

**Expanding Bicycle Access to Transit:
Providing Increased Secure Bicycle Parking
at Light Rail Stations in the Seattle Area**

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Abstract

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Sound Transit's Link light rail system provides high-capacity transit service to the Seattle area. Supporting bicycle use to reach Link can increase access to this important regional transit system. Providing safe and secure parking for bicycles at transit stations is an effective method for supporting bicycle access to the transit system, but half of the existing Link light rail stations do not have secure bike parking facilities. This thesis examines how to provide increased secure bike parking at Link light rail stations in three parts. The first is an examination of the practices used at several other transit agencies for providing bike parking. Second, four methods found in the literature are used to analyze the level of demand for bike access to the existing Link stations. The highest level of demand, and thus the greatest need for secure bike parking, is found at the University of Washington and International District/Chinatown Link stations, which currently have no secure bike parking. Finally, preliminary designs for secure bike parking facilities at these two stations are presented along with general recommendations for improvements to Sound Transit's methods of planning for secure bicycle parking.

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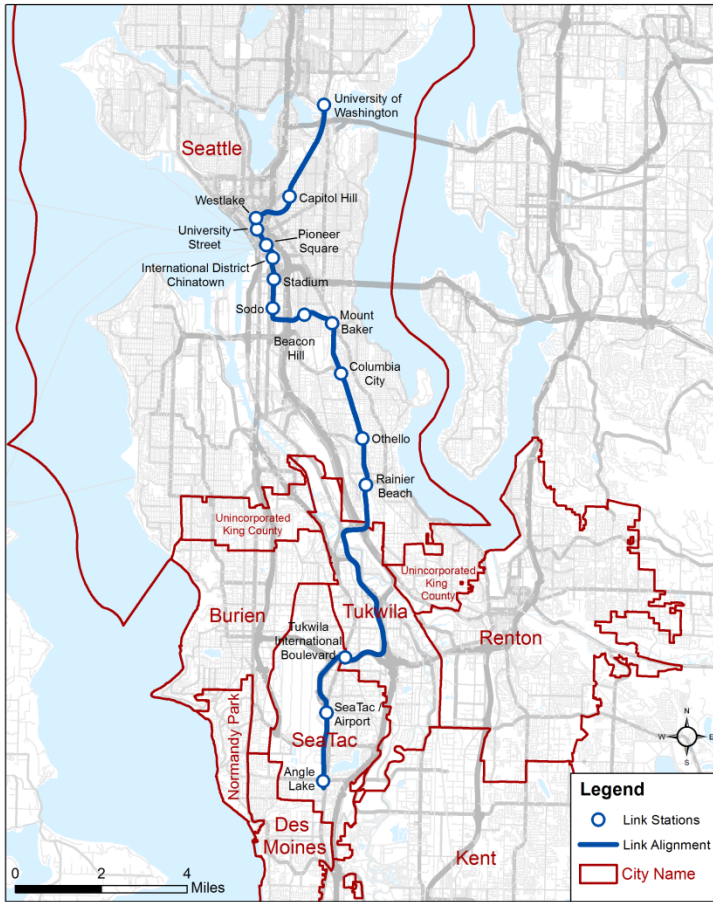
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Chapter 1: Introduction

Figure 1 – The Central Link Light Rail System in 2016



The Central Link light rail alignment and stations in 2016. There are sixteen stations including Angle Lake, which will open in late 2016 to serve as the line's southern terminus for the next five years.

Sound Transit's Link light rail line first opened in July 2009, initially providing service to fourteen stops along a 15.6-mile route between downtown Seattle and the Seattle-Tacoma International Airport. The light rail line provides a high level of transit service, with trains running every ten minutes or less most hours of the day. Since Link's launch, the line has seen consistent ridership growth of over 10% per year, with the average number of weekday boardings just below 40,000 in the first quarter of 2016.¹ Since reaching that milestone, the light rail

system has added two stations north of downtown Seattle, serving Seattle's Capitol Hill neighborhood and the University of Washington, which opened in March of 2016. The result has been a major increase in ridership on the Link light rail line, with 57,000 boardings recorded

1. "First Quarter 2016 – Service Delivery Quarterly Performance Report," Sound Transit, May 26, 2016, <http://www.soundtransit.org/sites/default/files/Q1%202016%20Service%20Delivery.pdf>.

on March 22, 2016.² Additional system expansion is planned, with the next station opening at Angle Lake south of the airport later in 2016.

