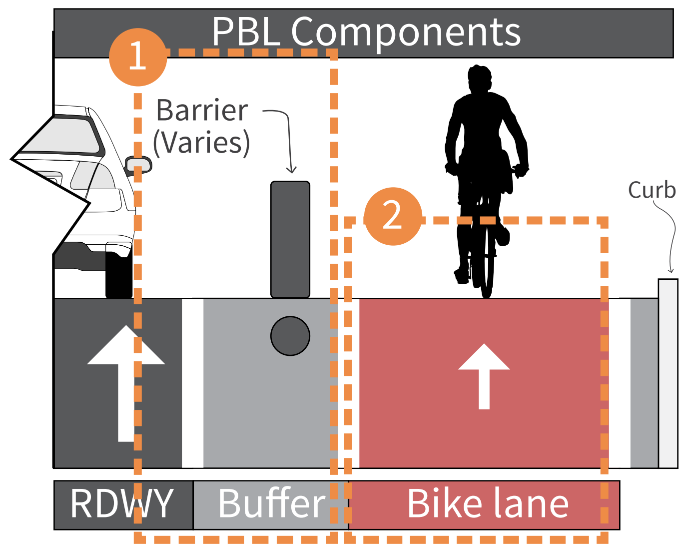


FIGURE 2.3: Overview of PBL components

1 Protective Barrier (Within the Buffer Area)

PBL barriers come in many different shapes and sizes, but the key differences are the level of protection they offer and their permeability (can bikes cross over the barrier). Bike lane types vary depending on specific dimensions and whether they are Uni-Directional or Bi-Directional. The general elements present in all configurations are the buffer area, the barrier itself, and the bike lane (FIGURE 2.3).

Protective Barrier Types
The bicycle advocacy group, People for Bikes, offers a guide to 14 different PBL types. Created by Nathan Wilkes (City of Austin), the guide provides some estimates on required dimensions, protection level, installation cost, durability and aesthetics of each PBL types (APPENDIX 1). The graphic guide is accompanied by an online excel worksheet that includes more detail and information on how the metrics were determined. The 8 barrier types selected for this project from the original 14 are shown in FIGURE 2.4. The protection level, durability, cost, and aesthetic scores came from the original guide whereas the permeability characteristic was created by the author for this project. Additionally, based on research, professional input, and informed value judgments, some of the protection level scores were adjusted for this project.

Protection level represents the perceived level of protection from motor vehicles. "Perceived" is language used in the original source, presumably due to a lack of actual testing of protection level. In other words, bollards and curbs were probably not actually tested by attempting to drive vehicles over them at various speeds, but the perception of cyclists (for good reason) is that a continuous concrete planter offers greater protection than delineator posts.

Permeability relates to the ability of a bicyclist to enter or exit the bike lane through the barrier. This is distinct from the ability of vehicles to cross over the barrier. For instance, vehicles cannot cross over rigid bollards, and thus, this type of barrier provides a high level of protection. However, cyclists can easily enter or exit the bike lane between bollards, providing a level of convenience.

Durability simply implies the longevity of the barrier type. For instance, delineator posts may require frequent replacement, whereas a raised bikeway is extremely durable as it is essentially just another part of the roadway.

Cost represents an estimated installation cost based on new construction costs.

Aesthetics is a subjective score representing the general attractiveness of the barrier type.

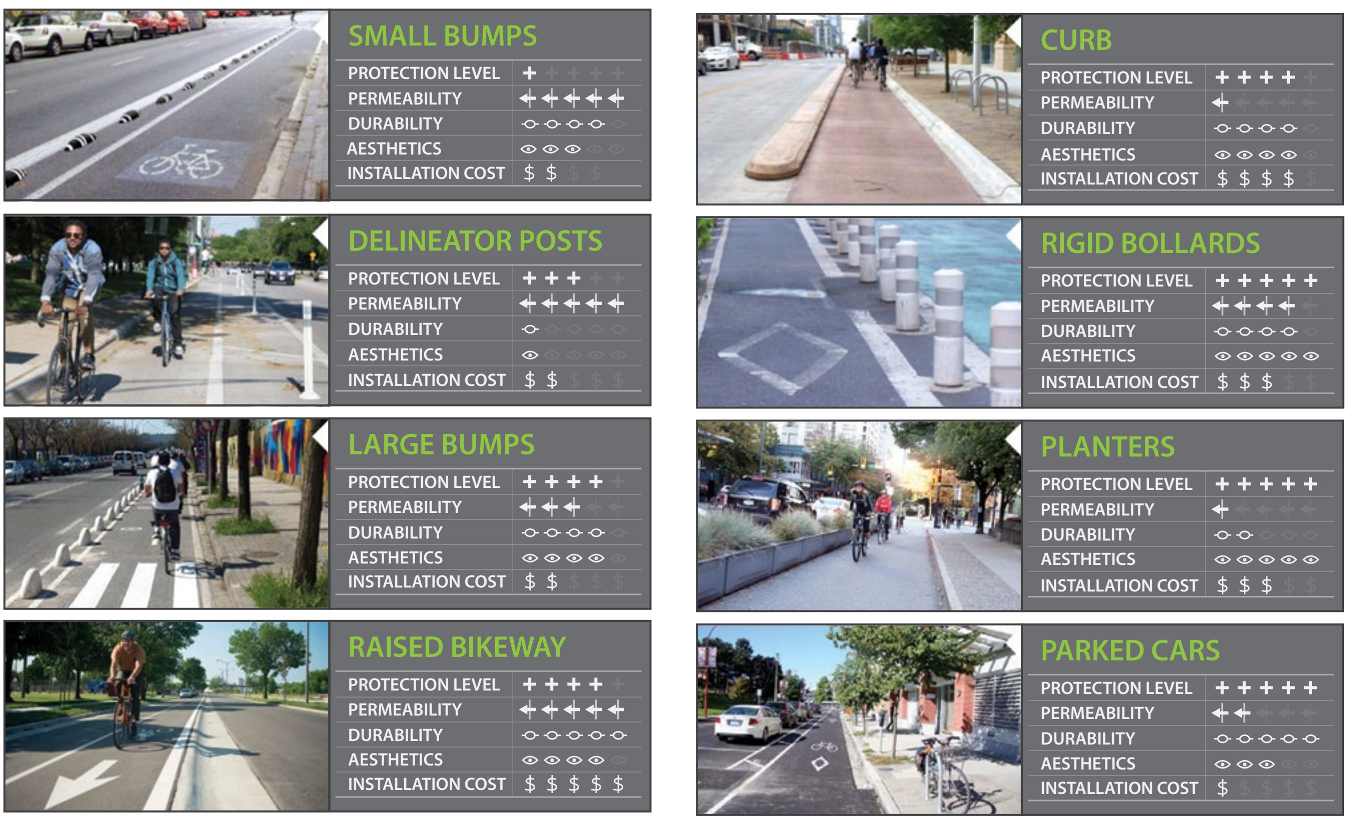


FIGURE 2.4: 8 Protected Bike Lane types selected for this project. The figure is adapted from People for Bikes[3] and some of the information has been augmented/ altered as discussed in section 2.2

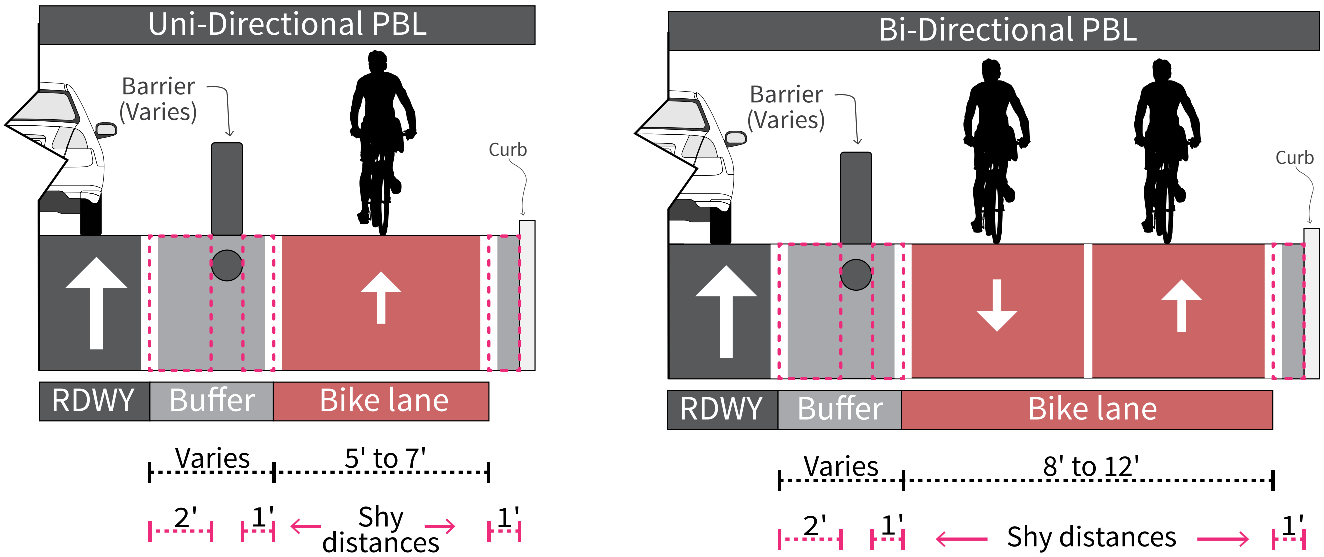


FIGURE 2.5: General dimensions of PBLs

2 Bike Lane Standards

Guidelines for bike facilities vary greatly and are constantly changing with new research and data. Unless otherwise noted, this project refers to the Urban Bikeway Design Guide published by the National Association of City Transportation Officials (NACTO) for all PBL guidelines.[5] The scope of this project is predominantly concerned with the width requirements of PBLs, but the Urban Bikeway Design Guide can (and should) be referenced for all other guidelines such as: lane markings, signage, intersection design, sight triangles for driveways, drainage, and maintenance.

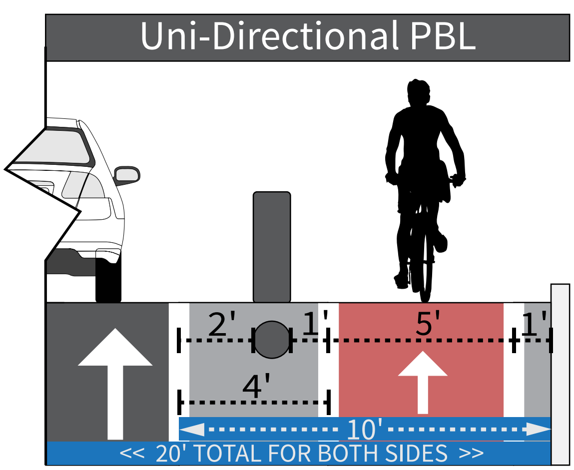
In terms of dimensions, the guide suggests that Uni-Directional PBLs should be between 5' and 7' wide, and Bi-Directional PBLs should be between 8' and 12' wide. Additionally, there should be shy distances of 1' on both sides of the bike lane between striping and the curb and the protective barrier. FIGURE 2.5 illustrates these dimension guidelines for both Uni and Bi-Directional PBLs. The buffer area dimensions vary depending on the specific barrier type used.

Uni-Directional versus Bi-Directional PBL

FIGURE 2.6 highlights some of the benefits and drawbacks of Uni-Directional and Bi-Directional facility types. The two most relevant factors to this project are the convenience for cyclists and the overall dimensions required for facility installation. Generally speaking, it is more convenient for a cyclist to be able to ride on either side of a street, allowing access to businesses and making intersections easier and quicker to navigate. Bi-Directional PBL options do have a couple of significant benefits, however. As the bikeway is much wider on a Bi-Directional facility, it allows for more comfortable riding and the ability to ride next to each other if desired. More importantly, Bi-Directional facilities require significantly less overall space within the R.O.W. as FIGURE 2.7 illustrates. The overall width for the bikeway is narrower in Bi-Directional facilities since the opposing directional bike lanes are connected, allowing cyclists to share the space. Further space is saved since only one buffer area is required instead of two. In the scenario illustrated in FIGURE 2.7 this can be a difference between needing 13' total for a Bi-Directional facility versus 20' required for two Uni-Directional facilities on either side of a street.

Uni-Directional PBL	Bi-Directional PBL
Benefits • More convenient for cyclists • Intersections are easier to design • Safer since cars expect bikers from normal direction	**Benefits** • Less overall space needed within R.O.W. • Wider overall lane for cyclists except for times when passing • Good on one-way roads to allow contra-flow traffic and if placed on the left side of the street, no interference with bus stops
Drawbacks • More overall space required within R.O.W.	**Drawbacks** • Increased conflict as drivers don't expect bikers from wrong direction • Intersections more complex to design • Less convenient for cyclists

FIGURE 2.6: Uni-Directional versus Bi-Directional PBL options and their benefits and drawbacks



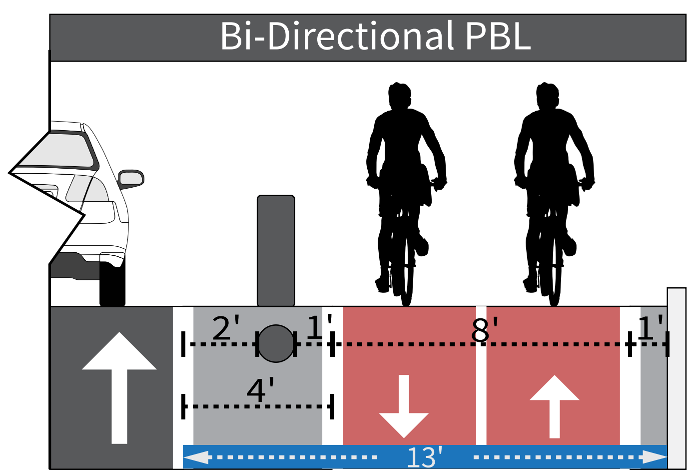


FIGURE 2.7: Saving space by using Bi-Directional PBLs

16 Protected Bike Lane Types

To summarize, each PBL has a unique barrier type with particular dimensions and characteristics. Additionally, within each PBL type, the specific dimensions of the bike lane itself can range from the minimum width and up. Counting both Uni-Directional and Bi-Directional options for each of the 8 different barrier types results in 16 distinct PBL types. The complete list of all 16 PBL types can be found in APPENDIX 2, but FIGURE 2.8 uses just one of the PBL types to summarize all PBL components discussed.

Overview of PBL Components

1. PBL type
2. PBL score card
3. Width requirements for PBL type from curb face to traffic lane striping
4. TOTAL width requirement for two Uni-Directional installations
    - In the Uni-Directional Bollard PBL below, if only one PBL is installed on one side of a street (for instance on a one-way street), the total required dimension is 10’-12’. In cases where the PBLs are installed on both sides, the total required dimension is 20’-24’

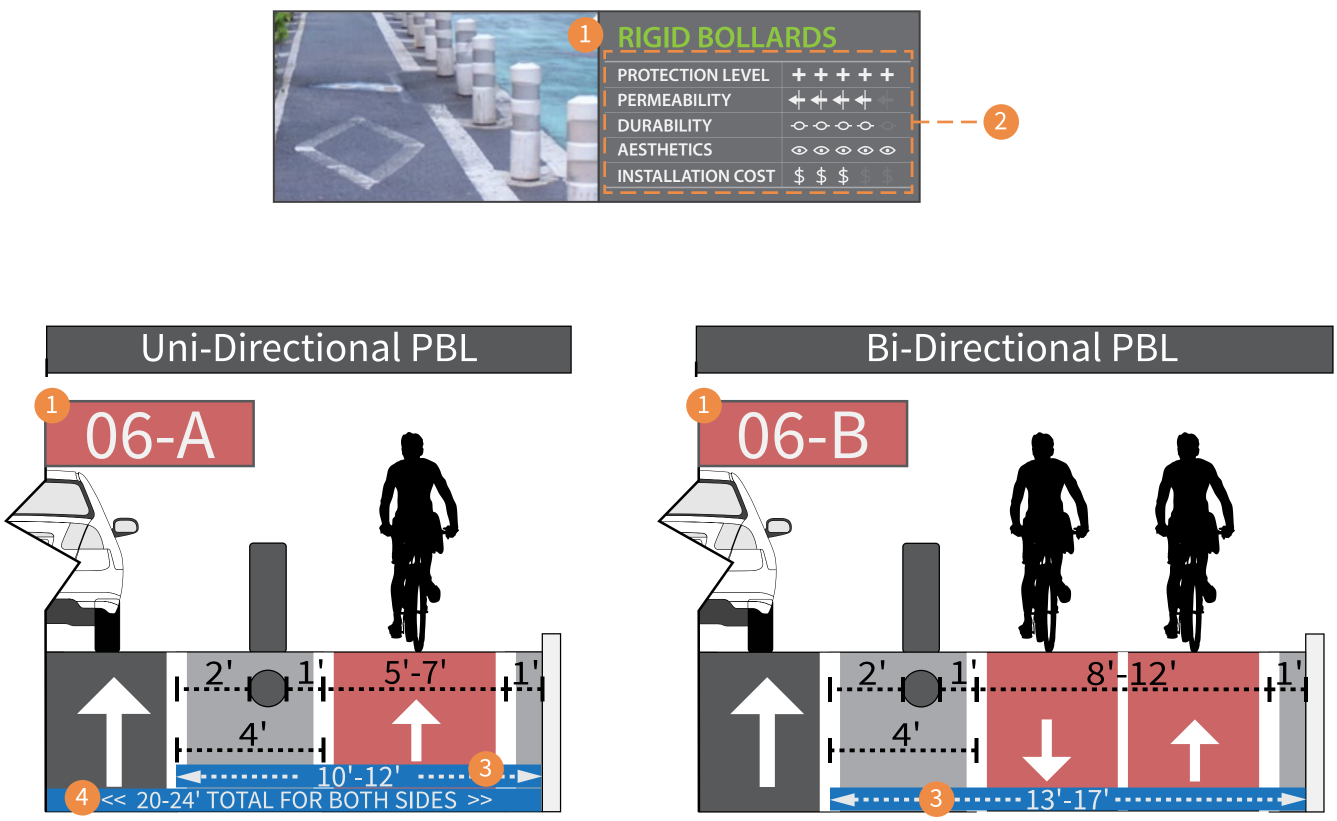


FIGURE 2.8: Typical PBL components

Summary

As this chapter illustrates, there are numerous moving parts when it comes to dimensions and other design standards for street components and for Protected Bike Lanes. Indeed, in addition to defining and establishing all of these, this chapter illustrates the need for a tool that will aid in matching any particular street configuration with the most suitable Protected Bike Lane type.