The expansion of the Sound Transit's light rail system comes a time when people throughout the Puget Sound region, and the United States in general, are shifting away from automotive travel, favoring public transit, walking, and bicycling instead. This trend is clear in the Puget Sound region. Between 2006 and 2013, the Seattle-Tacoma-Bellevue metropolitan statistical area saw a 2.8% decline in the proportion of workers commuting by car.³ In turn, transit use is up in the region. Between 2005 and 2010, the number of annual transit trips in the Seattle area increased by 30 million, or 9.5%.⁴ Non-recreational cycling rates have also increased significantly in the last decade. Nationwide, the number of bicycle commuters increased by 60.8% between 2000 and the 2008-2012 period, faster than the increase in all other modes.⁵ Seattle and the Puget Sound region have especially high rates of bicycle commuting, with Seattle ranking in the top five large cities in the United States for bike commute rates.⁶

Central Link light rail is intended to function as a major regional transit line through Seattle and the surrounding region. However, only two stations – Tukwila International Boulevard Station and the soon-to-open Angle Lake Station, both at the south end of the line –

2. Mike Lindblom, "Sound Transit to add longer trains to meet light rail demand," *The Seattle Times*, March 23, 2016, <http://www.seattletimes.com/seattle-news/transportation/sound-transit-to-add-bigger-trains-to-meet-ridership-demands/>.

3. Brian McKenzie, "Who Drives to Work? Commuting by Automobile in the United States: 2013," *American Community Survey Reports, ACS-32*, U.S. Census Bureau, 2015, 5.

4. "Transportation 2040 – Appendix O: Active Transportation Plan," Puget Sound Regional Council, May 29, 2014 28.

5. Brian McKenzie, "Modes Less Traveled—Bicycling and Walking to Work in the United States: 2008–2012," *American Community Survey Reports, ACS-26*, U.S. Census Bureau, 2014, 3.

6. Ibid.

include car parking spaces. Thus, access to the line depends on connecting bus service, walking, and bicycling for the vast majority of its riders. Because Sound Transit's focus is on regional rail transit, the agency has limited ability to alter the number of people walking or riding a bus to its light rail stations. Sound Transit can increase bicycle access to light rail stations by providing parking facilities. While adding car parking to existing light rail stations could be possible in theory, very limited space is available for parking lots as Link stations have been sited on small lots in developed areas. In addition, car parking is extremely expensive to build in the Puget Sound area. The City of Seattle estimates that new parking structures come at a cost of \$20,000-\$50,000 per parking space, a significant sum.⁷ Bicycle parking can be provided at much lower cost than car parking and requires much less space,⁸ making retrofitting bike parking into existing stations feasible. Unfortunately, Sound Transit has limited funds available for access improvements to existing stations. Given this constraint, capital investments in bicycle parking should be targeted to the light rail stations where they can achieve the greatest ridership gains. This thesis will focus on expanding the availability and quality of bicycle parking at Link light rail stations as a method for improving system access and increasing light rail ridership.

7. "Parking Review: Report to Council PLUS Committee," City of Seattle, April 13, 2015, <http://www.seattle.gov/dpd/cityplanning/2015parkingreport.pdf>.

8. Robert Schneider, "Integration of Bicycles and Transit, TCRP Synthesis of Transit Practice," *Transit Cooperative Research Program Synthesis 62*, 2005, 2.

Goal & Objectives

The overall goal of this thesis will be drafting a set of recommendations for implementing projects to provide increased secure bicycle parking at Sound Transit's existing Link light rail stations with the highest level of demand for bicycle access. Several intermediate objectives will need to be met along the way toward completing this thesis and meeting its primary goal:

- Make a case for the necessity of providing additional secure bike parking at Link light rail stations.
- Draft general recommendations for how to implement added secure bike parking at Link light rail stations. This will be done through examination of successful implementation of secure bike parking programs at Sound Transit's peer agencies and other agencies that provide innovative bike parking models.
- Determine the level of demand for bicycle access to Link light rail stations. Several methods for assessing bicycle demand have been proposed in the literature, including some that have been developed locally for directing investments into bike parking at transit stations.
- Apply the recommendations for implementing added secure bike parking to the Link light rail stations with the highest level of demand for bike access.

Chapter 2: Bicycle Access to Transit

The Need for Bicycle Access to Transit

The underlying goal of this thesis is to improve access to the Link light rail system by accommodating bicycles. While most rail transit systems provide a high level of transit service to passengers once they are at a station, reaching the station can be a challenge for many potential passengers. Four main methods are available for accessing public transit stations: walking, driving, using connecting transit service, and cycling. All of these access modes are important elements of the transportation system, but bicycle access to public transit systems tends to receive little attention from transit agencies. This low level of attention given to bicycle access and planning may not be entirely unwarranted by the numbers – Sound Transit surveyed customers in 2011 and found that only 1.7% of Link light rail passengers used a bicycle to get to the train station.⁹ Investment in bicycle access can potentially increase the use of bikes to reach the transit system. Bay Area Rapid Transit (BART) provides a high level of infrastructure to support bike access, and in 2012 4% of BART’s passengers reached the system by bicycle.¹⁰ BART is currently pursuing an 8% bike access rate through additional bicycle investment, and Sound Transit could set similar goals.

Despite low rates of biking to access public transit, the combination of bicycles and transit has great potential to expand the reach of the transit system and make it more useful and flexible for the system’s users. Literature on bicycles and transit identifies several benefits

9. Emily Yauskochi (Sound Transit Senior Policy Planner), e-mail message to author, April 22, 2016.

10. “BART Bicycle Plan: Modeling Access to Transit,” Bay Area Rapid Transit, July 2012, v.

to their integration. Primary among these is that using bikes as a transit access mode can significantly expand the catchment area for a transit stop or station. The expanded catchment area is particularly useful for rail transit stations, since they are usually spaced much farther apart than local bus stops. The rule of thumb used for rapid transit access is that most riders are willing to walk one-half mile to reach a station, which corresponds with roughly ten minutes of walking.¹¹ The same ten minutes will allow an average cyclist to travel two miles or more, meaning that the area within ten minutes of the station by bike is sixteen times larger than by foot – a very substantial improvement in range.¹²

The combination of bicycles and transit has other benefits as well. It can improve the efficiency of the public transit system by reducing the need for feeder bus service to transit stations.¹³ Bike and transit integration also supports and encourages cycling generally, which has several corollary benefits.¹⁴ More cycling means a reduction in automobile trips, resulting in reduced traffic congestion and improved air quality.¹⁵ As cycling is an active mode of transportation, increased cycling rates are strongly correlated with lower rates of obesity and diabetes.¹⁶

Methods of Providing Bicycle Access to Transit

There are several ways to facilitate bicycle access to the transit system. Reviews of transit agency bicycle policies show that all major transit agencies in North America provide

11. Kathryn Coffel, "Guidelines for Providing Access to Public Transportation Stations," *Transit Cooperative Research Program Report 153*, 2012, 66.

12. Ibid.

13. Kevin J. Krizek and Eric W. Stonebreaker, "Bicycling and Transit: A Marriage Unrealized," *Transportation Research Record*, no. 2144 (2010): 161.

14. Ibid.

15. Schneider, "Integration of Bicycles and Transit," 1.

16. John Pucher, Ralph Buehler, David R. Bassett, and Andrew L. Dannenberg. "Walking and cycling to health: a comparative analysis of city, state, and international data," *American Journal of Public Health* 100, no. 10 (2010).

parking for bikes at most transit stops and stations and equip their transit vehicles with racks and other equipment to carry bikes along on the transit vehicles themselves. These methods of accommodating bike access to transit are discussed in greater detail below. Providing parking and capacity on vehicles are common options primarily because they are directly under control of the transit agencies themselves. Other options for providing bike access to transit include improvements to cycling routes to transit stations and adding bike share facilities at transit stations. These methods are not widely used by transit agencies primarily because they typically require interagency cooperation for construction, maintenance, and operation.¹⁷ Roadway improvements to increase cyclist access are usually the responsibility of municipal transportation departments, while bike share systems may be publicly run by municipal governments or privately operated. Despite these challenges for implementation, these improvements are an important part of the full picture of bicycle access to transit.

Bike Share and Transit

Bike share systems are a relatively recent phenomenon in the United States and are not well-represented in the literature. Cities with extensive transit service and large bike share programs, such as Boston and Washington, D.C., seek to locate bike share locations near transit stations. This can reduce the need for dedicated parking for personal bicycles, though the effectiveness of this strategy for providing bike access to transit depends greatly on the size and usefulness of the bike share system.¹⁸

Seattle has its own bike share system, known as Pronto, which opened in October 2014.

Pronto bike share was purchased by the City of Seattle in 2016 and is now managed by the

17. Coffel, "Guidelines for Providing Access to Public Transportation Stations," 68.

18. *Ibid.*, 76.

Seattle Department of Transportation. Pronto covers downtown Seattle, Capitol Hill, and the University District, and bike share stations are located in close proximity to all six Link light rail stations in those locations. However, the system has a small number of subscribers at less than 3,000 and sees very low rates of use, averaging less than one ride per bike per day.¹⁹ This low rate of adoption of bike share in Seattle means that it is unlikely to significantly improve bicycle access to Link light rail even where it is convenient. Additionally, most of Link's stations are located outside of the Pronto bike share service area, and thus cannot be accessed using bike share.

Cycling Routes to Transit Stations

Improving bicycle routes to transit stations can be done by creating bicycle lanes or paths, through the provision of wayfinding signage, or through a combination of these approaches. While this is an important component of supporting bike and transit integration, very few transit agencies are able to make these improvements themselves.²⁰ Instead they must typically rely on local transportation departments who have jurisdiction over the street network. Some exceptions exist – Los Angeles and San Francisco counties both have transit agencies that are fully integrated into the countywide department of transportation, allowing their transit agencies to extend their bicycle planning beyond just the station areas.²¹

Unfortunately, Sound Transit is typical of most American public transit agencies in lacking the authority to make cycling route improvements beyond station plazas. Surrounding jurisdictions

19. Evan Bush, "Seattle's Pronto bike-share nonprofit teetering, seeks \$1.4M rescue by city," *Seattle Times*, January 29, 2016, <http://www.seattletimes.com/seattle-news/transportation/seattles-pronto-bike-share-program-at-risk-of-shutting-down/>.

20. Schneider "Integration of Bicycles and Transit," 17.

21. Ibid.

are generally supportive of cycling improvements, but Sound Transit has very limited ability to pursue this method of supporting bicycle access to its transit system.