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CHAPTER 3
CREATING THE PROTECTED BIKE LANE SUITABILITY TOOL

CH.3

FIGURE 3: Kid cycling on major street in Seville on PBL.
(http://whichwayaustin.blogspot.com/2012/06/biking-seville.html

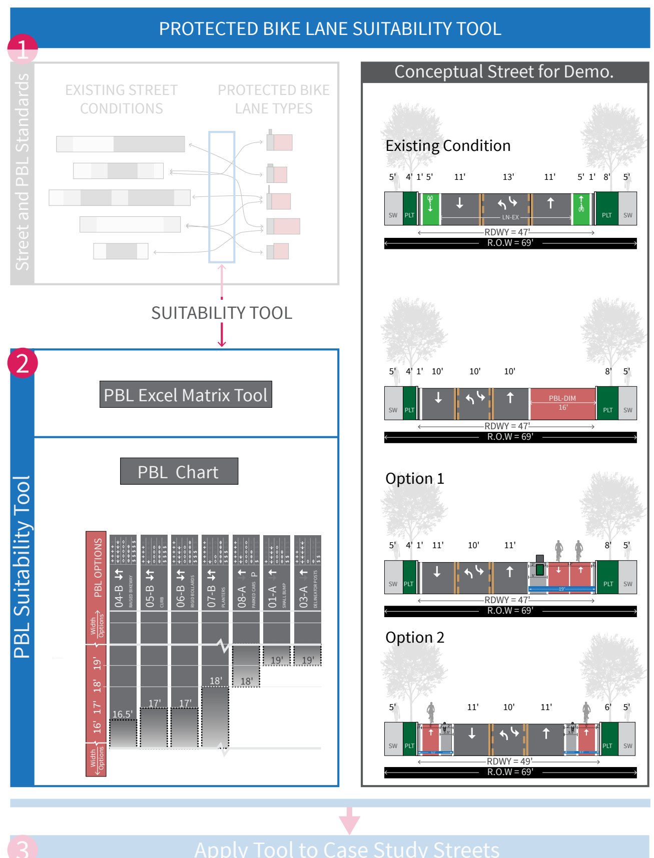
Overview

Now that all of the relevant street and Protected Bike Lane design standards have been defined and established, the PBL Suitability Tool can be created and demonstrated. As this main component of the project is essentially a tool, the description of it will be analogous to a step-by-step instruction guide accommodated with a graphic representation of how the tool is applied to a conceptual street.

This Chapter Includes:

1) Step-by-step instructional guide of the PBL Suitability Tool
   - Interactive PBL Excel Matrix Tool
   - PBL Characteristic Chart
   - Conceptual Street for Demonstration

2) Step-by-step instructional guide for the Interactive Excel Matrix



3.1 PBL Suitability tool: A Step-by-Step Guide

The PBL Suitability Tool has an interactive Excel Matrix component and a graphic chart component. Based on the user's input of existing street conditions, the Excel matrix provides a PLB-DIM number representing the maximum width available for a PBL. This number is used with the PBL Chart to narrow down the options to a set of potential PBL types given the maximum PLB-DIM width. Final choices are made from this set of possible PBL types based on several user-decided factors.

Refer to FIGURE 3.1 on the next page for the following detailed, step-by-step procedure.

1 **Existing Conditions**

The first step is analyzing the existing conditions of a street. Analysis includes dimensioning of all components and noting other relevant information like the presence or absence of street trees / utility poles etc. in the planting strip. Some of this can be done remotely with the use of Geographic Informational Systems (GIS), or aerial imagery, but it is likely that on-site groundtruthing will be necessary to get the exact dimensions of all street components.

The cross section of the conceptual demonstration street shows all of the relevant components and their dimensions:

- (69') R.O.W. : Right of way.
- (47') RDWY: The Roadway
- (35') LN-EX: Existing lane widths and configurations
- (5')(5') SW: 2 Sidewalks
- (4')(8') PLT: 2 Planting Strips
- (5')(5') Bike symbol: Existing conventional bike lane facilities

2 PBL-DIM: Deriving the Protected Bike Lane Dimension Number

This is a brief overview of how the Interactive PBL Excel Matrix fits into the overall process. The step-by-step instructions of the Excel Matrix are located after this overview. Essentially, the relevant dimensions from the existing street conditions are entered into the interactive Excel Matrix resulting in the PBL-DIM number representing the maximum width available for a PBL.

- The dimensions from the sidewalk, planting strip, travel lanes and parking are added together, and subtracted from the R.O.W. Then, the Excel Matrix allows the user to alter the lane widths and configurations of all street elements in order to increase the PBL-DIM number.

PBL-DIM= 16'

In this example, the Excel Matrix operations result in 16' of available space for a PBL.

3 PBL Chart

Using the resulting PBL-DIM number, the user now refers to the PBL Chart to narrow down the PBL choices.

FIGURE 3.1 shows just a part of the PBL Chart to illustrate where it fits within the steps. Refer to FIGURE 3.2 to follow along with the example on the complete PBL Chart.

The PBL Chart includes all of the 16 different PBL types. Each PBL type is described in terms of its ID number, a descriptive name, its score card, and whether it is Uni-Directional or Bi-Directional. The gray bars show the Minimum and Desired widths for each PBL. For Uni-Directional PBL types, each PBL bar is split into two options: 1) Uni-Directional PBL installed in both directions or 2) Uni-Directional PBL installed in only one direction (sometimes used on one-way streets).

4 Using the PBL Chart.

The user locates the PBL-DIM number and follows the corresponding line across the PBL bars. Each bar that the line crosses corresponds to a potential PBL type. For instance, with the 16' PBL-DIM number, all of the Bi-Directional PBL types are possibilities, but 16' is too narrow for any of the Uni-Directional PBLs.

Note that all of the Uni-Directional PBLs would still be possible if they were only installed on one side of the street, meaning only in one direction.

5 Making Decisions

Option 1 - Staying within the Roadway: At this point all of the Bi-Directional PBLs are available given the 16' PBL-DIM number, and the user would refer to the score card of each PBL type to make further decisions. In real scenarios, there may be other considerations for choosing a PBL type. For instance a specific PBL may be chosen so that it matches the PBL type that exists further down the street, or the surrounding context may also be an important factor. For the sake of this example, the Bi-Directional Planter PBL (07-B) is chosen.

Option 2 – Expanding the Roadway: As it was previously discussed, two Uni-Directional PBLs are typically more convenient for cyclists than one Bi-Directional PBL since it allows access to both sides of a street. They are also considered safer because cyclists approach intersections and driveways from the direction that drivers expect them, and thus see them. However, in order to install two Uni-Directional PBLs on this given street, a minimum of 19' is required. Note that there is the Parked Car PBL option, but it requires the existence of on street parking to provide the barrier area. As the detailed Excel Matrix instructions explain, entering a desired PBL-DIM number of 19' results in a necessary expansion of the existing roadway by 2'. In this case, the example works under the premise that the existing conditions allow the removal of 2' from the 8' Planting Strip. Thus, option 2 illustrates how two Uni-Directional Small Bump PBLs (01-A) can be installed with the 2' expansion of the Roadway.

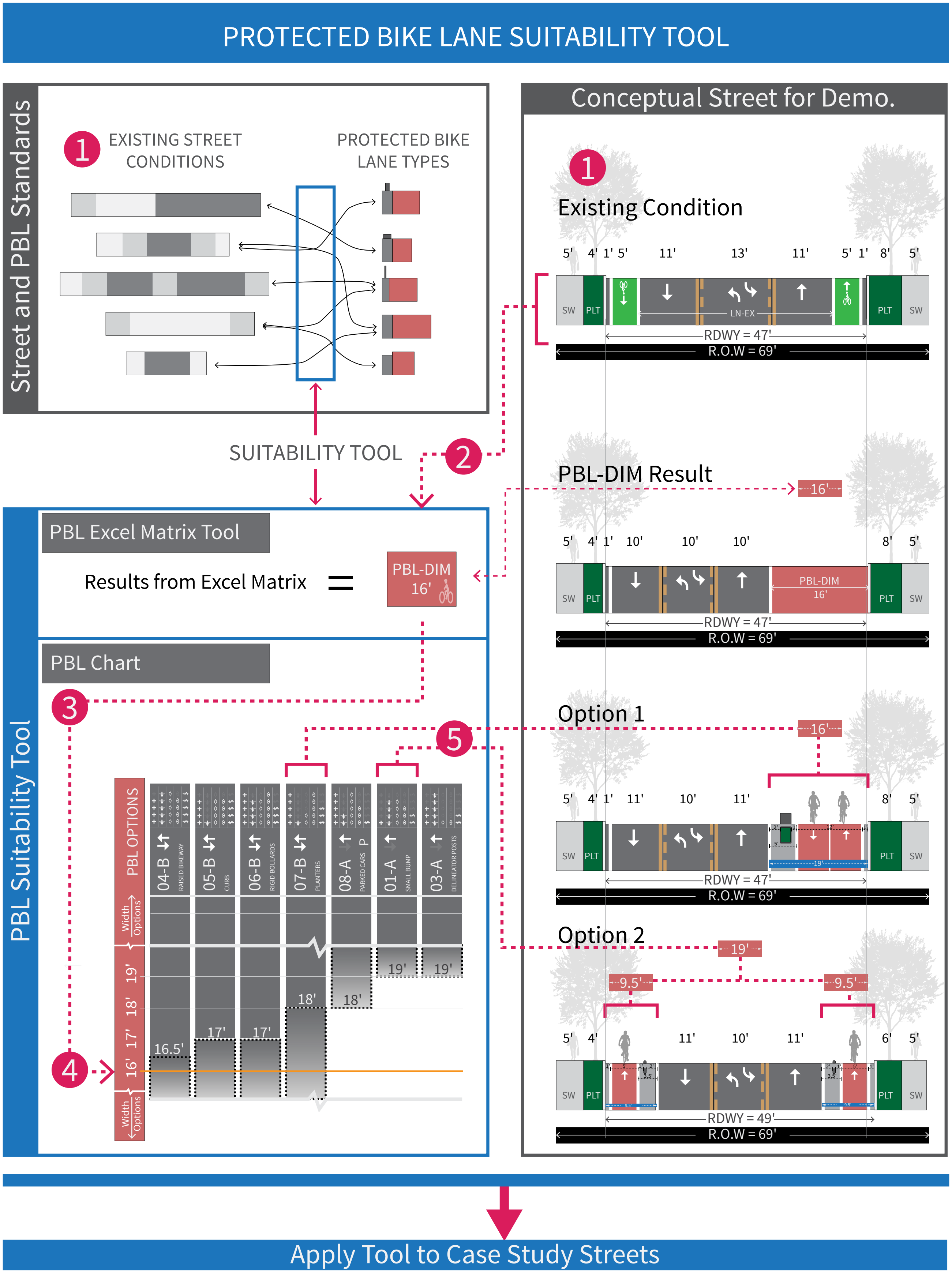


FIGURE 3.1: Step-by-Step process diagram of the Protected Bike Lane Suitability Tool

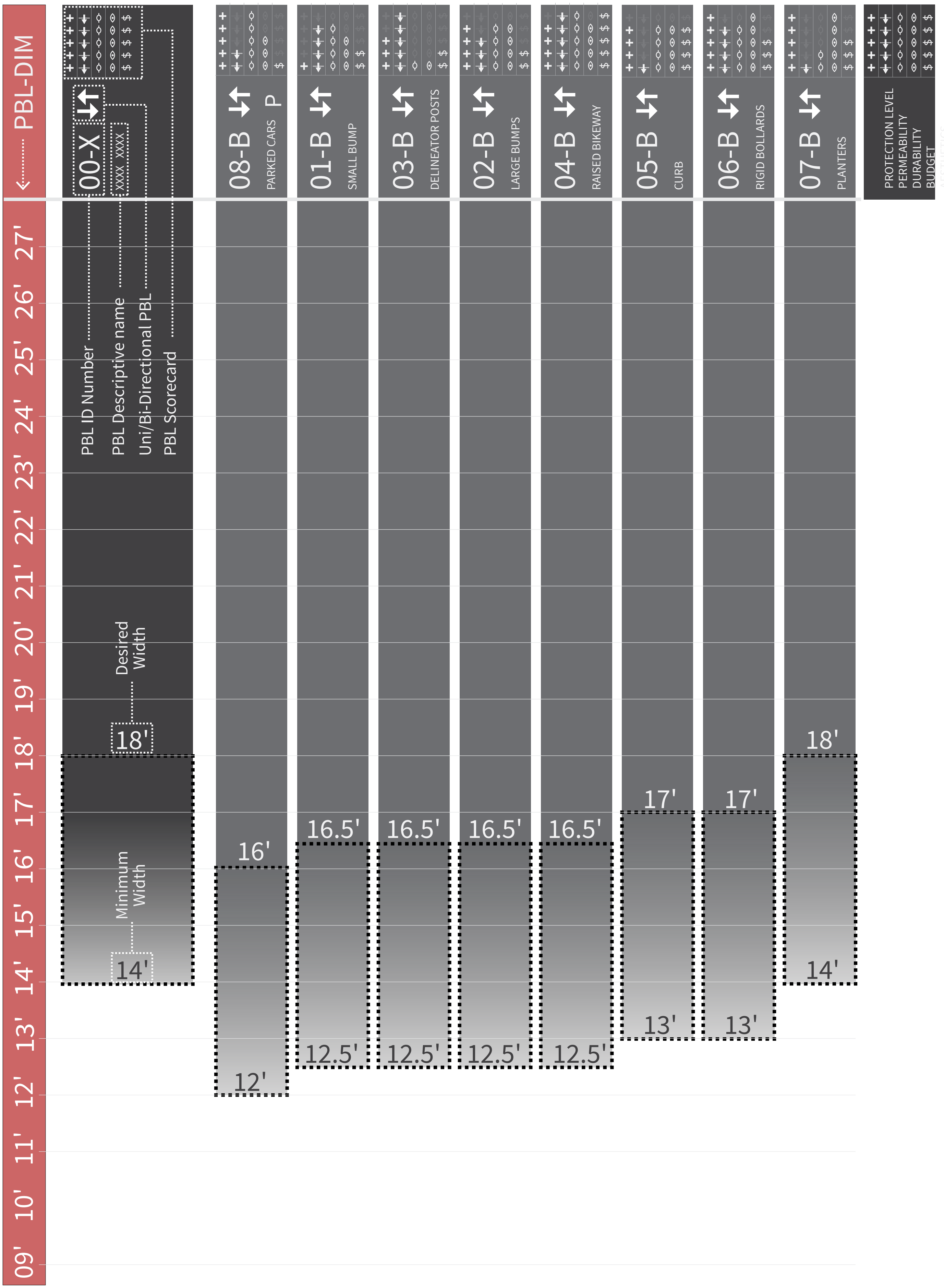
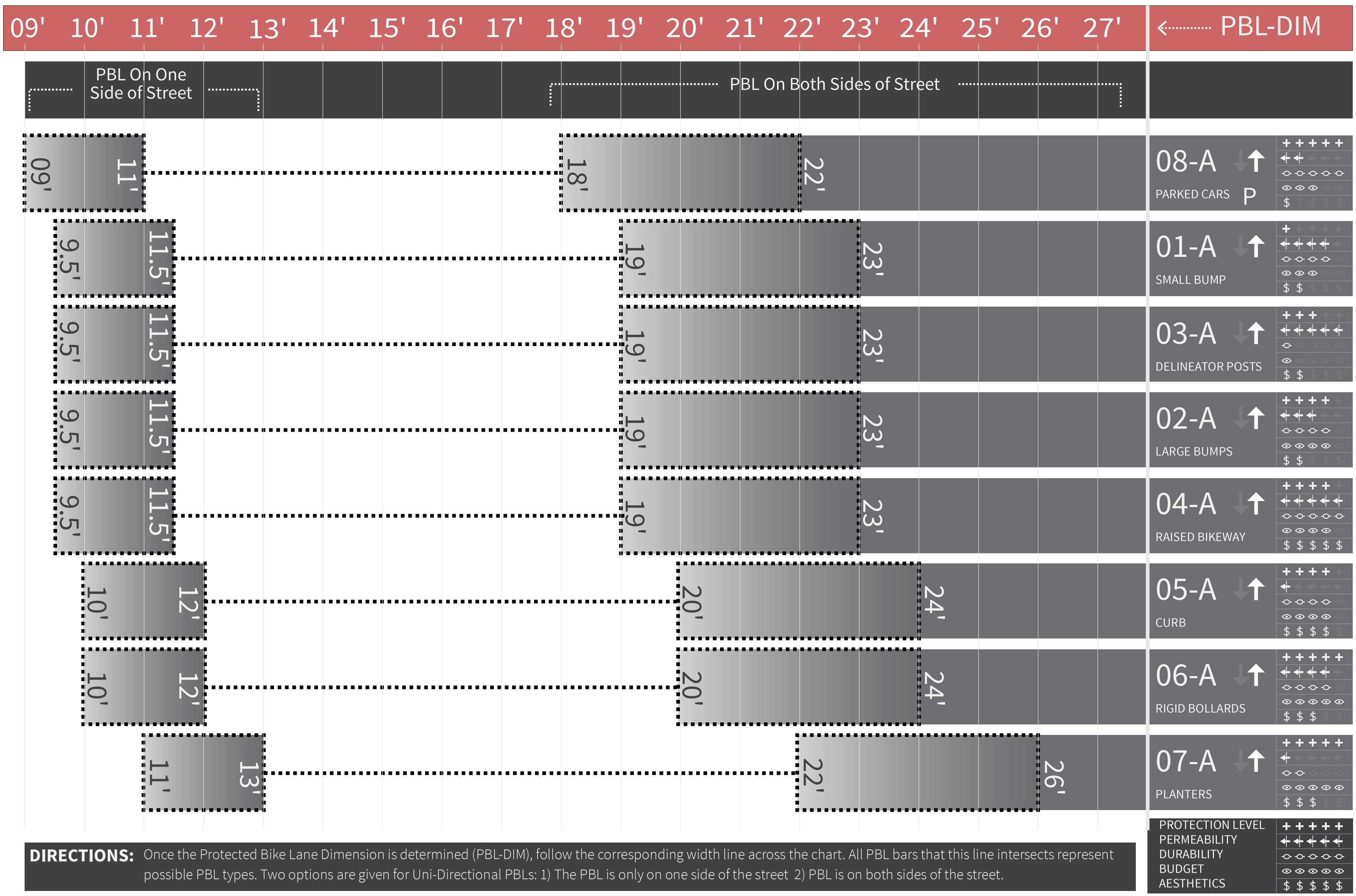


FIGURE 3.2: PBL Chart showing all PBL types and characteristics



DIRECTIONS: Once the Protected Bike Lane Dimension is determined (PBL-DIM), follow the corresponding width line across the chart. All PBL bars that this line intersects represent possible PBL types. Two options are given for Uni-Directional PBLs: 1) The PBL is only on one side of the street 2) PBL is on both sides of the street.

3.2 Interactive Excel Matrix: A Step-by-Step Guide

As mentioned in the overall step-by-step instructions, the Excel Matrix is the Interactive tool used to derive the PBL-DIM number. It is the main engine of the PBL Suitability Tool. First, the basic components of the matrix are explained, followed by a detailed step-by-step instruction guide using the sample conceptual street from the preceding overall instructions.

Basic Components of the Excel Matrix

The Excel Matrix FIGURE 3.3 is designed to be intuitive and requiring minimal instructions. User values are input into the green boxes, resulting in output values in the tan boxes. The matrix has the following components:

1 **Case Study Street**

The name of the case study street is entered here for reference. The distinct rows are as follows:

- Existing Conditions
    - All values in this row represent existing conditions of the street.
- Intervention Options
    - Everything below this separator line represents the various interventions made.
- Stay Within Curbs
    - Interventions are restricted to the roadway; the area between the existing curb faces. The sidewalks and/or planting strips are therefore locked and cannot be altered.
- Expand Curbs
    - Interventions include expanding the roadway by altering the sidewalks and/or planting strips

2 **Street Configurations**

This is where all of the relevant street component dimensions are entered
Input dimension values:

SW 1: Sidewalk 1
PLNT 1: Planting Strip 1
LANES EXIST: The combined width of existing travel lanes
LANES MIN: The minimum combined width that the lanes can be narrowed to
PARK: Existing parking
Shy: Existing and proposed Shy distances
PLNT 2: Planting Strip 2
SW 2: Sidewalk 2

3 **Results**

This is where the key output results are displayed based on the user input. The three outputs are:

- RDWY
    - Gives the roadway or curb-to-curb dimensions of the street.
- R.O.W
    - Gives the Right of Way dimensions of the street
- PBL-DIM
    - Gives the available dimension for a Protected Bike Lane. It essentially adds all of the necessary street components and subtracts it from the R.O.W.