Bikes on Transit Vehicles

Most transit agencies in North America provide capacity for carrying bicycles onboard transit vehicles. This allows cycling transit passengers who arrive at transit stops by bicycle to bring their bicycle with them as they continue their trip on transit. Cycling passengers can then continue their journey by bicycle at the end of their transit trip or keep their bike with them for security reasons. A series of interviews with bicycle planning staff at nine major North American transit agencies in 2015 revealed that all nine agencies fit bicycle racks on the front of buses and all agencies that run rail transit service include hooks or racks for bicycles inside the vehicles.²²

Though the use of bike-on-transit methods of integrating bicycles and transit is widespread, this method suffers from one significant drawback for cycling transit users. As bike-on-transit use becomes popular, and thus more commonly used, capacity is quickly reached. While the option of bringing a bicycle along on a bus or train trip can be useful to passengers, it is not reliable. If a bus or train arrives at the stop and its bicycle spaces are already full, cyclists intending to board must wait for the next vehicle to come. If bike on transit trips are popular, there is no guarantee that the next vehicle to arrive will have space open for a bike.

Additional complications are presented when bringing a bicycle aboard rail transit like Link. Since bikes must be brought inside the train car, they can present an obstruction to passenger loading and unloading and may occupy space that could otherwise accommodate

22. Brand Koster, "How Transit Agencies Handle Bicycles: An analysis of nine North American transit agencies," (PhD diss., University of Washington, 2015), Appendix B.

more passengers. During peak hours, when trains are likely to be at or near capacity, bicycles can therefore impede access to the train and reduce its capacity. Because of this problem, several agencies currently prohibit bikes from being loaded onto some or all train cars during peak hours, including transit agencies for Chicago, Los Angeles, New Jersey, New York, San Diego, San Francisco, and Vancouver, B.C.²³ Vancouver's TransLink also prohibits bikes at all hours at one station because the presence of bikes interferes with passenger circulation.²⁴

While bike-on-train programs are generally quite popular with cycling transit passengers, these peak-hour restrictions on bicycles are reportedly the primary complaint about these programs from cyclists.²⁵

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23. Schneider, "Integration of Bicycles and Transit," 31.

24. Koster, "How Transit Agencies Handle Bicycles," Appendix B.

25. Schneider, "Integration of Bicycles and Transit," 29.

Sound Transit currently allows bikes on all Link train cars at all times of operation. The train cars each have capacity for four bikes – there are two hooks for hanging bikes, and two more cyclists are allowed to stand with their bikes.²⁶ Link typically operates in two-car trainsets, so each light rail train can carry a maximum of eight bikes. The bike hook area is also shared with luggage, and since the Link line serves the region’s major airport, luggage is often stored where bikes would normally be loaded on the train (see Figure 2). This means that Link’s practical capacity for bikes is often lower than the stated maximum, as no more than two standing bikes are allowed per train. At present, bike crowding problems on Link light rail have only been reported anecdotally, though Sound Transit only performs use counts of its bicycle

Figure 2 – Luggage Filling the Bike Area on a Link Light Rail Train



The bike area on Link light rail trains also functions as a luggage storage area. Since the line serves the airport, luggage frequently reduces Link’s capacity for carrying bikes. Photo by author, April 30, 2016.

26. “Bicycle Riders Guide,” Sound Transit, April 13, 2016, <http://www.soundtransit.org/sites/default/files/BRO%20ST%20BikeBrochure%202016%20FINAL.pdf>.

facilities and services annually.²⁷ If a bike capacity problem were to develop on Link vehicles, it would likely be identified through passenger complaints rather than active monitoring. The fact that Sound Transit has banned oversized bikes and cargo bikes from being brought onto Link light rail trains poses an access challenge for some riders and provides an indication that further restrictions on bicycles onboard trains will be needed as Link's ridership grows.²⁸

Bike Parking at Transit Stations

Storage facilities for bicycles at transit stations provide an alternative for cyclists to access the transit system without bringing a bicycle onboard the transit vehicle. Typically, cyclists will leave from home, bike to the transit station, secure their bike at the station, and continue the final leg of their journey on transit. Other trip combinations are also possible. For example, a cyclist may store their bike at a transit station overnight so they have access to a bike at the end of their transit trip. In both of these cases, secure bicycle parking is key to making the multimodal connections reliable.

The Department of Justice reports that transit stations have a high incidence of bicycle vandalism and theft.²⁹ Since bikes will usually be left unattended for eight hours or more when used as part of a bike and transit commute, secure parking facilities help ensure that a bike will still be there and in usable condition when its rider returns. This makes secure bike parking a critical part of the infrastructure needed to support bicycles access to transit. Literature and transit agency experience both support the assertion that the availability of secure bike parking

27. Koster, "How Transit Agencies Handle Bicycles," Appendix B.

28. "Bicycle Riders Guide," Sound Transit.

29. Shane D. Johnson, et al., "Bicycle Theft," *Problem-Oriented Guides for Police Problem-Specific Guides Series 52*, United States Department of Justice, June 2008, 4.

at transit stations is a significant factor in a transit user's decision to access the transit system by bicycle, discussed further in chapter 3.

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Chapter 3: Secure Bicycle Parking at Transit Stations

Secure Bicycle Parking Background

Bicycles are most commonly parked using standard bicycle racks on the street or sidewalk. This arrangement offers several advantages over other types of bike parking facilities. Chief among these is low cost – standard bicycle racks may cost as little as \$150 each while accommodating several bikes.³⁰ This low cost combined with the fact that bike racks require very little space means that they can be installed within easy reach of most destinations. Large numbers of bikes can be accommodated at transit stations using standard racks – several BART stations have capacity for over one hundred bikes at their bike racks.³¹

While cheap and easy to implement, bicycle racks have a major weakness: security. Bicycles are vulnerable to inclement weather, damage, vandalism, and theft even when carefully secured to a bike rack with a quality lock.³² This has been a longstanding problem with the use of bicycles for transportation. In 1979, it is estimated that roughly 2.6 million bicycles were stolen.³³ While the problem has lessened somewhat in the intervening years, the numbers are still discouraging to cyclists. A 2006 estimate by the National Crime Victim Survey put the number of bike thefts that year at 1.3 million, which equates to just under 2.5 bike thefts per minute.³⁴ A Department of Justice report on bicycle theft indicates that bike theft is particularly

30. Schneider, "Integration of Bicycles and Transit," 36.

31. "BART Bike Parking Capital Program: Increasing bike access while reducing bikes onboard," Bay Area Rapid Transit, April 2015, 56.

32. Rachel Aldred and Katrina Jungnickel, "Matter in or out of place? Bicycle parking strategies and their effects on people, practices and places," *Social & Cultural Geography* 14, no. 6 (2013): 605.

33. Michael A. Replogle, *Bicycles & Public Transportation: New Links to Suburban Transit Markets* (Emmaus, PA: The Bicycle Federation, Washington, D.C, 1983), 130.

34. Johnson, "Bicycle Theft," 4.

likely to occur at public transit stations, primarily because they are locations where bicycles are left unattended for long periods of time.³⁵

Several studies using stated preference surveys have shown that the availability of secure bike parking has a strong influence on people's choice to use cycling as a transportation mode. In the starkest example, a 2007 survey of cyclists in Edmonton, Alberta found that knowing secure parking is available at the cyclist's destination was equivalent to reducing the cycling trip time by 26.5 minutes.³⁶ More recently, a 2011 survey of Vancouver, British Columbia cyclists found that the availability of secure indoor bike storage was the most positive influence on willingness to cycle to a destination outside of environmental and route factors like weather, topography, and quality of bike lanes.³⁷ There is ample evidence that the issue of bicycle parking security directly affects the use of bike parking at transit stations. A 1997 study found that lockers at transit stations were tied with already being a bike commuter as the second-most important factor in a cyclist's decision to use a bike to access public transit, following closely behind the availability of bike lanes.³⁸ A 2011 survey of BART passengers who brought bikes on board the system with them revealed that 25% did so because they did not have secure bike parking available at the station.³⁹ It is likely that the lack of access to secure bike parking at transit discourages many more people from riding to transit stations in the first place.

35. *Ibid.*, 8.

36. JD Hunt and JE Abraham, "Influences on Bicycle Use," *Transportation*, no. 34 (2007): 463.

37. Meghan Winters et al., "Motivators and deterrents of bicycling: comparing influences on decisions to ride," *Transportation*, no. 38 (2011): 158.

38. Dean Taylor and Hani Mahmassani, "Analysis of Stated Preference for Intermodal Bicycle-Transit Transfers," *Transportation Research Record*, no. 1556 (1997): 94.

39. "BART Bike Parking Capital Program," 56.

Defining Secure Bicycle Parking

The San Francisco Municipal Transportation Authority (SFMTA) places bicycle parking into two classifications: short-term (class II) and long-term (class I). Short-term parking is intended to hold bikes for two hours or less, and includes various types of on-street or sidewalk bicycle racks. Long-term parking is intended for storing bikes for any time period longer than two hours, and includes bicycle lockers, bicycle cages and rooms, bicycle stations, and monitored bicycle parking.⁴⁰ Standard (non-secure) bicycle parking, comprising unenclosed racks located on the street or sidewalk, is best used for brief bicycle stops. Even then, SFMTA is careful to point out that security should be a goal when designing short-term parking. While the SFMTA classification is not definitive, it provides a useful distinction between types of bicycle parking. Most importantly, this classification has been adopted by Sound Transit for their bicycle planning purposes.⁴¹

The Transit Cooperative Research Program (TCRP) Report 153 *Guidelines for Providing Access to Public Transit Stations* provides a definition of secure bike parking that is based on form rather than length of time. Secure bike parking is any type of bicycle parking that provides a greater degree of security than a standard bicycle rack.⁴² While this definition is structured differently from that used by SFMTA, the end result is the same, with bicycle parking divided between standard bicycle racks and all other forms of bicycle parking facilities. Additional review of literature on the subject of bicycle parking maintains this distinction, and so for the

40. "Bicycle Parking: Standards, Guidelines, Recommendations," San Francisco Municipal Transportation Agency, 2015, 9.