	PBL 1 ---->	SELECT PBL TYPE								PBL 2 ---->			SELECT PBL TYPE		
1 CASE STUDY STREET	2 STREET CONFIGURATIONS									3 RESULTS			4 ADDITIONAL OPTIONS		
TEMPLATE	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->				---------											---------
INTERVENTION OPTIONS															
Stay within Curbs			---------				---------			######				#VALUE!	Add interventions here
Expand Curbs			---------				---------							#VALUE!	Add interventions here

FIGURE 3.3: PBL Interactive Excel Matrix Overview

4 Additional Options

The Excel Matrix provides some additional options to make the process more convenient and iterative.

- Desired PBL-DIM
    - If the user knows the exact dimension required for a project, this number can be entered here resulting in the next output:
- Add Width Required
    - Based on the Desired PBL-DIM input, the additional width required for a PBL is given.
- Interventions Made
    - This box is for the user to input in their own language the specific interventions made for their own record. For instance the input could be : “expanded curb by 3' into west side planting strip”.

5 PBL Selection Pull Down Menus

There are two pull down menus at the top of the chart that show all of the possible PBL types and their range of dimensions from minimum to preferred (FIGURE 3.4). If a Bi-Directional PBL is desired, only one selection is necessary. If two Uni-Directional PBLs are preferred, each pull down selection represents one side of the street. The user can choose two of the same PBLs or two different ones. The dimensions can then be added together and input into the Desired PBL-DIM input box as previously described.

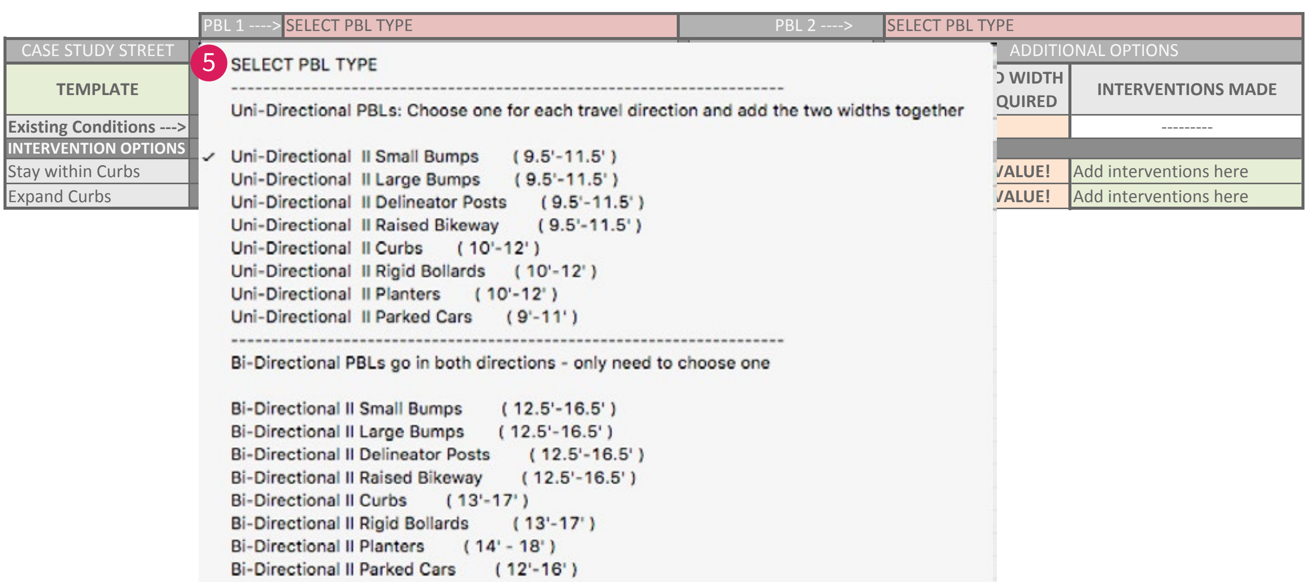


FIGURE 3.4: Excel Matrix Pull-Down menu showing all 16 PBL types

Step-by-Step Guide to the Excel Matrix

Conceptual Case Study Street

The following instructions use the conceptual street example from the overall instructions to demonstrate how the Excel Matrix works. Recall that the intent in this conceptual scenario was to install PBLs in both travel directions and that this can be accomplished with either a single Bi-Directional PBL, or two Uni-Directional PBLs. The following step-by-step instructions show both options. Refer to FIGURE 3.5 for option 1.

1 Existing Conditions

The first step is to input all of the collected existing street condition numbers in the green input boxes. Once all necessary boxes are filled in, the matrix produces three outputs:

2 RDWY: The roadway is 47'

R.O.W. : The Right of Way is 69'

PBL-DIM: At this point, the only available dimension for a PBL is the existing bike lane dimension, which sums to 10'

3 Intervention 1: Staying within the Roadway

The first option for intervention is to stay within the existing curbs by re-striping (re-configuration of) the roadway. Thus, on the second row, the sidewalks and planting strip boxes are locked and cannot be altered.

The three new inputs are:

LANES MIN: The new width of the travel lanes. This number depends on minimum lane width standards specific to each street condition. In the illustrated example, the existing lane dimensions were narrowed to: two 10' wide travel lanes and a 10' center turn lane for a total of 30'.

PARKING: Existing parking can be changed in width or eliminated all together if necessary.

SHY: Most streets have a certain shy distance, which often houses the street gutters. This area between the lane striping and the actual curb face is usually between 12”-16”. As the dimensions of all PBLs include this shy distance, the user should enter 1' in cases where only one side of the street will have a PBL, or 0' if both sides of the street will have PBLs. In this example, as the PBL-DIM suggests that only Bi-Directional PBLs would fit, a 1' shy distance is entered.

NOTE: EXISTING BIKE LANES: There is no input value for existing bike lane widths, as this dimension will be added to the potential PBL-DIM width.

4 Output for Intervention 1: PBL-DIM = 16'

As the curb-to-curb dimension and the R.O.W. stay the same, the only change is the PBL-DIM number. In this case, narrowing the lanes alone resulted in a 16' PBL-DIM number. Following the previous example then, the Bi-Directional Planter PBL is chosen

	PBL 1 ---->	SELECT PBL TYPE								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CONCEPT STREET	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	4	35	---------	0	2	10	8	5	47	69	10			---------
INTERVENTION OPTIONS															
Stay within Curbs	5	4	---------				---------	8	5	47	69			#VALUE!	Add interventions here
Expand Curbs			---------				---------				69			#VALUE!	Add interventions here

	PBL 1 ---->	Bi-Directional II Planters (14' - 18')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CONCEPT STREET OPTION 1	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	4	35	---------	0	2	10	8	5	47	69	10			---------
INTERVENTION OPTIONS															
Stay within Curbs	5	4	---------	30	0	1	---------	8	5	47	69	16		#VALUE!	Minimized Lanes
Expand Curbs			---------				---------				69			#VALUE!	

FIGURE 3.5: Option 1: Bi-Directional Planter PBL

Intervention 2: Expanding the Roadway
The second intervention option illustrates a scenario where two Uni-Directional PBLs are preferred. Refer to FIGURE 3.6 for Option 2.

1. **The existing conditions remain the same, as do the inputs for parking and minimum lane dimensions. However, since this intervention calls for PBLs on both sides of the street, and since all PBLs include the necessary shy distance, the shy distance is set to 0 in this case.**

2. **PBL-DIM = 17'**
The extra foot of space from the shy distance is why the resulting PBL-DIM number is 17' instead of 16'.

3. **PBL Selection**
Selecting two Uni-Directional Small Bump PBLs (01-A) from the pull-down menus shows that a minimum of 19' is required for installation (2x 9.5')

4. **PBL-DIM and ADD Width Required**
Entering 19' into the Desired PBL-DIM box shows that an additional 2' of width is required.

5. **In this scenario, the roadway is expanded 2' by narrowing the 8' planting strip down to 6'**

	PBL 1 --->	Uni-Directional II Small Bumps (9.5'-11.5')								PBL 2 ---->			Uni-Directional II Small Bumps (9.5'-11.5')		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CONCEPT STREET OPTION 2	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	**5**	**4**	**35**	---------	**0**	**2**	**10**	**8**	**5**	**47**	**69**	**10**	**19**	**9**	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	4	---------	30	0	0	---------	8	5	47	69	**17**	19	**2**	Minimized Lanes
Expand Curbs			---------				---------				69		19	**#VALUE!**	

	PBL 1 --->	Uni-Directional II Small Bumps (9.5'-11.5')								PBL 2 ---->			Uni-Directional II Small Bumps (9.5'-11.5')		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CONCEPT STREET OPTION 2	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	**5**	**4**	**35**	---------	**0**	**2**	**10**	**8**	**5**	**47**	**69**	**10**	**19**	**9**	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	4	---------	30	0	0	---------	8	5	47	69	**17**	19	**2**	Add interventions here
Expand Curbs	5	4	---------	30	0	0	---------	6	5	49	69	**19**	19	**0**	Add interventions here

FIGURE 3.6: Option 2: Two Uni-Directional Small Bumps PBLs

Summary

This chapter described the nuts and bolts of the PBL Excel Matrix and the PBL Chart, and demonstrated how the two components are used in tandem to find a suitable PBL type for a cross-section of a conceptual street. The next step is to apply the PBL Suitability Tool to real case study streets in Eugene, OR.

CHAPTER 4
APPLYING THE TOOL TO CASE STUDY STREETS

CH.4

FIGURE 4: Adolescents riding in Holland (https://aseasyasridingabike.wordpress.com/2013/12/31/not-dangerous/)

Overview

Now that the Protected Bike Lane Suitability Tool has been created, its components described, and its use demonstrated on a conceptual street, the next step is to apply the tool to case study streets within Eugene, OR in order to demonstrate its flexibility and versatility in a real-life scenario.

First, a number of case study streets will be identified and briefly described in terms of quantitative and qualitative characteristics. Then, a template is provided showing how to read the results of the PBL Suitability Tool, which then is followed by the results.

This Chapter Includes:

1) Case study street selection criteria are described
2) Three case study streets selected from Eugene, OR
3) How to read the results
4) Results of the PBL Suitability Tool

4.1 Case study selection criteria

The PBL Suitability Tool is meant to work on any street with a diversity of street conditions. For the purpose of demonstration, however, streets with complex challenges are more suitable than streets that are either too 'simple' or where PBLs are not feasible. For instance, streets that are relatively homogeneous (unchanging lane configurations, R.O.W, street dimensions etc.), with ample space for any of the PBL types would not adequately demonstrate the Tool's capabilities. Likewise, streets that are too restrictive for any PBL installation would simply return zero results. Therefore, case study street selection was based on both objective and subjective criteria explained below.

Minor or Major Arterial.
PBLs are not necessary for all street types. Bike lanes and/or shared lane markings are more appropriate for most local and collector streets that have low traffic volume and speeds. On high volume and higher speed streets, however, PBLs are essential in providing safety for cyclists. Thus, this project only considers minor or major arterial streets within Eugene.

Variety of Conditions.
Street conditions like lane configurations often change over the course of a street's corridor. For instance, the number of lanes and their dimensions may change, on-street parking is not constant, and planting strip characteristics vary continuously. Thus, to demonstrate how the tool can address a variety of conditions and challenges, streets were chosen to include the following:

- Variety of R.O.W. widths
- Both one way streets and two way streets
- Some on-street parking, some without parking
- Condition where intervention has to remain within the curbs
- Condition where the curbs can be expanded

4.2 Three Case Study Streets

The map of Eugene (FIGURE 4.1) highlights the three case study streets as well as the rest of the minor and major arterials, shown as orange and magenta respectively. While the PBL Suitability Tool could be applied to any street, the three highlighted streets were chosen for the following of reasons:

Chambers Street
- Chambers St. is a minor arterial south of 7th Ave and a major arterial north of it. (6th and 7th avenues are the two major arterials running east and west through Eugene).
- 5 distinct segments were identified along Chambers, each with a particular existing street condition.
- Chambers St. is a major north-south corridor, and one of the only connections between North and South Eugene.

River Road
- Chambers St. crosses a major railroad via an overpass, after which, the road turns into River Road.
- With two lanes in each direction, it is the largest of the three case study streets
- River Rd. is a major north-south corridor, and one of the only connections between North and South Eugene.

High Street
- High St. is a minor arterial
- It is a one-way street with two travel lanes and parallel parking. There are a significant number of streets in Eugene that have identical or very similar lane configurations
- 2 distinct segments were identified, one within the downtown area, and one just south of it.
- High St. is an important connector between Amazon trail to the south, and the Ruth Bascom Bike Multi-Use Path to the north.

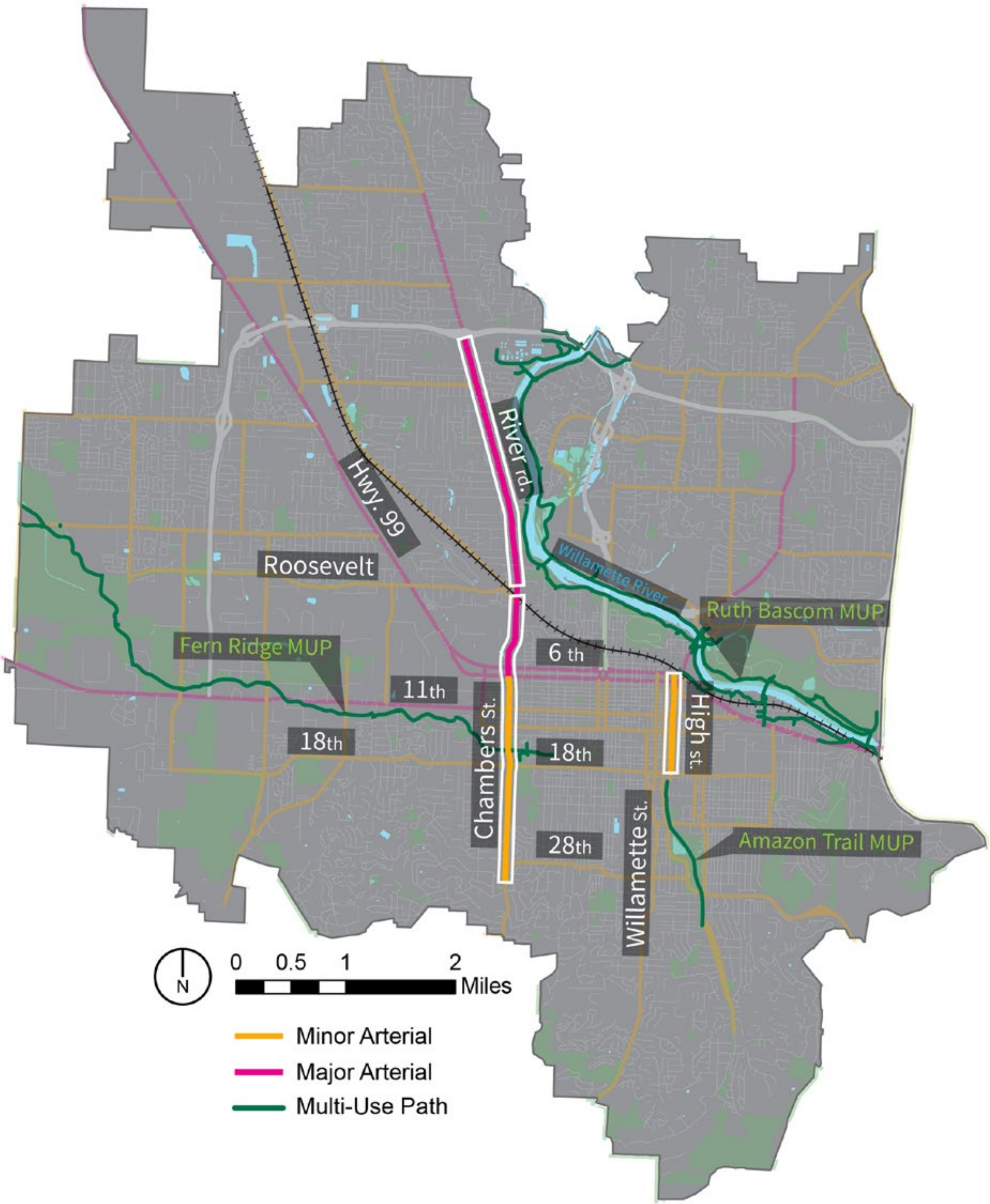


FIGURE 4.1: Eugene, OR context map showing three case study streets outlined in white

4.3 Reading The Results

This page demonstrates how to read the results found for the case study streets.

Each of the three case study streets will first be introduced with an overview page including a context map of the street and its distinct segments.

The overview page is then followed by a number of pages illustrating the results of applying the PBL Suitability Tool to each segment.

The opposite page shows the layout template used to display the results for each segment of each street.

1

Existing Conditions

This section will provide a brief overview of the existing street conditions found within the particular segment. This information may include specific lane configuration and dimensions as well as any qualitative observations. The dimensions of street components were found by on-site measurement, and are illustrated in the provided graphic cross-section on the bottom of the page.

2

Deriving the PBL-DIM Number Using Excel Tool

(Refer to Chapter 3 for step-by-step instructions)

This section shows the resulting PBL-DIM number derived from working with the PBL Excel Matrix. As a reminder, the relevant dimensions from the existing street conditions are entered into the interactive Excel Matrix resulting in the PBL-DIM number representing the maximum width available for a PBL. Due to the number of steps involved in the whole process, this section only talks about the resulting PBL-DIM number and provides an image of the filled out Excel Matrix on the bottom of the page. The step-by-step guide for using the PBL Excel Matrix is provided in chapter 3.

3

Intervention

Refer to PBL Chart (FIGURE 3.2)

This section discusses how the PBL Chart is used with the PBL-DIM number to make decisions on the most suitable PBL type. Again, as the PBL Chart is too extensive to show with each results page, this section only refers to the PBL types that are selected from the Chart. FIGURE 3.2 should be referred to follow along with the complete PBL Chart.

Chambers St. Segment 1 of 5

(Between 28th ave. and 24th ave.)

1

Existing Conditions

The street configuration in segment 1 is: a single lane in each direction with parallel parking on the west side of the street and bike lanes on both sides of the street. There is a wide planting strip on the east side, and no planting strip on the west side.

2

Deriving the PBL-DIM Number Using Excel Tool

(Refer to Chapter 3 for step-by-step instructions)

As explained in the previous section, the existing street component dimensions are entered into the Excel table as shown below. As the table shows, the first intervention of narrowing the 14' travel lanes down to 10' each results in a PBL-DIM number of 21'.