41. Rebecca Roush (Sound Transit bicycle coordinator), e-mail message to author, April 21, 2016.

42. Coffel, "Guidelines for Providing Access to Public Transportation Stations," 74.

purpose of this thesis, secure bicycle parking will include all bicycle parking facilities other than standard racks.

Types of Secure Bicycle Parking

Leased Bicycle Lockers

Leased lockers are the most common type of bike parking other than standard racks, and the most common type of secure bike parking currently in use.⁴³ Leased lockers may also be known as subscription lockers. In this setup, individual lockers are restricted to access by only one particular cyclist through the use of a key or an individualized electronic access code. Leased lockers can be leased for any amount of time, but are commonly leased for three or six months at a time. Locker lease fees vary by agency and lease period but rarely exceed \$100 per year.⁴⁴

Leased lockers offer three primary benefits to their users. The first is that users do not need to provide their own lock, as one is built into the door. Second, most locker designs obscure the locker contents from public view, so potential thieves remain unaware of the value of a locker's contents or even whether a locker has anything in it at all. The third benefit is that leased bike lockers guarantee their users a secure space to park their bike at all times.⁴⁵ Other secure bike parking options are first-come, first-served, meaning that users cannot be guaranteed a space. Leased lockers avoid this potential issue because they only provide access to one user.

⁴³ Ibid.

⁴⁴ Ibid.

⁴⁵ Ibid.

Figure 3 – Leased Bicycle Lockers at the SeaTac/Airport Link Station



This photo shows a CycleSafe ProPark leased bike locker in use by Sound Transit at the SeaTac/Airport Link light rail station. This type of locker is in widespread use by Sound Transit at light rail stations and other transit facilities, and each locker is internally divided to provide secure storage space for two bikes. Photo by author, January 15, 2016.

Leased lockers have some challenges in addition to their benefits. The primary drawback of leased lockers is that they require a large amount of space per bicycle accommodated. The CycleSafe ProPark bike locker shown in Figure 3 above is one of the bike locker models currently in use by Sound Transit. The locker itself holds two bikes in internally divided compartments in a 38”x78” footprint. CycleSafe recommends installing lockers with six feet clear from either door to provide adequate access, meaning that one locker requires an area of roughly three feet by eighteen feet.⁴⁶ This is 58.6 square feet per locker, or 29.3 square feet per bike. Additionally, since each leased locker is only accessible by one cyclist per leased space, the capacity of leased lockers goes unused much of the time. Audits of King County Metro bike

46. “ProPark Bike Locker,” CycleSafe, accessed April 13, 2016, <http://cyclesafe.com/bike-lockers/propark/>.

lockers have found that only 40% of leased lockers are actually in use during weekday business hours, when locker utilization is expected to be highest.⁴⁷ Table 1 presents data from an audit of leased bike lockers in the BART system in 2011, which found on average only 17% of leased bike lockers were occupied.⁴⁸ Low rates of leased locker use have led several transit agencies to move toward other methods of providing secure bike parking at their stations.⁴⁹

Table 1 – Leased Bicycle Locker Occupancy at Selected BART Stations in 2011

This table shows leased bicycle locker occupancy at selected BART stations collected on a single spring day in 2011. BART's audit of leased lockers found that only 17% were occupied at the time of data collection. Data source: "BART Bicycle Plan," 13-17.

BART Station	Leased Lockers	Occupied Lockers	Leased Locker Occupancy Rate (%)
Ashby	24	6	25
Bay Fair	16	4	25
Orinda	8	0	0
San Leandro	12	4	33
Union City	20	7	35
Walnut Creek	64	1	2
West Oakland	8	4	50
Average Leased Locker Occupancy Rate: 17%			

Electronic Bicycle Lockers

Electronic bicycle lockers are sometimes known by the terms on-demand lockers or e-lockers. These are very similar in design to leased lockers and offer users the same security benefits as leased lockers. The primary difference from leased lockers is that electronic lockers are not leased to a specific individual. Instead, they are available on a first-come first-served basis to anyone with access to the electronic locker system. While multiple access options are possible, most electronic lockers use a keycard access system, which doubles as the method of

47. Hannah J. McIntosh, "Bicycle Parking and Transit: A Demand Analysis for Bicycle Lockers at King County Metro Park and Ride Lots," (Master's thesis, University of Washington, 2007), 4.

48. "BART Bicycle Plan," 13-17

49. Coffel, "Guidelines for Providing Access to Public Transportation Stations," 74.

payment.⁵⁰ Charges for use of electronic lockers are usually low at only a few cents per hour. For example, BART's electronic lockers charge 3 to 5 cents per hour depending on occupancy levels,⁵¹ while King County Metro charges 5 cents per hour at all times for use of their electronic lockers (shown in Figure 4).⁵²

Figure 4 – Electronic Bicycle Lockers at Seattle's Northgate Transit Center



King County Metro has partnered with BikeLink to provide electronic bike lockers at the Northgate Transit Center. There are currently six of these on-demand lockers available at the transit center, providing parking for twelve bikes. Photo by author, April 30, 2016.

Electronic bike lockers have the same dimensions as leased lockers and therefore are subject to the same space requirements. However, electronic lockers can store more bikes in the same amount of space because they are available to multiple users. Though occupancy rates for electronic lockers are not published, BART cited significantly increased usage rates for electronic lockers compared to leased lockers when it more than doubled its inventory of

50. Ibid.

51. "Bike on BART," Bay Area Rapid Transit, accessed April 21, 2016, <http://www.bart.gov/guide/bikes>.

52. "Bike Travel: On-Demand Bike eLockers," King County Metro Transit, accessed April 21, 2016, <http://metro.kingcounty.gov/tops/bike/parking/elockers.html>.

electronic bike lockers in 2011 and 2012.⁵³ BikeLink, the main vendor of electronic bike locker systems in the United States, states that their usage data indicates at least five times as many cyclists use electronic lockers as use leased lockers, though their data are not published.⁵⁴ A 2011 count of bike locker usage at BART stations found that 57% of electronic lockers were in use, compared with only 17% of leased lockers.⁵⁵ Data for BART’s electronic lockers are presented in Table 2 below.

Table 2 – Electronic Bicycle Locker Occupancy at Selected BART Stations in 2011

This table presents electronic bicycle locker occupancy at selected BART stations collected on a single spring day in 2011. BART’s audit of electronic lockers found that 57% were occupied at the time of data collection. Data source: “BART Bicycle Plan,” 13-17.

BART Station	Electronic Lockers	Occupied Lockers	Electronic Locker Occupancy Rate (%)
12th St/Oakland	8	7	88
19th St/Oakland	8	7	88
Concord	16	0	0
Daly City	4	1	25
Dublin/Pleasanton	12	4	33
El Cerrito Plaza	48	35	73
Lake Merrit	32	29	91
MacArthur	40	32	80
North Berkeley	48	37	77
Pleasant Hill	24	22	92
Richmond	16	0	0
Rockridge	32	16	50
San Leandro	20	20	100
Walnut Creek	16	0	0
West Oakland	18	9	50
Average Electronic Locker Occupancy Rate: 57%			

53. “BART more than doubles number of electronic bike lockers,” Bay Area Rapid Transit, January 30, 2012, <http://www.bart.gov/news/articles/2012/news20120130>.

54. “Benefits,” BikeLink, accessed April 23, 2016, <https://www.bikelink.org/help/benefits>.

55. “BART Bicycle Plan,” 13-17.

Electronic bike lockers are more expensive than leased lockers and require more management, leading to higher overall costs. However, they can be less expensive per cyclist served due to their higher occupancy rates.⁵⁶ The great benefit of electronic lockers is also their largest drawback: they are not reserved for individual users. As a result, they may fill up if demand for bike parking is high, leaving cyclists unable to access secure bicycle parking. Cyclists would then have to lock their bike at a standard bike rack or forego storing their bike at that location.

Bicycle Cages and Bicycle Rooms

Bicycle cages and bicycle rooms are two variations on a single theme – providing bicycle parking in an area with controlled access. Bike cages differ from bike rooms only in that they have bars, screens, or fencing in place of solid walls. For both rooms and cages, entry is controlled using electronic keycards or individualized electronic access codes. Inside the bike room or cage bike racks are provided onto which bikes can be secured. This requires the use of an additional user-provided lock, as the racks inside bike cages are functionally very similar to standard bike racks. The racks inside bike cages are commonly mounted vertically on the wall or stacked into two levels to maximize the use of the cage space. An example of a bike cage is presented in Figure 5 on the following page.

56. “Questions frequently asked by people considering purchasing BikeLink equipment,” eLock Technologies LLC, 2010, accessed April 23, 2106, <http://elocktech.com/docs/BikeLink%20brochure%20-%20general.pdf>.

Figure 5 – Bicycle Cage in Use at the Beacon Hill Link Station



(A) This bicycle cage was added to Sound Transit's Beacon Hill Link station in 2016. It has capacity to securely store 48 bikes in a footprint of 14.5 x 45 feet, requiring less than half as much space per bike as bicycle lockers. (B) Entry is controlled by keycode access and provides a record of every person who accesses the bike cage. (C) Double-decked racks help make the best use of space inside the bike cage. Photos by author, April 30, 2016.

The primary benefit of bike cages and bike rooms is that they are able to use space more efficiently than the bike locker arrangements discussed previously. Because the racks inside bike cages are typically stacked, they are also more space-efficient than standard bike

racks. Sound Transit has installed a bike cage at the Beacon Hill Link station (shown in Figure 5) with capacity for 48 bikes. This bike cage measures 14.5 feet by 45 feet, covering a total area of 652.5 square feet.⁵⁷ This translates to 13.6 square feet per bike, or less than half of the space required per bike using bike lockers. Like lockers, bike rooms and cages protect bikes from the elements, which is a particular concern for bikes parked in Seattle's rainy climate.