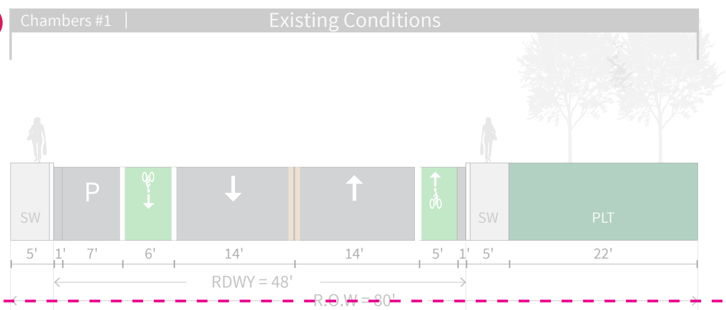
3

Intervention

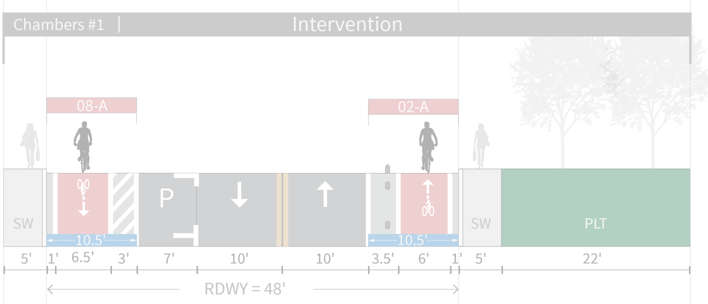
Refer to PBL Chart FIGURE 3.2

As the PBL Chart shows, a PBL-DIM number of 21' allows for almost all PBL options. In this case, to preserve the existing parallel parking on the west side of the street, the Parked Car PBL (08-A) will be used on that side. As this PBL type requires a minimum of 9', there is 12' left for the other side of the street. Again, as the PBL Chart shows, 12' of space allows for any of the Uni-Directional PBL choices, so the decision from here can depend on specific project factors like budget, aesthetics, context and so on. For this example, Large Bumps PBL (02-A) is used which requires a minimum of 9.5'. Since only 18.5' are used out of the possible 21', the left over width in this case is added to the PBL dimensions to make for wider bike lanes.

1



3



Interventions

- Narrow lanes to 10'
- Parking retained
- Parking PBL(08-A) on west side
- Large Bump PBL (02-A) on east side

2

	PBL 1 ---->	Uni-Directional II Parked Cars (9'-11')								PBL 2 ---->			Uni-Directional II Large Bumps (9.5'-11.5')		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CHAMBERS 1	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	CURB TO CURB	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	0	28	---------	7	2	11	22	5	48	80	11	18.5	7.5	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	0	---------	20	7	0	---------	22	5	48	80	21	18.5	-2.5	Minimized Lanes
Expand Curbs			---------				---------				80		18.5	#VALUE!	Add interventions here

4.4 Results

Chamber Street Overview

The first case study analyzed is Chambers Street, a major north-south thoroughfare in Eugene. Site analysis revealed five distinct segments (with unique existing street conditions) along the corridor between W. 28th Ave on the south end, and the railroad bridge on the north end (FIGURE 4.2).

- Chambers St. is a minor arterial south of 7th Ave and a major arterial north of it. (6th and 7th avenues are the two major arterials running east and west through Eugene).
- 5 distinct segments were identified along Chambers, each with a particular existing street condition.
- Chambers St. is a major north-south corridor, and one of the only connections between North and South Eugene.

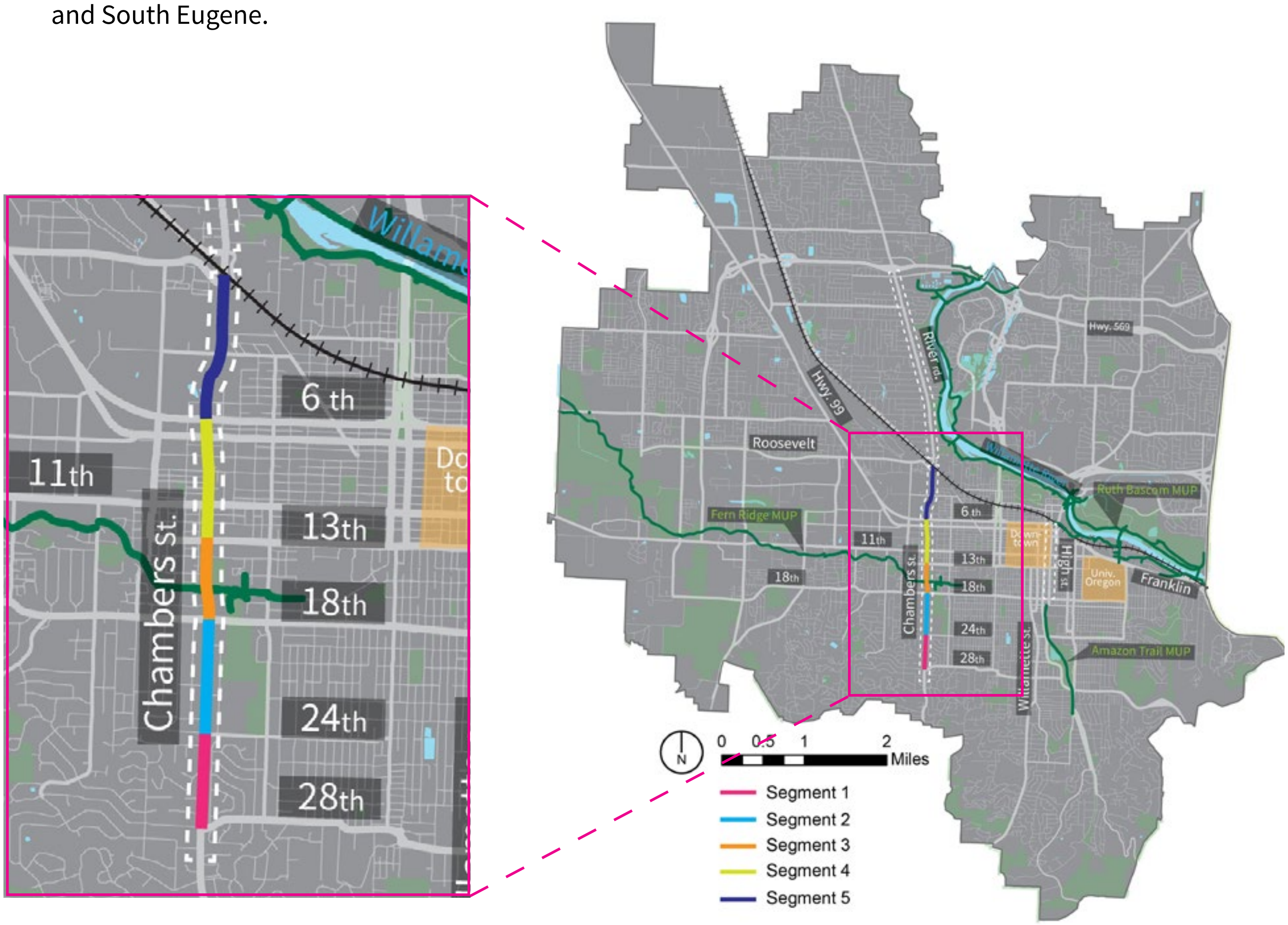


FIGURE 4.2: Case study 1: Chambers St. and its 5 distinct segments

Chambers St. Segment 1 of 5

(Between 28th ave. and 24th ave.) (length = 0.4mi)

1 **Existing Conditions**

The street configuration in segment 1 is: a single lane in each direction with parallel parking on the west side of the street and bike lanes on both sides of the street. There is a wide planting strip on the east side, and no planting strip on the west side.

2 **Deriving the PBL-DIM Number Using Excel Tool**

(Refer to Chapter 3 for step-by-step instructions)

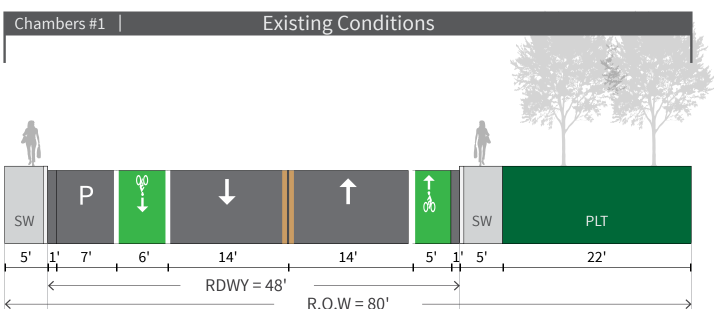
As explained in the previous section, the existing street component dimensions are entered into the Excel table as shown below. As the table shows, the first intervention of narrowing the 14' travel lanes down to 10' each results in a PBL-DIM number of 21'.

3 **Intervention**

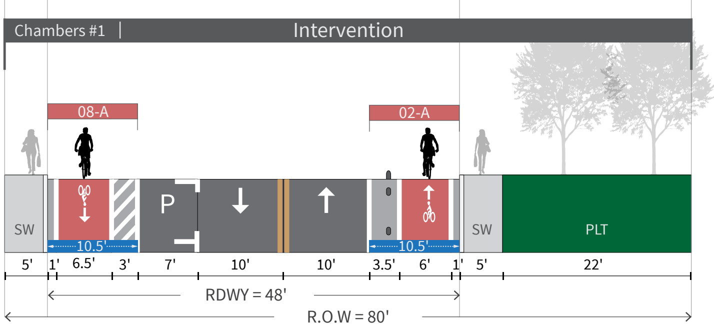
Refer to PBL Chart FIGURE 3.2

As the PBL Chart shows, a PBL-DIM number of 21' allows for almost all PBL options. In this case, to preserve the existing parallel parking on the west side of the street, the Parked Car PBL (08-A) will be used on that side. As this PBL type requires a minimum of 9', there is 12' left for the other side of the street. Again, as the PBL Chart shows, 12' of space allows for any of the Uni-Directional PBL choices, so the decision from here can depend on specific project factors like budget, aesthetics, and context. For this example, Large Bumps PBL (02-A) is used which requires a minimum of 9.5'. Since only 18.5' are used out of the possible 21', the left over width in this case is added to the PBL dimensions to make for wider bike lanes.

1



3



Interventions

- Narrow lanes to 10'
- Parking retained
- Parking PBL(08-A) on west side
- Large Bump PBL (02-A) on east side

2

	PBL 1 ---->	Uni-Directional II Parked Cars (9'-11')								PBL 2 ---->			Uni-Directional II Large Bumps (9.5'-11.5')		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CHAMBERS 1	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	CURB TO CURB	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	**5**	**0**	**28**	---------	**7**	**2**	**11**	**22**	**5**	**48**	**80**	**11**	**18.5**	**7.5**	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	0	---------	20	7	0	---------	22	5	48	80	**21**	18.5	**-2.5**	Minimized Lanes
Expand Curbs			---------				---------				80		18.5	**#VALUE!**	Add interventions here

Chambers St. Segment 2 of 5

(Between 24th ave. and 18th ave.) (length = 0.5mi)

1 **Existing Conditions**

Although some of the dimensions are different at Segment 2, the general street configuration is similar to Segment 1: a single lane in each direction with parallel parking on the east side of the street and bike lanes on both sides of the street. The wide planting strip on the east side is still present as well. The main difference is that the parking is on the opposite (east side) of the street.

2 **Deriving the PBL-DIM Number Using Excel Tool**

(Refer to Chapter 3 for step-by-step instructions)

The first intervention of narrowing the 12' travel lanes down to 10' each results in a PBL-DIM number of 15'. The PBL Chart reveals that this is only enough to use Bi-Directional PBLs. In order to continue PBL types from segment 1, the PBL-DIM number needs to be at least 18.5'. Entering this into the Excel matrix results in an additional required width of 3.5'. For this example, this 3.5' is taken from the large planting strip on the east side of the street.

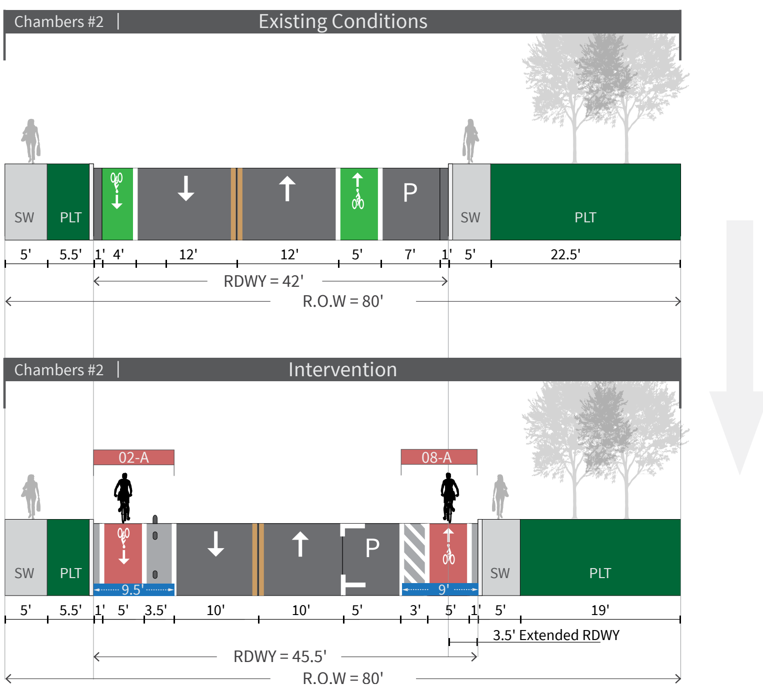
3 **Intervention**

Refer to PBL Chart FIGURE 3.2

Again, since this segment is essentially a mirror of segment 1, it makes sense to use the same PBL configurations as well, just mirrored. In other words, the east side will have the Parked Car PBL (08-A), and the west side will have the Large Bumps PBL (02-A). Additional width could be added to the bike lanes if further expansion into the eastern planting strip would be possible.

1

3



Interventions

- Expand RDWY to 45.5' by cutting into east side planting strip
- Narrow lanes to 10'
- Parking retained
- Parking PBL(08-A) on east side
- Large Bump PBL (02-A) on west side

2

	PBL 1 ---->	Uni-Directional II Large Bumps (9.5'-11.5')								PBL 2 ---->			Uni-Directional II Parked Cars (9'-11')		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CHAMBERS 2	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	CURB TO CURB	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	5.5	24	---------	7	2	9	22.5	5	42	80	9	18.5	9.5	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	5.5	---------	20	7	0	---------	22.5	5	42	80	15	18.5	3.5	Minimized Lanes
Expand Curbs	5	5.5	---------	20	7	0	---------	19	5	45.5	80	18.5	18.5	0	Expanded curbs 3.5' into PLNT 2

Chambers St. Segment 3 of 5

(Between 18th ave. and 13th ave.) (length = 0.4mi)

1 Existing Conditions

At segment 3, the street configuration changes while keeping a similar R.O.W. and RDWY width. A center turn lane replaces the parallel parking and the existing bike lanes are significantly narrower.

2 Deriving the PBL-DIM Number Using Excel Tool

(Refer to Chapter 3 for step-by-step instructions)

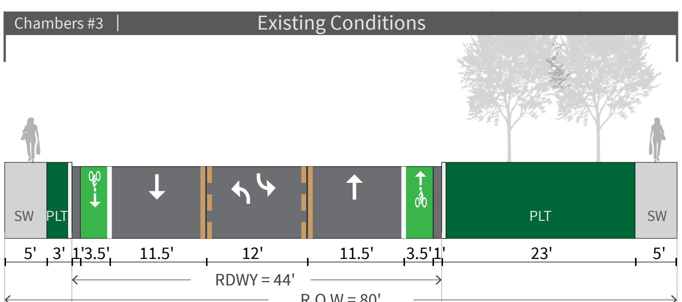
The first intervention of narrowing the travel lanes and the center turn lane down to 10' each results in a PBL-DIM number of 14'. The minimum required width for two Uni-Directional PBLs without existing parking is 19'. Entering this into the Excel matrix returns an additional required width of 5'. As with the previous segments, there is sufficient space within the east-side planting strip to accommodate the expansion of the RDWY to 49'.

3 Intervention

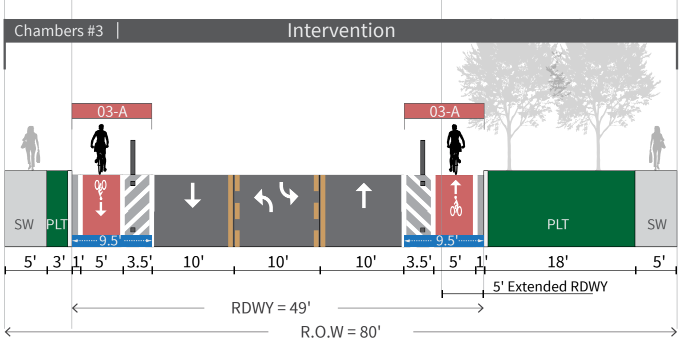
Refer to PBL Chart FIGURE 3.2

According to the PBL Chart, 19' of PBL-DIM leaves four choices for two Uni-Directional PBLs. Again, the selection from here can depend on specific project factors such as budget, aesthetics, and context. For this example, both sides of the street are installed with Uni-Directional Delineator Post PBLs (03-A).

1



3



Interventions

- Expand RDWY to 49' by cutting into east side planting strip
- Narrow lanes to 10'
- Delineator Post PBL (03-A) both sides

2

	PBL 1 ---->	Uni-Directional II Delineator Posts (9.5'-11.5')								PBL 2 ---->			Uni-Directional II Delineator Posts (9.5'-11.5')		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CHAMBERS 3	**SW 1**	**PLNT 1**	**LANES EXIST**	**LANES MIN**	**PARK**	**SHY***	**BIKE LANES EXISTING**	**PLNT 2**	**SW 2**	**CURB TO CURB**	**ROW**	**PBL-DIM**	**DESIRED PBL-DIM**	**ADD WIDTH REQUIRED**	**INTERVENTIONS MADE**
Existing Conditions --->	**5**	**3**	**35**	---------	**0**	**2**	**7**	**23**	**5**	**44**	**80**	**7**	**19**	**12**	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	3	---------	30	0	0	---------	23	5	44	80	**14**	19	**5**	Minimized Lanes
Expand Curbs	5	3	---------	30	0	0	---------	18	5	49	80	**19**	19	**0**	Expanded curbs 5' into PLNT 2

Chambers St. Segment 4 of 5

(Between 13th ave. and 6th ave.) (length = 0.5mi)

1 Existing Conditions

At segment 4, Chambers Street narrows to a 60' R.O.W. with very narrow planting strips and sidewalks. The street configuration includes a single lane in each direction, a center turn lane, and narrow bike lanes on both sides.

2 Deriving the PBL-DIM Number Using Excel Tool

(Refer to Chapter 3 for step-by-step instructions)

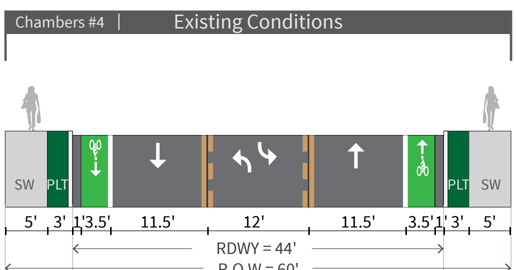
The first intervention of narrowing the travel lanes and the center turn lane down to 10' each results in a PBL-DIM number of 13'. Due to the restricted nature of this segment it would be extremely difficult to expand the curbs so 13' is the final PBL-DIM number.

3 Intervention

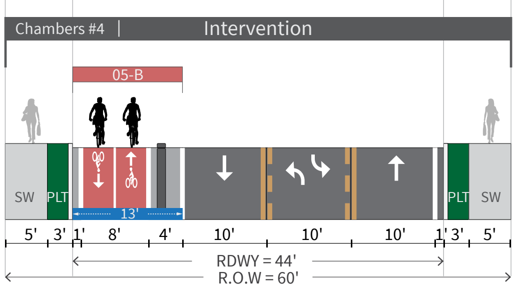
Refer to PBL Chart FIGURE 3.2

While Uni-Directional PLBs are no longer an option here, 13' of space allows for most of the Bi-Directional PBLs. This means that somewhere between segments 3 and 4, there has to be a transition between Uni to Bi-Directional PBLs. While this is not ideal, it can be done at intersections and is preferable to not having PBLs at all (intersection considerations will be addressed in the discussion chapter). Specific PBL selection again depends on the particular project needs but for this example, a Bi-Directional Curb PBL will be installed on the west side of the street. The west side is chosen because the Chambers Bridge over the railroad has a wide sidewalk on this side that could be retrofitted to accommodate a PBL. The PBL could be installed on either side but in a budget-constrained project, this option is likely to be preferred.

1



3



Interventions

- Narrow lanes to 10'
- Curb PBL (05-B) on west side

2

	PBL 1 ---->	Bi-Directional II Curbs (13'-17')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CHAMBERS 4	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	CURB TO CURB	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	3	35	---------	0	2	7	33	5	44	90	7	13	6	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	3	---------	30	0	1	---------	33	5	44	90	13	13	0	Minimized Lanes
Expand Curbs			---------				---------				90		13	#VALUE!	Add interventions here

Chambers St. Segment 5 of 5

(Between 6th ave. and the RR Overpass) (length = 0.6mi)

1 **Existing Conditions**

Chambers is classified as a major arterial north of 6th Ave, and the speed limit increases from 30mph to 35 mph. The street widens out to two lanes in each direction, a center turn lane, bike lanes on both sides and 6-8' planting strips.

2 **Deriving the PBL-DIM Number Using Excel Tool**

(Refer to Chapter 3 for step-by-step instructions)

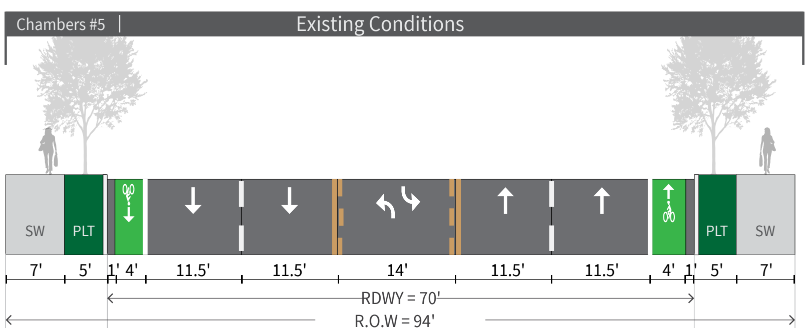
Continuing the Curb PBL from the previous segment requires 13'. Entering this into the Desired PBL-DIM input of the Excel Matrix, showed that 5' of additional width was required. As this segment has higher speed and traffic volume, than the previous minor arterial segments, the travel lanes are narrowed to 11' instead of 10'. Doing so showed that the required 13' PBL-DIM can be acquired by narrowing the center turn lane from 14' to 12'.

3 **Intervention**

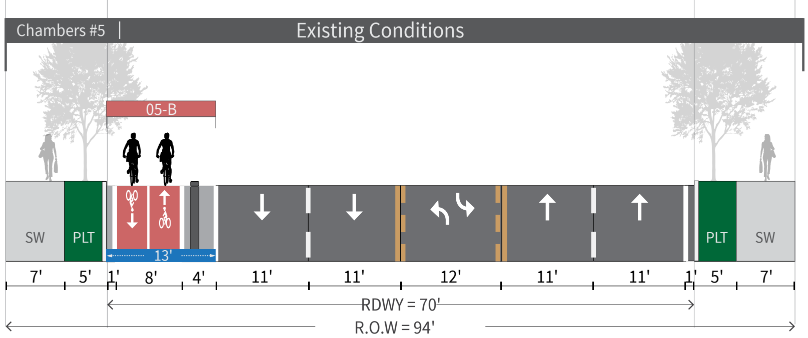
Refer to PBL Chart FIGURE 3.2

In this case, the PBL Chart was not required, as the same Curb PBL is used from the previous segment. There are other options given the 13' PBL-DIM number, so a different PBL type could theoretically be chosen.

1



3



Interventions

- Narrow lanes to 11'
- Narrow center turn lane to 12'
- Curb PBL (05-B) on west side

2

CASE STUDY STREET	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
	PBL 1 ---->	Bi-Directional II Curbs (13'-17')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
CHAMBERS 5															
Existing Conditions --->	7	5	60	---------	0	2	8	5	7	70	94	8	13	5	---------
INTERVENTION OPTIONS															
Stay within Curbs	7	5	---------	56	0	1	---------	5	7	70	94	13	13	0	Minimized Lanes
Expand Curbs			---------				---------				94		13	#VALUE!	Add interventions here

Chambers St. All 5 Segments

Chambers St. is interesting in that the street cross-section changes significantly over just 2.5 miles. As a helpful summary, FIGURE 4.3 shows all five segments with the existing and proposed conditions. The figure illustrates that the transition between most segments would be straightforward; although the PBL type changes between segments 1 and 2, this change would not pose any conflict to the cyclist. However, in cases such as the intersection of segments 3 and 4, where the PBL changes from Uni to Bi-Directional, cyclists have to essentially cross over Chambers St to continue on their journey.

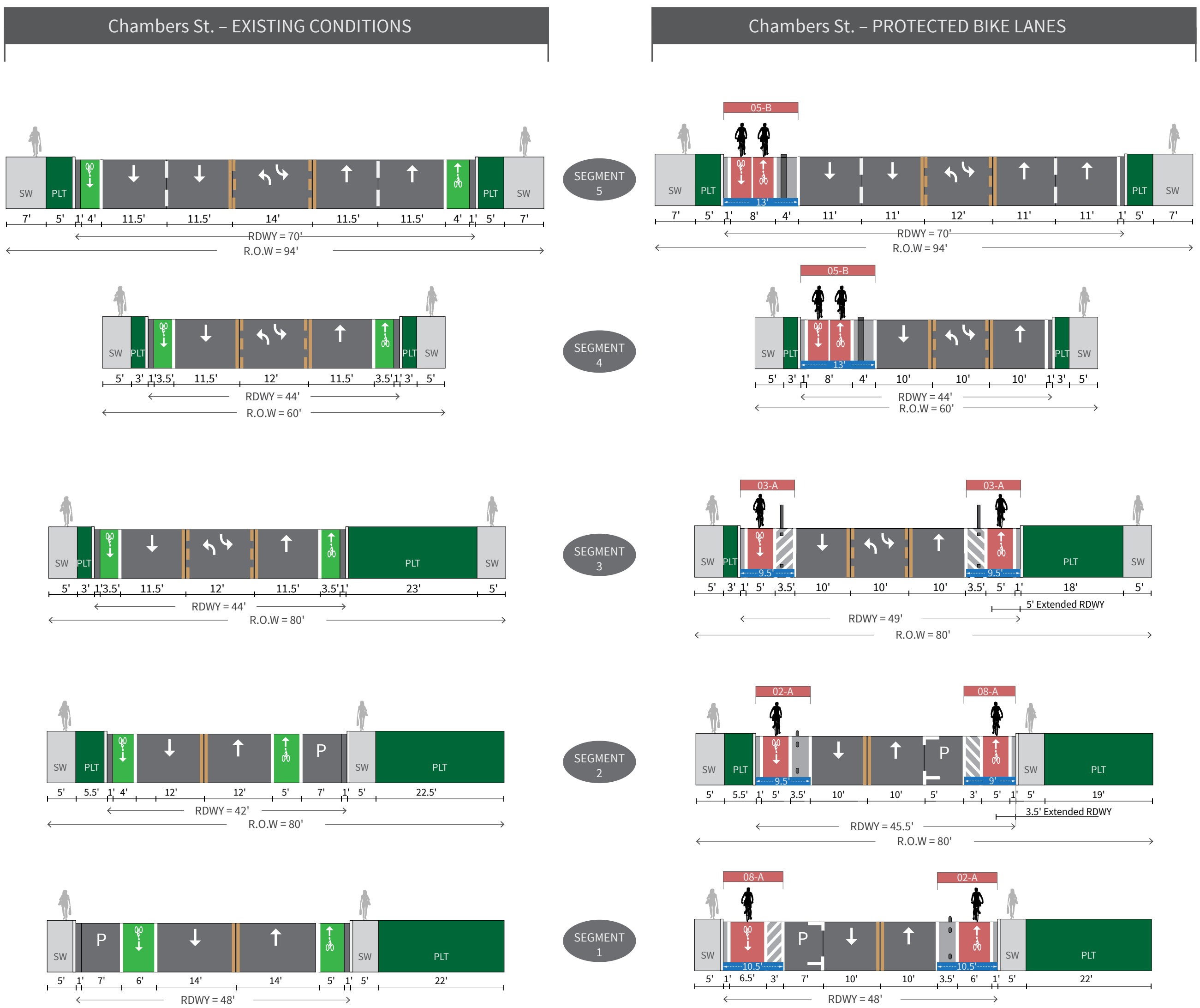


FIGURE 4.3: All 5 segments of Chambers with existing and proposed conditions.

River Road Overview

Chambers Street turns into River Road north of the railroad bridge. Because the railroad bisects much of North and South Eugene, this bridge, (and thus these two roads) is an important connector. The River Rd. segment spans from this bridge to the Randy Pape Beltline to the north.

- River road is classified as a major arterial with a 40mph speed limit and high traffic volume
- It is a two-way road with two lanes in each direction, a center turn lane and bike lanes on both sides.

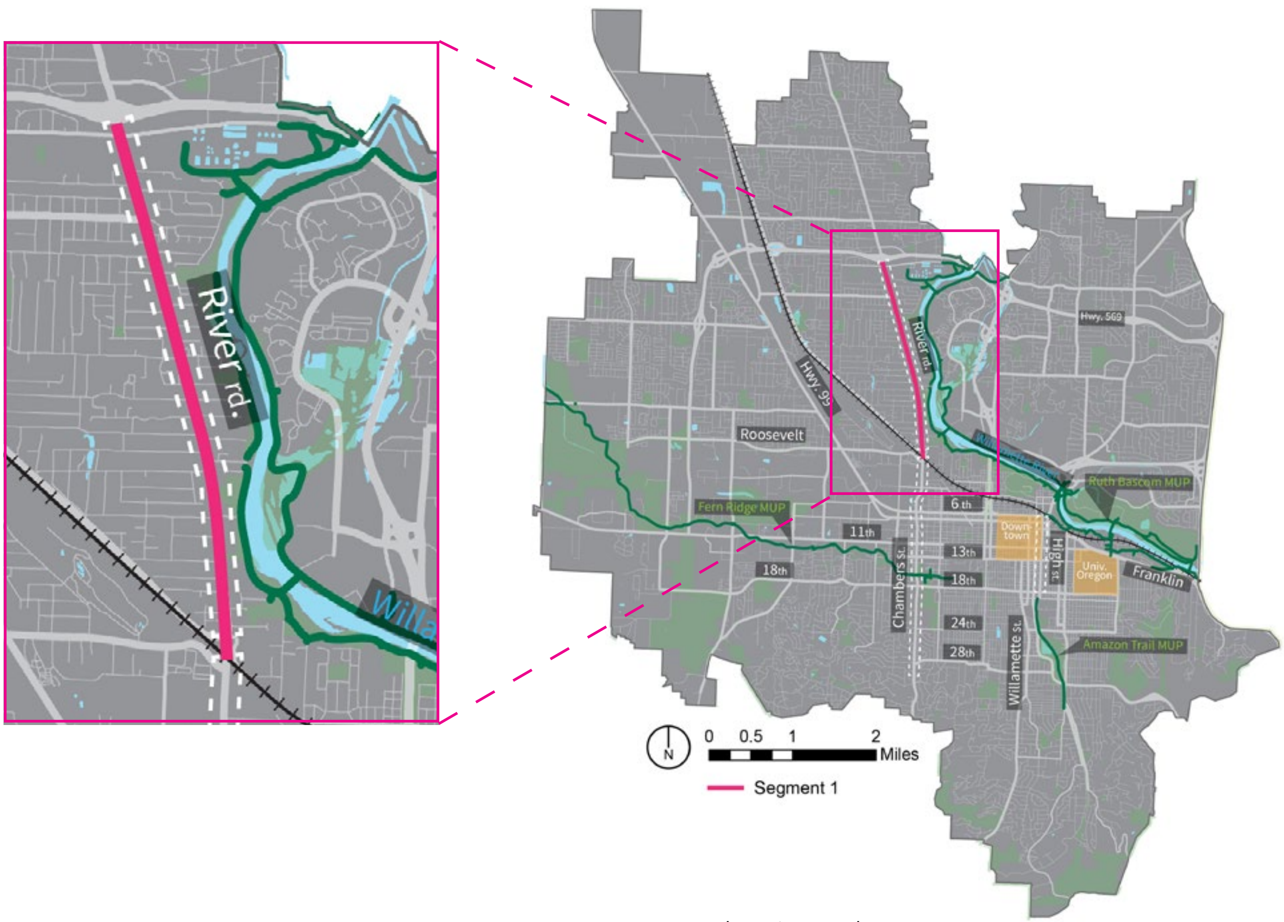


FIGURE 4.4: Case study 2: River Road

River Rd. Segment 1 of 1

(Between the RR and Hwy 569) (length = 2.3mi)

1 Existing Conditions

The River Rd. segment is composed of two lanes in each direction, a center turn lane, bike lanes on both sides and 6-8' planting strips.

2 Deriving the PBL-DIM Number Using Excel Tool

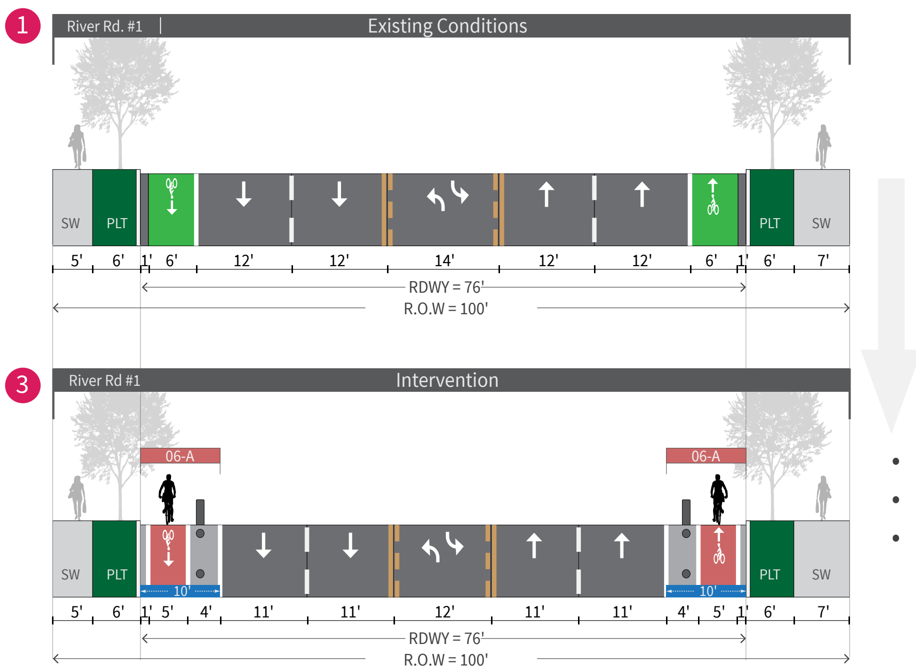
(Refer to Chapter 3 for step-by-step instructions)

As this segment has higher speed and traffic volume, the travel lanes and the center turn lane were initially narrowed to 11' instead of 10'. This resulted in a PBL-DIM number of 21', which allows for almost all of the PBL types.

3 Intervention

Refer to PBL Chart FIGURE 3.2

Since room allows it, a Uni-Directional PBL type should be used here, and due to the high traffic speed and volume, the protection level should also be prioritized. Therefore, this segment will be installed with Rigid Bollard PBLs requiring a minimum of 20' for both sides. The extra 1' could either be added to the bike lane widths or, as the section-cut shows, it could be added to the center turn lane, making it 12'.



Interventions

- Narrow lanes to 11'
- Narrow center turn lane to 12'
- Rigid Bollard PBL (06-A) on both sides

2

	PBL 1 ---->	Uni-Directional II Rigid Bollards (10'-12')								PBL 2 ---->			Uni-Directional II Rigid Bollards (10'-12')		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
RIVER 1	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	**5**	**6**	**62**	---------	**0**	**2**	**12**	**6**	**7**	**76**	**100**	**12**	**20**	**8**	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	6	---------	55	0	0	---------	6	7	76	100	**21**	20	**-1**	Minimized Lanes
Expand Curbs			---------				---------				100		20	**#VALUE!**	Add interventions here

High Street Overview

High St. is a two-lane, one-way minor arterial, and the case study segments span from 19th Ave at the south end, to 6th Ave at the north end. As previously mentioned, this section of High St. is an important connector between the trail systems of Amazon Park in the south, and the Ruth Bascom Multi-Use Path along the Willamette River in the north. This same section of High St. is also one of the only streets in Eugene that was planned for a PBL installation in the Eugene Pedestrian and Bicycle Master Plan of 2012.(1)

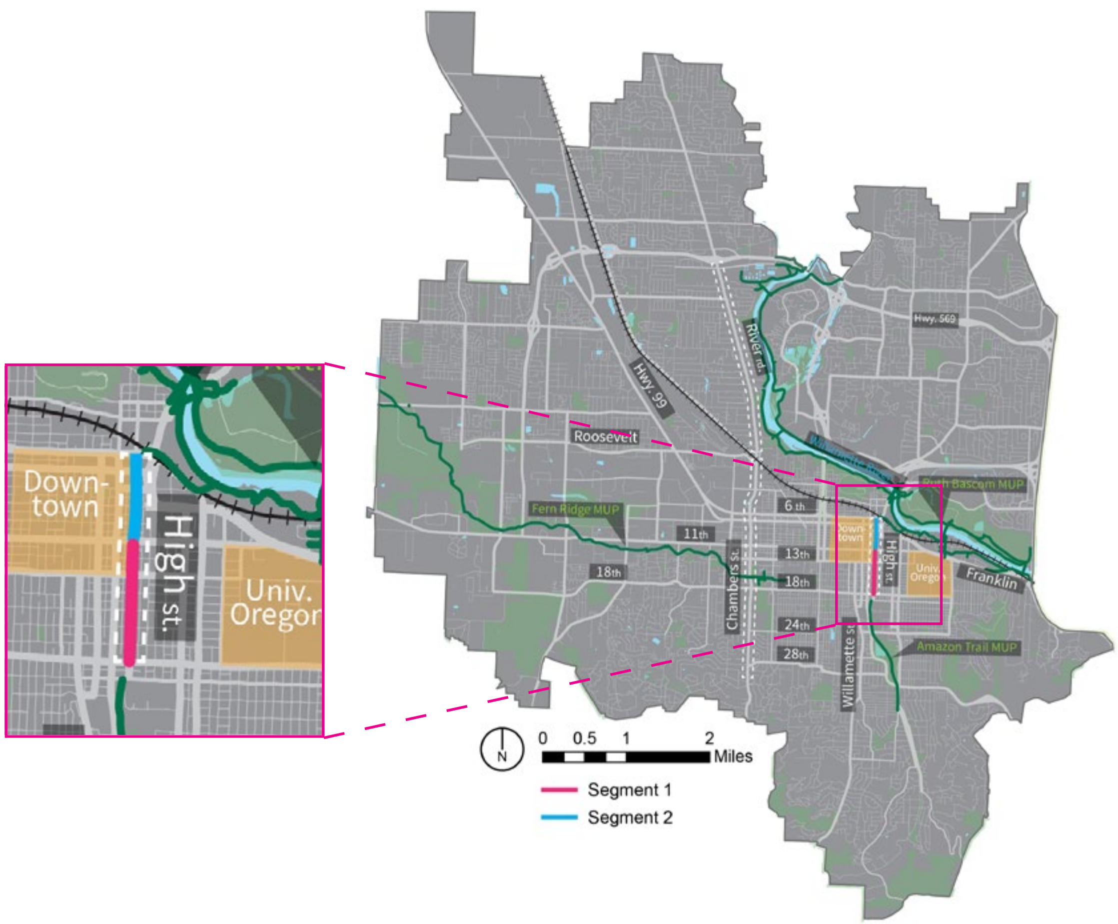


FIGURE 4.5: Case study 3: High St. and its two segments

High St. Segment 1 of 2

(Between 19th and 11th) (length = 0.5mi)

1 Existing Conditions

In segment one, High street is a north-bound, one way street with two travel lanes, parallel parking on the east side of the street, a bike lane on the west side of the street and two fairly wide planting strips on both sides.

2 Deriving the PBL-DIM Number Using Excel Tool

(Refer to Chapter 3 for step-by-step instructions)

Narrowing the travel lanes to 10' resulted in a 8' PBL-DIM number which is not enough for any of the PBL types.

3 Intervention

*Refer to PBL Chart FIGURE 3.2*To demonstrate how the Excel table and the PBL Chart are used together to consider different options, three different PBL options are shown.

3a Option 1

To install the Uni-Directional Delineator Post PBL (03-A) on the west side of the street, 9.5' are needed, therefore requiring the expansion of the curb 1.5' into the planting strip. Doing so retains the lane configurations and keeps the parking on the same side.

3b Option 2

Another option is to utilize the existing parking by installing the Parked Car PBL (08-A) which requires an additional 1' of curb expansion into the planting strip. The PBL could go on either side, but it is often preferred to place it on the left side of a one-way street to avoid conflict with transit stops.

3c Option 3

There are two ways to provide PBL facilities in both directions in street systems dominated by one-way streets. First option is to install Uni-Directional PBLs on each of two parallel one-way streets. For instance, a west direction PBL would be installed on 11th street (a west direction one-way street), and a east direction PBL would be installed on 13th street (an east direction one-way street).

The other option is to install a bi-directional PBL on only one of the candidate streets. This example shows option 3 with a Bi-Directional Delineator Post PBL requiring the expansion of the curbs by 4.5' into the planting strips.

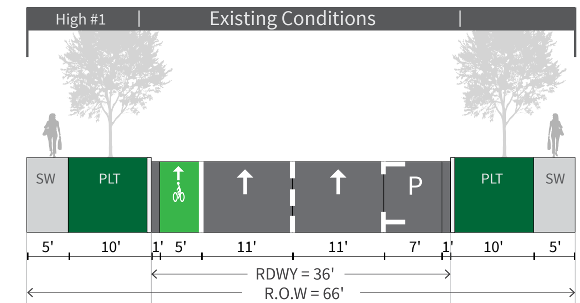
2

	PBL 1 ---->	Uni-Directional II Delineator Posts (9.5'-11.5')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
HIGH ST. 1 (1-way PBL) Option 1	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	10	22	---------	7	2	5	10	5	36	66	5	9.5	4.5	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	10	---------	20	7	1	---------	10	5	36	66	8	9.5	1.5	Minimized Lanes
Expand Curbs	5	8.5	---------	20	7	1	---------	10	5	37.5	66	9.5	9.5	0	Expand curb 1.5' into PLNT 1

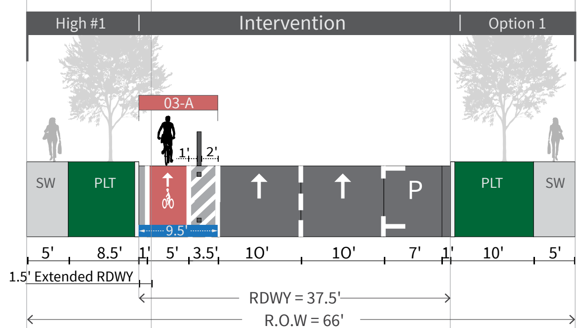
	PBL 1 ---->	Uni-Directional II Parked Cars (9'-11')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
HIGH ST. 1 (1-way PBL) Option 2	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	10	22	---------	7	2	5	10	5	36	66	5	9	4	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	10	---------	20	7	1	---------	10	5	36	66	8	9	1	Minimized Lanes
Expand Curbs	5	10	---------	20	7	1	---------	9	5	37	66	9	9	0	Expand curb 1' to PLNT 2

	PBL 1 ---->	Bi-Directional II Delineator Posts (12.5'-16.5')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
HIGH ST. 1 (2-way PBL)	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	10	22	---------	7	2	5	10	5	36	66	5	12.5	7.5	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	10	---------	20	7	1	---------	10	5	36	66	8	12.5	4.5	Minimized Lanes
Expand Curbs	5	7.5	---------	20	7	1	---------	8	5	40.5	66	12.5	12.5	0	Expand curb for a total of 4.5'

1



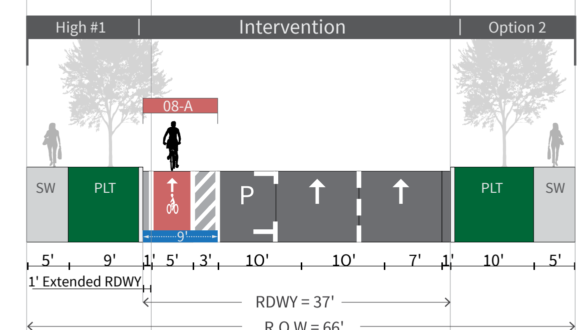
3a



Intervention Option 1

- Narrow lanes to 10'
- Expand RDWY to 37.5' by cutting into west side planting strip
- Delineator Post PBL (03-A) on west side

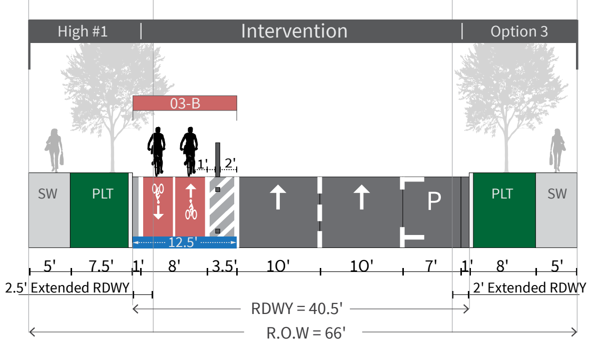
3b



Intervention Option 2

- Narrow lanes to 10'
- Expand RDWY to 37' by cutting into west side planting strip
- Move Parking to west side
- Parked Car PBL (03-A) on west side

3c



Intervention Option 3

- Narrow lanes to 10'
- Expand RDWY to 40.5' by cutting into both planting strips
- Bi-Directional Delineator Post PBL (03-B) on west side

High St. Segment 2 of 2

(Between 11th and 6th) (length = 0.4mi)

1 Existing Conditions

Segment 2 of High St. goes through the eastern edge of downtown Eugene as a one-way street with two 11.5' lanes, parallel parking on both sides, a bike lane on the west side, and two 6' planting strips on either side.

2 Deriving the PBL-DIM Number Using Excel Tool

(Refer to Chapter 3 for step-by-step instructions)

Narrowing the travel lanes to 10' results in a PBL-DIM number of 9' and the on-site analysis revealed that expansion of the curbs would not be possible due to the narrow planting strip and its mature trees. So any intervention would have to stay within the curbs.

3 Intervention

Refer to PBL Chart FIGURE 3.2

As in the previous segment of High Street, two options are provided here as well.

3a Option 1

The first option would be fairly simple, as all lane configurations can stay the same. The PBL-DIM of 9' is just enough for a Uni-Directional Parked Car PBL (08-A) on the west side of the street.

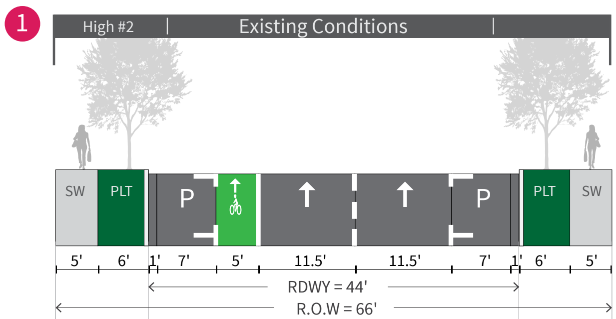
3b Option 2

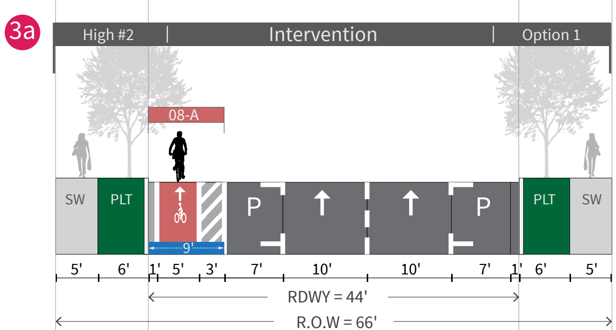
As in segment 1, a Bi-Directional PBL option is shown. However, since all Bi-Directional PBL need more than the available 9', the only way to install this without expanding the curbs is by removing one side of parking. As the Excel Table shows, doing so results in 16' of space, which is enough for all of the Bi-Directional PBLs. Since this segment goes through downtown Eugene, it is a good opportunity to emphasize aesthetics along with safety. Thus, the example shows the installation of a Bi-Directional Planter PBL (07-B) on the west side of the street.

2

	PBL 1 ---->	Uni-Directional II Parked Cars (9'-11')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
HIGH ST. 2 (1-way PBL)	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	6	23	---------	14	2	5	6	5	44	66	5	9	4	---------
INTERVENTION OPTIONS															
Stay within Curbs	5	6	---------	20	14	1	---------	6	5	44	66	9	9	0	Minimized Lanes
Expand Curbs			---------				---------				66		9	#VALUE!	Add interventions here

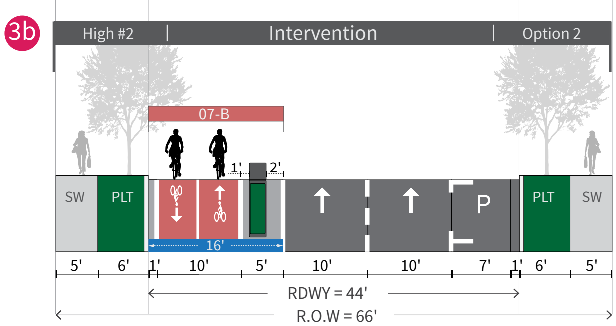
	PBL 1 ---->	Bi-Directional II Parked Cars (12'-16')								PBL 2 ---->			SELECT PBL TYPE		
CASE STUDY STREET	STREET CONFIGURATIONS									RESULTS			ADDITIONAL OPTIONS		
HIGH ST. 2 (2-way PBL)	SW 1	PLNT 1	LANES EXIST	LANES MIN	PARK	SHY*	BIKE LANES EXISTING	PLNT 2	SW 2	RDWY	ROW	PBL-DIM	DESIRED PBL-DIM	ADD WIDTH REQUIRED	INTERVENTIONS MADE
Existing Conditions --->	5	6	23	---------	14	2	5	6	5	44	66	5	14	9	---------
INTERVENTION OPTIONS													1		
Stay within Curbs	5	6	---------	20	14	1	---------	6	5	44	66	9	14	5	Minimized Lanes
Take out one side parkin	5	6	---------	20	7	1	---------	6	5	44	66	16	14	-2	Take out one side of parking





Intervention Option 1

- Narrow lanes to 10'
- Parked Car PBL (03-A) on west side



Intervention Option 2

- Narrow lanes to 10'
- Remove parking on west side
- Bi-Directional Planter PBL (07-B) on west side

Summary

The final maps show each case study street with the resulting PBL type indicated by different colors. Uni-Directional PBLs are represented by narrower lines and are on both sides of the street, whereas Bi-Directional PBLs are only on one side of the street and are represented with a wider line. High St. in this case is only shown with the Bi-Directional options, as it is difficult to show all three options on a single map.

This chapter shows the results of applying the Protected Bike Lane Suitability Tool to three actual streets in Eugene, OR. The tool did make the process interesting and most importantly, efficient. However, as the following chapter discusses, there are a number of considerations and limitations that have to be addressed.

FIGURE 4.6: High Street with recommended PBL types

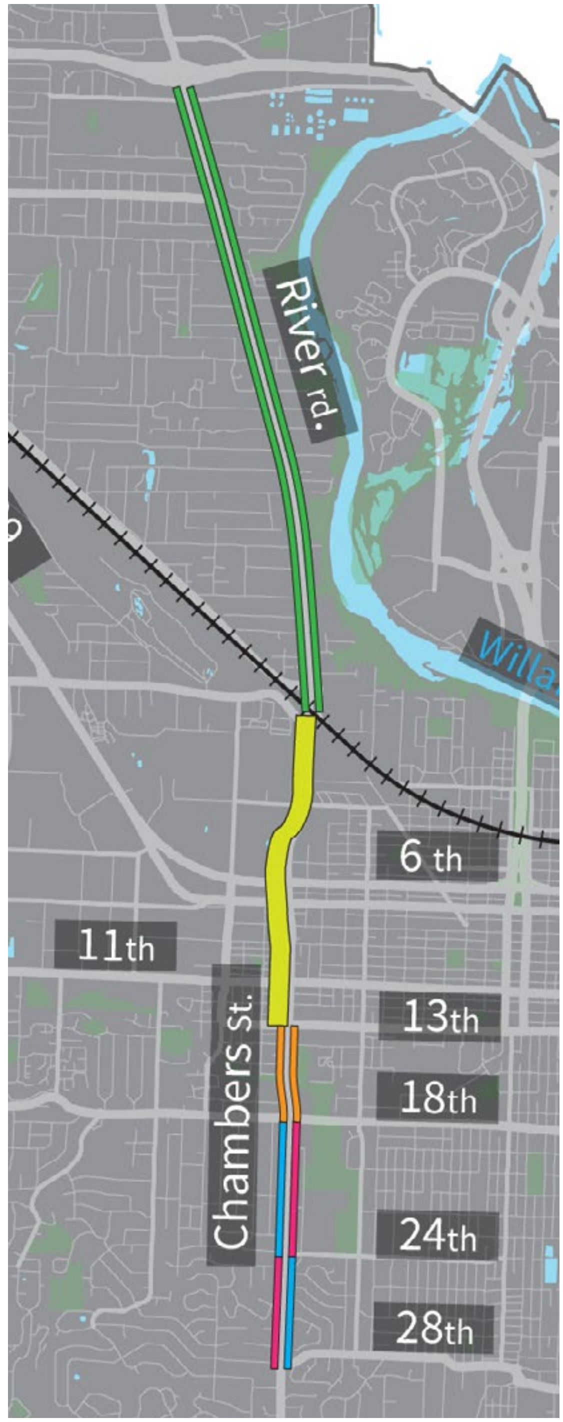


FIGURE 4.7: Chambers Street and River Road with recommended PBL types

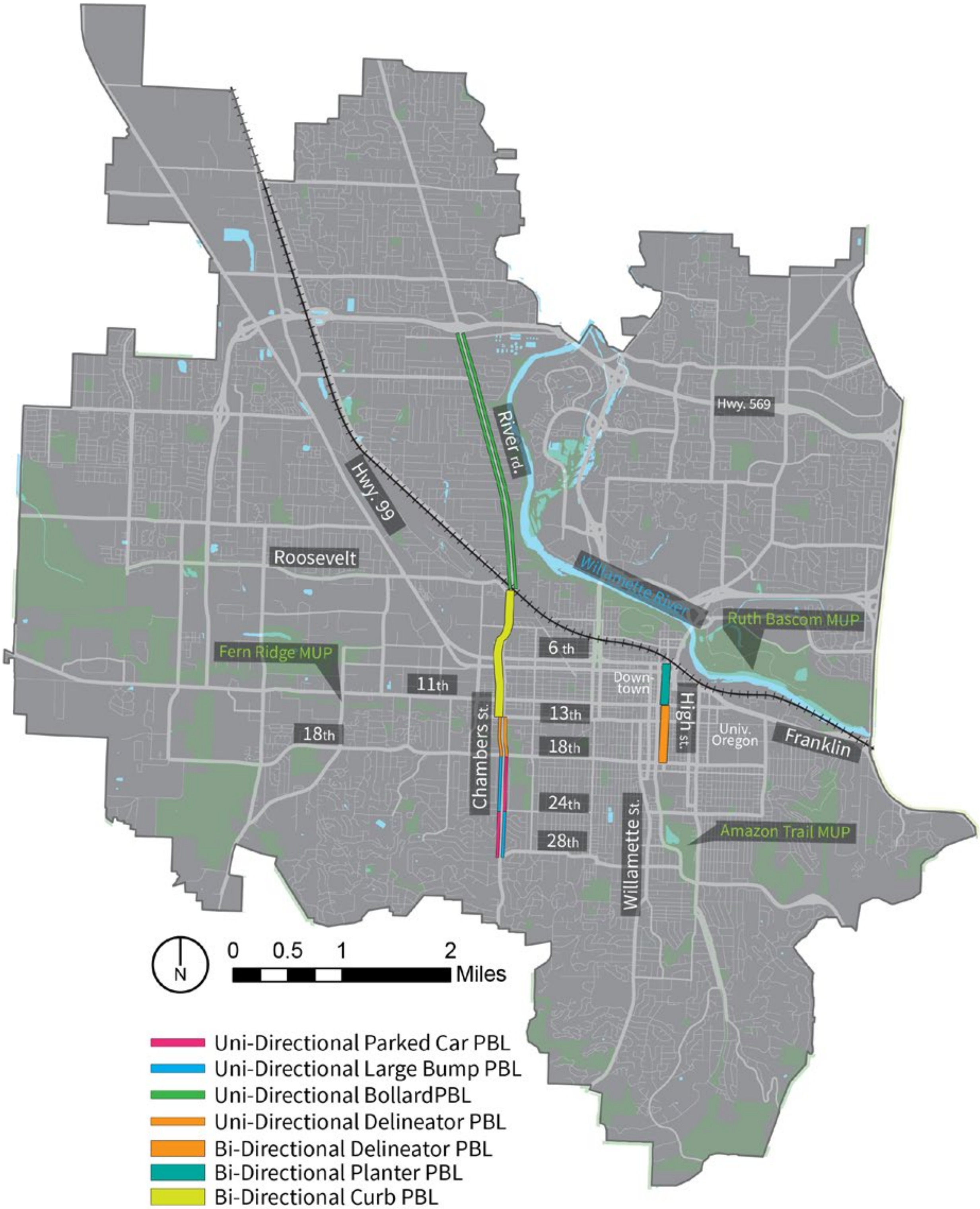


FIGURE 4.8: Three case study streets with recommended PBL types

CH.4 ENDNOTE REFERENCES

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CHAPTER 5
DISCUSSION

CH.5

FIGURE 5: Casual biking with an umbrella on a PBL. (https://aseasyasridingabike.wordpress.com/2013/12/31/not-dangerous/)

Overview

As the preceding chapters illustrate, the Protected Bike Lane Suitability Tool is a versatile, interactive tool that can be used to match particular existing street conditions with the most suitable Protected Bike Lane (PBL) type. Working with the Excel Matrix in tandem with the PBL Chart (described in chapter 3) is an iterative process that leads the user through the decision-making process. Chapter 4 demonstrates how applying the tool to real case study streets results in a variety of PBL types even along a short segment of a particular street. This tool, and the information it provides, will be instrumental in the planning of PBL projects.

However, the PBL Suitability Tool is not designed to address all of the inevitable challenges involved in the actual implementation of a project, and the results are not meant to be conclusive. It simply allows a user to determine which PBL types are best suited for a particular street, based on 1) the dimensional cross section of the particular street, 2) the desired PBL characteristics and 3) contextual details such as: can the roadway be expanded, would utilities have to be altered, would trees need to be removed, what is the traffic volume, and what are the adjacent land uses .

Applying the tool to the case study streets revealed several important considerations that will be discussed in this chapter. There are also a number of issues that, while the tool is not tasked with addressing, are relevant to PBL projects, and thus are worthy of discussion as well.

This Chapter Includes:

1) PBL Suitability Tool Considerations
- Insufficient Space for Any PBL Intervention
- Consistency of Facility Type
- Expanding the Roadway

2) Protected Bike Lane Conflicts
- Intersections
- Driveways
- Transit Stops
- Garbage Collection

3)Limitations

4)Next steps

5.1 PBL Suitability Tool Considerations

Insufficient Space for Any PBL Intervention

Because most PBL projects will be retrofit, as opposed to new construction, the feasibility of installing a PBLs depends on the limitations of existing conditions. Generally speaking, streets in the U.S. have ample space for PBLs. Travel lanes typically exceed the recommended standards and often there are more lanes and parking than is necessary. In the recent past, transportation planners have taken advantage of this opportunity by proposing road diets and complete streets. [1]

The application of the PBL Suitability Tool in CH.4 demonstrated that a number of PBL types were feasible on any of the three case study streets. This, of course, will not always be the case in real world applications. Even with the case study streets, in situations where the roadway had to be expanded, the assumption was made that this was feasible. So what happens when the existing conditions are too restrictive for any PBL option?

Minimize the Bike Lane

As detailed in CH.2, the minimum dimension for the actual riding surface of a Uni-Directional PBL is 7' (5' for the bike lane plus two shy distances of 1' on either side). While this is certainly desirable, it may be possible to narrow this dimension down depending on a number of factors. For instance, the 1' shy area allotted for the strip adjacent to the curb where the stormwater inlets normally exist could be included in the bike lane dimension. FIGURE 5.1 - FIGURE 5.3 illustrate the difference between a conventional inlet and "bike-safe" inlets.

The 5' allotted for the bike lane itself could be narrowed if necessary. Again, this is not ideal, but a 4' bike lane with 2' extra shy distances would still be preferable to no PBL. It should be noted here for comparison that most conventional bike lanes are less than 5' in width (including a shy distance) and they provide zero protection from traffic. Let's consider the case study streets, for example, and in order to

FIGURE 5.1: Stormwater Inlet occupies most of bike lane and directs cyclists into the travel lane
(http://bikeportland.org/2011/12/26/stripes-in-bike-lane-pose-interesting-legal-question-64315)

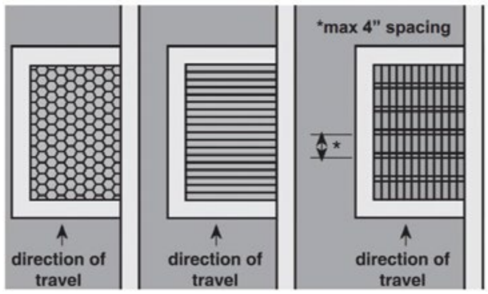


FIGURE 5.2: Bike-Safe stormwater inlets
(http://www.pedbikesafe.org/BIKESAFE/countermeasures_detail.cfm?CM_NUM=1)

FIGURE 5.3: Bike-Safe stormwater inlet
(http://www.lbiw.com/product/resources/D72%20Drainage%20Inlets/drainageinlets,pipeinletsandgrates.html)

1 *Road Diets refer to a reconfiguration of a street, typically reducing the number of travel lanes in favor of bike lanes. A common application of this is to turn a 4-lane street into a street with a single lane in each direction, a center turn lane, and bike lanes on both sides.*

Complete Streets refer to a street that is either newly constructred, or re-configured, to accomodate multi-modal transportation options instead of just cars. They typically include wide sidewalks, bike lanes, transit-only lanes and conventional travle lanes. Guides for both road diets and complete streets can be found in the NACTO Urban Street Design Guide.(1)

compare the existing with the proposed, let's forget about the shy distances and focus on the 'rideable surface', defined as the area that exists between non-rideable surfaces (eg.: curb, travel lane, protective barrier, or parked car). In these terms, the rideable surface dimensions are 4.5'-6' on Chambers St., 5'-6' on High St., and 7' on River Rd., which, as a reminder, is a 40mph 4 lane major arterial road. In contrast, the minimum rideable surface for Uni-Directional PBLs is 7'. However, in addition to the 7', the PBLs have a protective barrier plus 2' between the barrier and the motor vehicle travel lanes.

It should be stated, that PBLs by design should be somewhat wider than a conventional bike land since the cyclist is constrained to the bike lane itself. For instance, as opposed to riding in a conventional bike lane, the cyclist in a PBL cannot use the vehicle travel lane to pass another cyclist. Regardless of the circumstance, sub-standard PBLs (narrower than recommended) should not be used for long stretches of a route. But if a 5mi long PBL route has to be narrowed down for a 0.5mi segment, that should be preferred over not installing the PBL. For instance, NE. Multnomah Ave. in Portland Or. has been upgraded with two Uni-Directional PBLs on a 1.2mi stretch. Site analysis of this route revealed that the PBL width varies quite a bit, including a section where, due to width constraints, the width between the curb face and the buffer strips was only 4' (FIGURE 5.4).

FIGURE 5.4: PBL width restricted to 4' from crub face to buffer striping
(PHOTO: Krisztian Megyeri)

Minimize the Travel Lanes
While there are possibilities to fit in PBLs by narrowing the bicycle facility, it may also be feasible to alter the travel lanes in order to accommodate a PBL project. Depending on the city and the particular street, it may be possible to have travel lanes or center turn lanes that are below the minimum standards. Center turn lanes are a great option for stretches of streets with numerous driveways (especially to businesses), but in places where they are under utilized (only a few private driveways), they could be removed to create the required space. On-street parking could also be narrowed, or removed all together as the city of Seattle, WA. has done on many of the streets.[2]

As previously discussed, the typically wide roadways of the U.S. can be viewed as an invaluable asset, allowing the reconfiguration of streets without the complications of roadway expansion and/or land acquisition. With flexibility in design standards along with creative problem solving, the majority of streets can be reconfigured to accommodate Protected Bike Lanes.

Consistency of Facility Types
One of the strengths of the PBL Suitability Tool is that it outputs the most suitable PBL type for each cross section input. For instance if 5 unique segments are identified on a 3-mile segment of a particular street, the tool may output 5 different PBL types instead of trying to make one type fit over the whole 3-mile segment. While this is useful, it needs to be balanced by maintaining a level of facility consistency along a PBL route. For instance, transitioning from a Bi-Directional PBL on one side of a street, to two Uni-Directional PBLs should be avoided if possible. Specific barrier types and PBL widths should also remain constant if possible.

Expanding the Roadway
The PBL Suitability Tool also gives the option to expand the Roadway (the area between the two existing curbs) in cases where it is not wide enough to accommodate a PBL. Since doing so takes space away from either the planting strips or the sidewalks, this decision has to be carefully considered, and depends on a number of factors. For instance if the planting

strips are narrow (less than 6') and have mature trees, it is unlikely that an expansion would occur. Furthermore, the expansion of the roadway would likely require moving or altering some utilities (electrical poles, sewer lines, traffic signals). Due to these potential complications (each of which comes at a high cost), this option should be avoided if possible.

5.2 Protected Bike Lane Conflicts

Although the scope and purpose of this project is not to create master plan document which resolves every possibly challenge, some of the more common and relevant PBL design considerations will now be addressed.

Intersections

Intersections pose a particular challenge for PBLs, especially for Bi-Directional PBLs as one of the biking directions flows against the direction of vehicular travel. Fortunately, there are a number of invaluable resources available for design recommendations. The FHWA's "Separated Bike Lane Planning and Design Guide"[3] offers a number of solutions shown in FIGURE 5.5. Just like PBLs themselves, the best type of intersection option depends on the specific existing conditions of the street and the design intent for the PBLs.

A common and simple solution is to discontinue the barrier of the PBL as it approaches the intersection and treat it like a conventional bike lane. As FIGURE 5.6 shows, this results a place where cars and bikes share the roadway, know as a "mixing zone". An alternate option that maintains full separation through

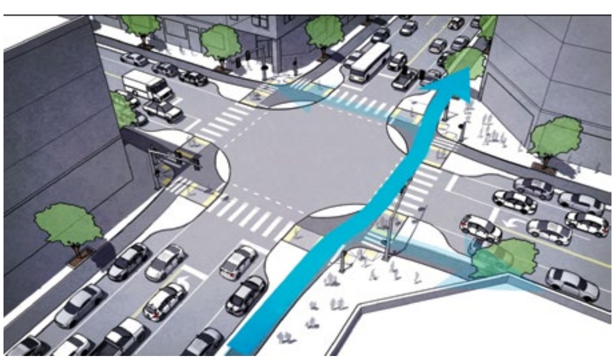
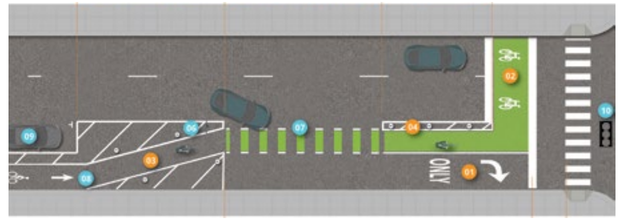
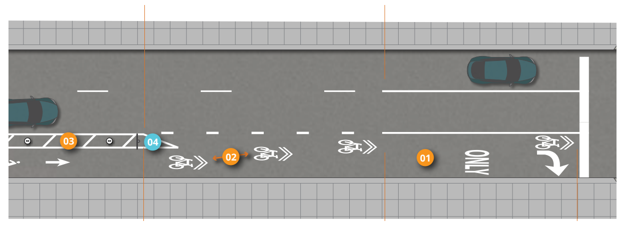


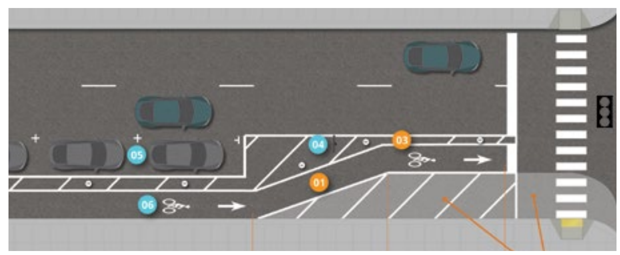
FIGURE 5.7: Protected Intersection
(http://www.protectedintersection.com/)



PBL Intersection: Lateral Shift



PBL Intersection: Mixing Zone



PBL Intersection: Bend In

FIGURE 5.5: PBL Intersection options. (FHA, 2015)

FIGURE 5.6: PBL Intersection: Mixing zone in NYC.
(FHA , 2015)

the intersection is referred to as a “protected intersection”. These types of intersections are common in places like the Netherlands, and are gaining support in the U.S. as well. FIGURE 5.7 illustrates how a basic protected intersection is designed, and how the cyclists would make a number of turns (blue arrows).

Driveways

Vehicular access to driveways poses a similar challenge as intersections, albeit at a smaller scale. The most common solutions include simply discontinuing the PBL barrier for the duration of the driveway. For instance, the bollards on a Bollard PBL would discontinue at the driveway with enough space to allow the necessary vehicle turning radius. In the case of Raised PBLs, the curb cuts can be installed at the driveways as in FIGURE 5.8. The FHA guide gives clear guidance on some of the design details like angle of sightlines and distance of on street parking restrictions from the driveway (FIGURE 5.9).

Transit Stops

Special considerations and design solutions are also required on streets with existing transit. As previously discussed, the easiest solution is if the PBL is on the opposite side of the actual transit stops. For instance in the case of the High St. case study, (a two lane, one-way street), the decision to place the PBL on the left side of the street was made to avoid conflict with the existing bus stops on the right side. However, there are many instances (like on Chambers St.) where the PBL runs on the same side as the transit stops. If there is existing on-street parking, a good solution is to use the parking area for the bus stop, and if space allows it, creating an island for transit passengers by bumping out the PBL (FIGURE 5.10). In areas where space is constrained, the PBL barrier could be discontinued for the duration of the bus stop, essentially creating a similar ‘mixing zone’ that exists with conventional bike lanes.

FIGURE 5.8: Raised PBL at a driveway
(FHA , 2015)

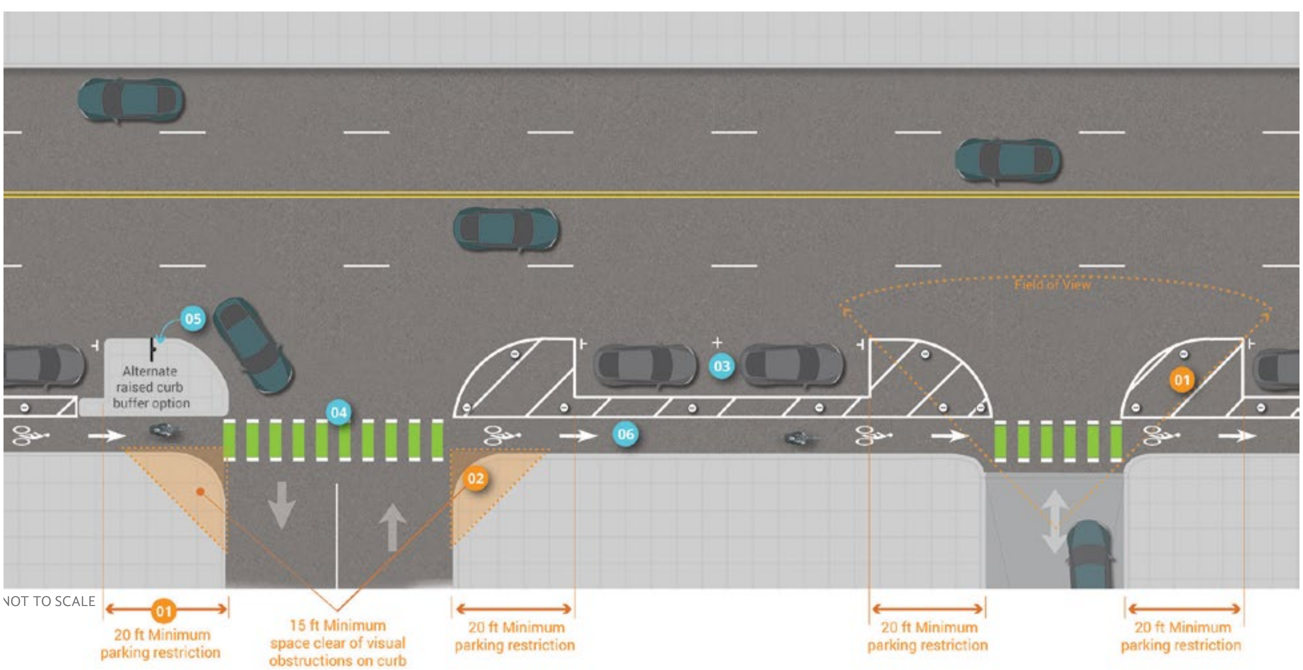


FIGURE 5.9: PBL treatments at driveways
(FHA , 2015)

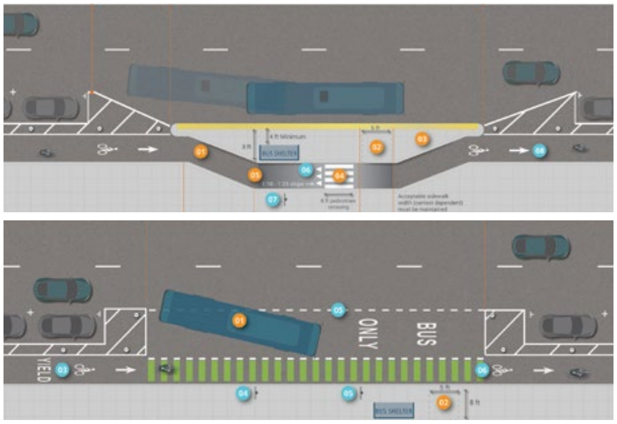


FIGURE 5.10: PBL solutions at transit stops.
(FHA , 2015)

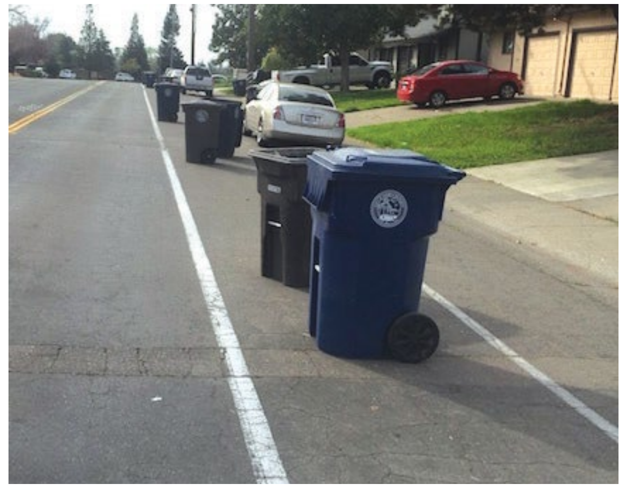


FIGURE 5.11: Trash bins in a conventional bike lane
https://gettingaroundsac.wordpress.com/2016/03/11/trashing-the-bike-lanes/

Garbage Collection

Garbage collection is a similar issue to transit stops, with the key difference that the garbage truck has to stop at each house. FIGURE 5.11 shows what happens too often with conventional bike lanes as homeowners place the garbage bins right in the bike lane. This can, and does, happen with PBLs if they are either not designed with garbage collection in mind, or if the homeowners are not mindful (FIGURE 5.12). On streets with parking, the bins should be placed between cars or in open parking spaces, as is done on any other street without PBLs. Ideally, the PBL should be designed as to allow a space for garbage bins (FIGURE 5.13). All of the PBLs in this project, for instance, have a buffer of at least 3', so whether it is a Bollard or Curb PBL, there is ample space for garbage bins, out of the bike lanes.

FIGURE 5.12: Trash bins in a Protected Bike Lane
http://bikeportland.org/2011/07/15/the-trouble-with-trash-cans-on-the-cully-cycle-track-56355

FIGURE 5.13: PBL designed to accommodate trash collection
http://sfb.nathanpachal.com/2015/11/how-to-build-protected-bike-lanes-new.html

5.3 Limitations

As the preceding sections illustrate, the PBL Suitability Tool does not (and is not designed to) address many of the inevitable challenges involved in the actual implementation of a project. The intent is that this tool would be utilized in tandem with other resources; it is one of many tools within a larger toolbox.

As previously explained, the PBL Suitability Tool is designed to determine which PBL types are best suited for a particular street, based on three key factors:

1) The dimensional cross section of the particular street
2) The desired PBL characteristics
3) Contextual details such as: can the roadway be expanded, would utilities have to be altered, would trees need to be removed, what is the traffic volume, and what are the adjacent land uses

Applying the tool to the case study streets revealed that, while it is interactive, user-friendly, and practical, there are several important limitations that should be acknowledged, and hopefully, resolved.

Street Cross-Sections

The main factor that the tool operates on is the user-input dimensions of all of the street components (Sidewalks, planting strips, bike lanes, travel lanes, shy distances), which result in the Excel-generated output of the PBL-DIM number (the potential dimension allotted for a PBL). Once the existing street component dimensions are available for a particular cross-section, the Excel Table works efficiently.

The significant limitation with this process lies in the assumption that a single cross sections at a specific point along a street is representational of a whole segment of that street. In the case of Chambers St., for instance, while 5 distinct segments were identified by the primary site analysis, it is certain that the dimensions of the right of way, the roadway and all of its components change continuously, even within a short 0.5mi segment. To address this issue, a segment's final cross section should represent the average of multiple cross-sections taken at frequent intervals (every 100 feet) within a particular segment. Due to time constraints, however, these measurements would need to be automated instead of taken by hand.

Desired PBL Characteristics

Once the PBL-DIM number is determined, the facility options are narrowed down via the PBL Chart using the PBL 'score cards' (each PBL is scored in 5 categories: Protection Level, Permeability, Durability, Aesthetics, and Installation Cost). While this is a valuable part of the decision-making process, the values may not be 100% dependable. For instance, the installation costs were calculated under the premise of new construction costs, while most PBL installations will likely be retrofit projects. To increase the value of the 'score cards', each criterion needs to be backed up by solid data, particularly the key criteria such as safety and cost.

Contextual Details

Each construction project will have some unique challenges that are particular to the specific context. Finding a suitable PBL based on street component dimensions is a good start, but there are many relevant factors that are not yet built into the tool. It is likely that the single factor that most PBL projects will depend on is whether or not the PBL facility can fit within the existing roadway (ie: without expanding the curbs). The PBL Suitability Tool does allow roadway expansion in the calculations, but assessing the feasibility of roadway expansion is left to the user's input. Some additional options would make the tool even more useful. For instance, the feasibility of roadway expansion into a particular planting strip could be based on a number of user-input factors such as size and age of trees, and/or the type of utilities if any. Again, this process would be tedious if the necessary information had to be gathered manually, but could be automated if the relevant data existed in a computer database as discussed in section 5.4.

Time

As previously stated, once all of the relevant data are available for a particular cross-section, the PBL Suitability Tool works quickly and intuitively. That said, of the greatest limitations to the tool at this point is the amount of time (a valuable resource) it would take on a real project. All street component dimensions were taken on-site by the author, which is especially problematic given the earlier realized limitation that taking one section per "segment" is not enough to get a thorough dimensional profile of that segment, let alone an entire street. In fact all data collection had to be conducted on site including: the presence or absence of trees and utility poles, lane configurations, and roadway integrity.

If the data were readily available and in a form that would be compatible with the PBL Suitability Tool, the process could actually be quite powerful.

5.4 Next Steps

GIS

The experience of completing this project and developing the PBL Suitability Tool revealed not only its limitations but also the potential benefits if it were taken to the next levels of development. As discussed, the greatest limitation at this time is the lack of integration of the tool with the relevant data that the decision process depends on (street component dimension, utility information, street tree data). The most apparent solution to this would be to use GIS (Geographic Informational Systems) as the interface between the PBL Suitability Tool and all necessary data files.

Assuming GIS data exists for all relevant dimensions (R.O.W., Roadway, Sidewalks, Planting Strips, Bike Lanes, Travel Lanes, Parking Areas), at any and all cross sections along a street, an algorithmic GIS tool could be developed that would essentially provide the PBL-DIM number at any location. Additionally, GIS data on utilities and trees could be used to show the feasibility of roadway expansion along each street (on a scale of 1-5, for instance).

Automating those two factors alone (Deriving the PBL-DIM number and determining roadway expansion feasibility) would significantly increase the viability of the PBL Suitability Tool, and would make a system-wide planning process much more streamlined.

The developed GIS tool would run the algorithm on each street and output the actual PBL-DIM numbers at any particular cross section. The results could be displayed as unique colors for each foot of PBL-DIM width as the sample map shows in FIGURE 5.14. In this example, the Bi-Directional PBLs are represented with a gradient of blue routes and the Uni-Directional PBLs, are represented with a gradient of purple routes. Uni-Directional PBLs are also divided into routes that have PBLs on only one side of the street versus routes that have PBLs on both sides of the street. While this is only a conceptual map used for illustration, one can imagine what an entire system map could look like.

In addition to providing an intuitive way to visualize the system potential, the true power of this GIS integration would be the data processing and feedback associated with the geospatial information. Having all of the necessary data (dimensions, restrictions, traffic volume, existing bike count numbers, PBL-DIM) available for GIS operations would be a powerful and efficient way to tackle a complete system-wide Protected Bike Lane master plan.

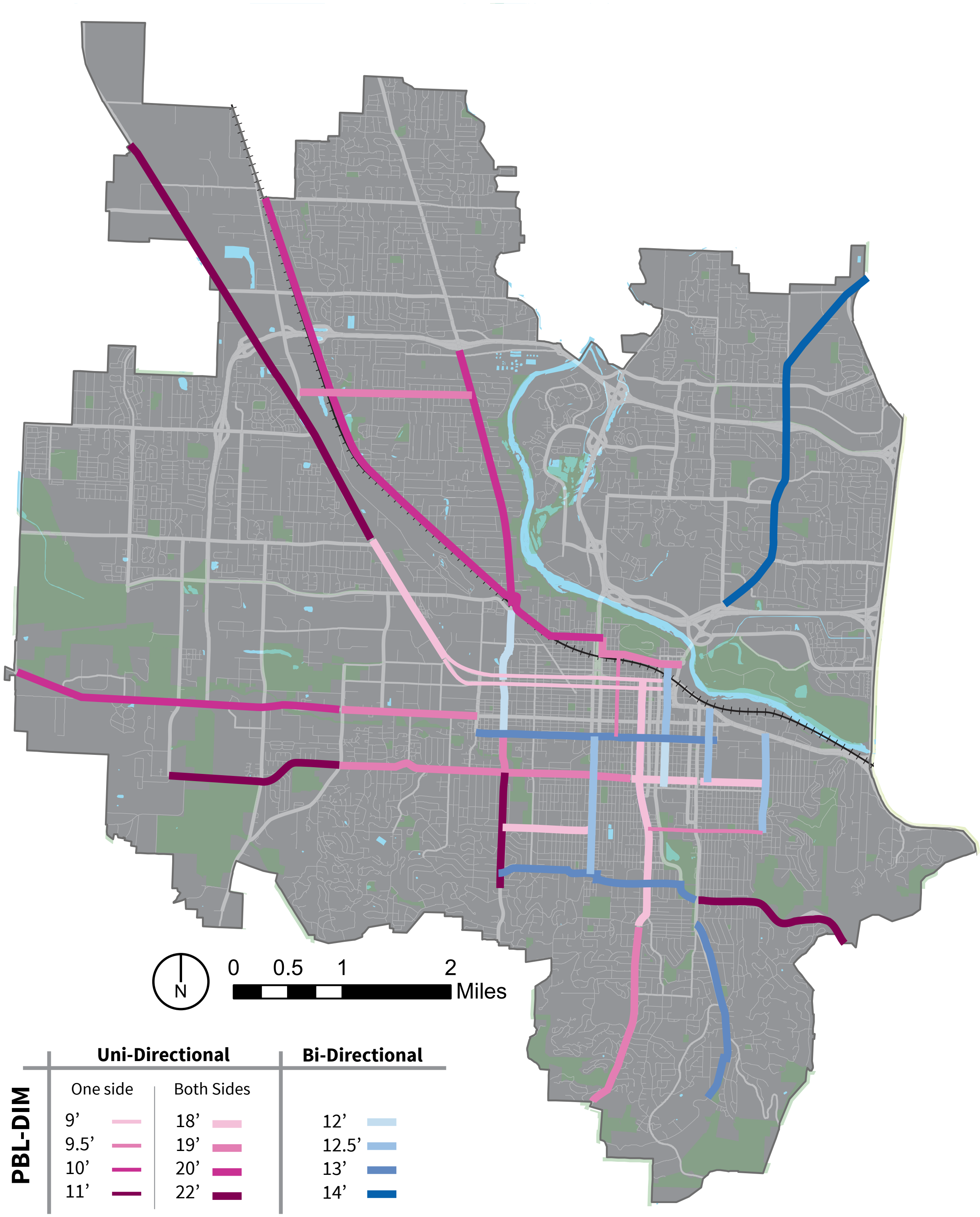


FIGURE 5.14: Conceptual map illustrating the potential integration of the PBL Suitability Tool with GIS

5.5 Conclusion

Increasing the number of people who choose to bike instead of drive will have significant positive impact on the environment and our society. While there are a number of ways to increase bicycle ridership, research suggests that the key factor is providing bicycle infrastructure that prioritizes safety. We must go beyond conventional bike lanes that separate bikes from cars with a mere stripe on the road. Instead, bikes have to be physically protected from vehicles with the use of Protected Bike Lanes.

The goal of this project was to contribute to the planning + design process of Protected Bike Lanes by creating a PBL Suitability Tool, which can be used to match any particular existing street condition with the most suitable Protected Bike Lane type. While a number of limitations arose over the course of the project, applying the PBL Suitability Tool to the three Eugene case study streets demonstrated the tools promising potential.

Taking the PBL Suitability Tool past this conceptual stage could be done via the integration of Geographic Informational Systems (GIS). Doing so would automate most of the steps that had to be completed manually for this project, thereby significantly increasing its viability. It is hoped that a GIS-based PBL Suitability Tool could optimize the planning + design process so that an increased number of PBL projects will actually be built.

Ultimately, the goal is to provide infrastructure that will allow more people to experience the beauty and freedom of riding a bike without being in constant fear for their lives.

FIGURE 5.15: Bike infrastructure made for everyone. (https://departmentfortransport.wordpress.com/2014/02/)

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THE BACK

the back

FIGURE 6.1: Holland cyclists. (http://www.charlottebellamy.com)

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List of Figures

Front Cover image: Hornby St. in Vancouver: https://www.flickr.com/photos/pwkrueger/

Back Cover Image: Holland cyclists. (http://www.charlottebellamy.com)

APPENDIX 1:

All 14 Protected Bike Lane Types from the People For Bikes guide. The PBL selected for this project are outlined.

STRIPED BUFFER
1.5 ft. additional width; $8k-$16k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

DELINEATOR POSTS
1.5 ft. additional width; $15k-$30k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

TURTLE BUMPS
1.5 ft. additional width; $15k-$30k per lane-mile

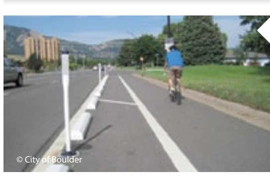
PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

LARGE BUMPS
1.5 ft. additional width; $15k-$30k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

OBLONG LOW BUMPS
1.5 ft. additional width; $10k-$20k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS


© City of Boulder

PARKING STOPS
6 in. additional width; $20k-$40k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS


© trafficlogix.com

LINEAR BARRIERS
6 in. additional width; $25k-$75k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

PARKED CARS
11 ft. for parking + buffer; $8k-$16k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

JERSEY BARRIERS
2 ft. additional width; $80k-$160k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

PLANTERS
3 ft. additional width; $80k-$400k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

RIGID BOLLARDS
2 ft. additional width; $100k-$200k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

CAST IN PLACE CURB
12 in. additional width; $25k-$80k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

12" PRECAST CURB
1.5 ft. additional width; $400k-$600k per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

RAISED BIKEWAY
No additional width; $8m-$26m per lane-mile

PROTECTION LEVEL
INSTALLATION COST
DURABILTY
AESTHETICS

The ratings for aesthetics are subjective, based on full life-cycles. For details on all ratings, visit bit.ly/14bikelanes.

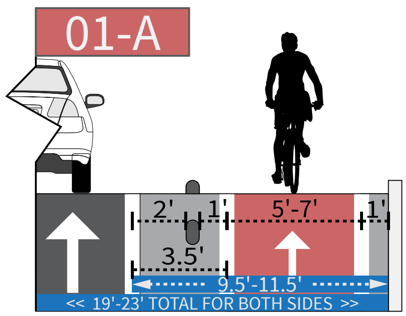
APPENDIX 2:

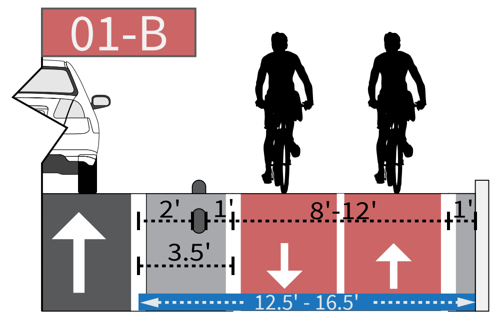
This appendix shows the 8 Protected Bike Lane Types chosen for this project.

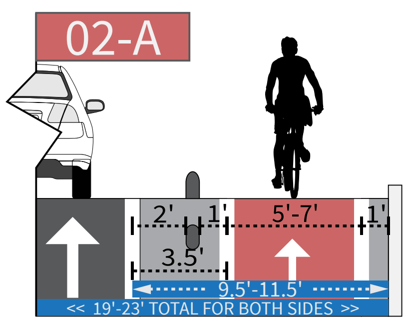
Each PBL type is represented with a photo of the facility type, the score card, and the dimensional cross sections of both Uni and Bi-Directional versions.

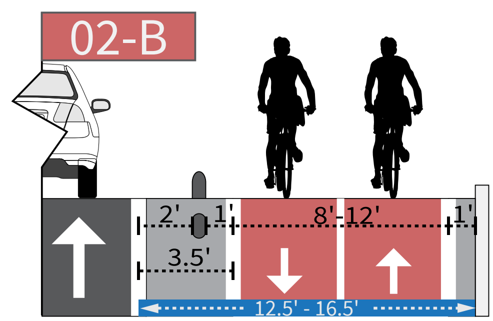
Uni-Directional PBL

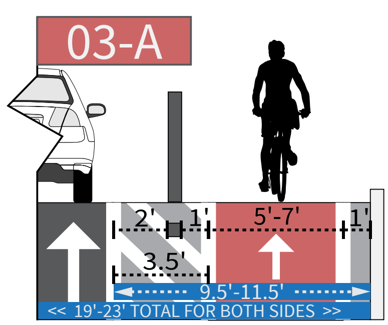
Bi-Directional PBL

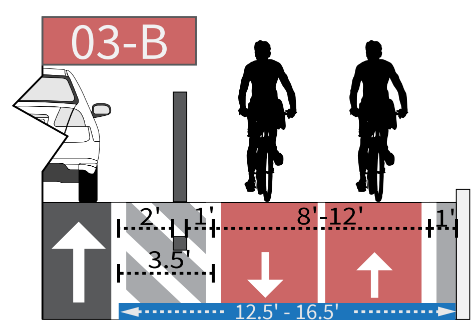


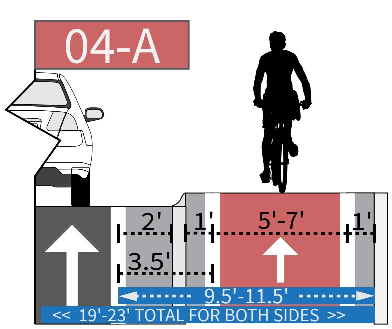


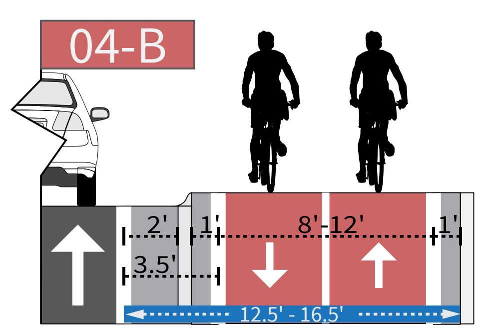












APPENDIX 2:

This appendix shows the 8 Protected Bike Lane Types chosen for this project.

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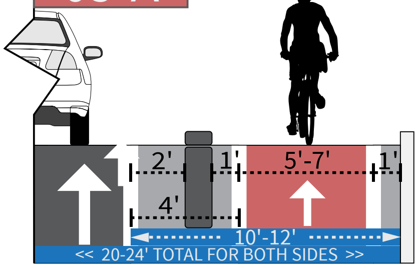
Uni-Directional PBL	Bi-Directional PBL

05-A



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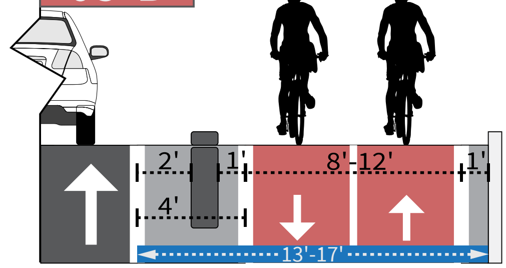

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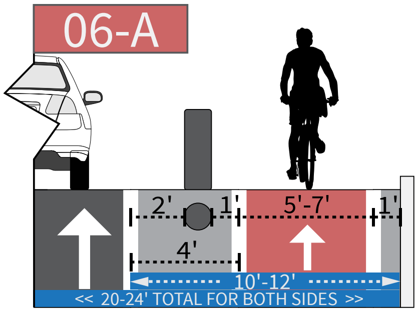

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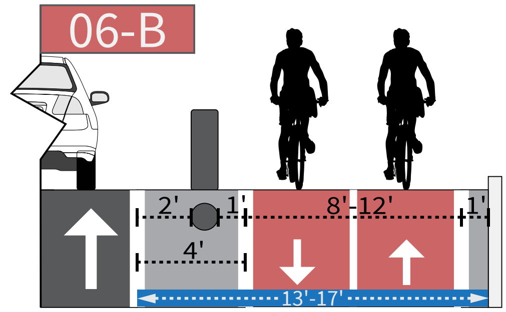

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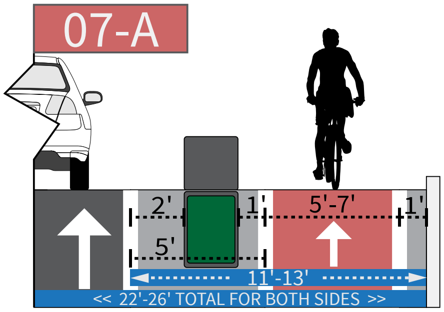

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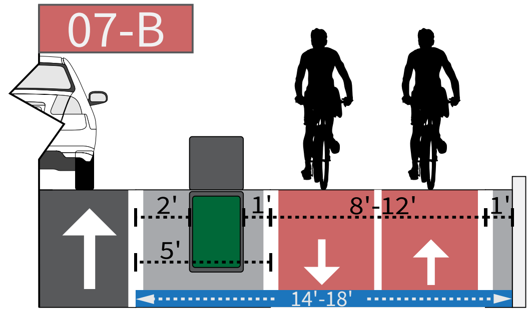

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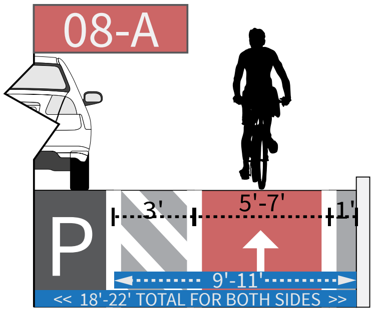

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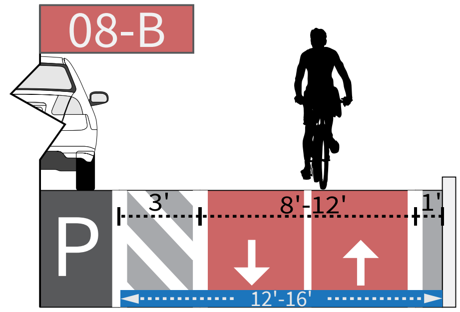

FIGURE: Holland cyclists. (http://www.charlottebellamy.com)

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