The level of security provided by bike rooms and cages is intermediate between standard racks and bike lockers. All bike cages provide an extra layer of security over standard racks with their restricted access. Sound Transit's implementation of bike cages improves upon this with surveillance cameras to monitor the bike cages as an extra theft deterrent. However, bike rooms and bike cages require cyclists to provide their own locks, which can be burdensome to riders as good quality locks can be quite heavy. If a bicycle is not well-locked inside a bike room or cage, it may still be subject to theft or vandalism if bike thieves are able to gain entry. Security depends partly on the caution of authorized users of bike cages. While holding the door for another user of a bike room or cage may be viewed as polite, it may also be granting unauthorized access to the secure bike facility.

Staffed Bicycle Parking Facilities

Staffed bicycle parking facilities may also be known as bike valets or staffed bike stations and provide a high level of convenience and security to cyclists. The first staffed bike parking facility in the United States was built in Long Beach, California in 1996, though the concept had

57. Author's fieldwork and calculations, April 30, 2016.

been in use in many European countries previously.⁵⁸ Many staffed bike parking facilities have opened in the US since the Long Beach BikeStation's debut, including facilities run by several transit agencies.⁵⁹ Staffed bike parking, as its name implies, relies on the presence of dedicated staff to manage and monitor stored bikes. Typically, a bicycle storage area is provided that is only accessible by staff at the parking facility. Bicycles are placed in the storage area by facility staff when dropped off by customers and retrieved when customers return for their bikes. The exact operational details vary at different facilities, but the general concept is similar to valet parking for cars. Staffed bike parking facilities vary in cost depending on the agency in charge. Some may charge an hourly fee or require or a membership for use, while several staffed bike parking facilities are free for customers to use.⁶⁰

Staffed bike parking offers many benefits to its users. Staffed parking is extremely easy to use, since customers do not have to deal with storing or locking their bikes at all. It is also very secure, since public access to stored bikes is prevented and the stored bikes are actively monitored by the parking facility staff. Many staffed bike parking facilities also include bike repair and retail facilities, which can add significant convenience for bike commuters. Users of the staffed parking facility can have their bike repaired while they go about their usual daily routine, avoiding the need for a separate trip to a bike shop.⁶¹

Using staffed parking also provides a significant benefit to its operators: extremely efficient use of space when parking large numbers of bicycles. Go By Bike, a staffed bicycle

58. Kim Upton, "Grand ol' opening for Long Beach Bikestation," *The Source* (Los Angeles County Metropolitan Transportation Authority), last modified September 15, 2011, <http://thesource.metro.net/2011/09/15/grand-ol-opening-for-long-beach-bikestation/>.

59. Coffel, "Guidelines for Providing Access to Public Transportation Stations," 74.

60. Schneider, "Integration of Bicycles and Transit," 39.

61. *Ibid.*

parking facility in Portland, Oregon, operates a bike valet and a small repair shop in an area that measures 48 x 58 feet, or 2,784 square feet.⁶² A maximum of 350 bikes can park at the Go By Bike valet at one time; this means that only 7.8 square feet of space are needed per bike.⁶³ This is barely over half of the space needed for bike cages and just one quarter the space needed per bike using bike lockers.

The benefits of staffed bicycle parking are balanced against one potential inconvenience and a significant cost, both of which stem from the need for staffing. First, since staff must be available to operate the facility, bike valets are not open at all hours. Most staffed bike parking facilities close down overnight. While overnight storage for bikes may be available at some staffed bike parking facilities, bikes stored overnight cannot be accessed while staff is away. While the hours of operation are unlikely to be a problem for most bike commuters who would use a bike valet, they may cause some inconvenience. More serious, however, are the costs associated with keeping parking facilities staffed. While operating costs will depend on the hours of operation for a bike valet, estimates range from \$50,000-\$100,000 per year.⁶⁴ Portland's Go By Bike valet service is open 13.5 hours per day for five days per week and sees annual operating costs of \$100,000.⁶⁵ This is a significant ongoing cost that other types of secure bike parking do not incur.

62. Measurements via Google Maps, April 15, 2016.

63. Kiel Johnson (owner of Go By Bike), e-mail message to author, April 19, 2016.

64. Schneider, "Integration of Bicycles and Transit," 40.

65. Kiel Johnson (owner of Go By Bike), e-mail message to author, April 11, 2016.

Existing Secure Bike Parking at Link Light Rail Stations

Sound Transit currently offers secure bike parking at eight of Link light rail's sixteen stations. All eight of those stations have leased bike lockers, while two of those stations also have bike cages installed.⁶⁶ The number of secure and non-secure bike parking spaces at each Link station is shown in Table 3 on the following page, along with the number of bike parking subscribers. Many of the stations without secure bike parking have high ridership and are in areas where cycling is common, such as the University of Washington and Capitol Hill stations. Though the existing secure bike parking at Link stations is underused, it is likely that significant unmet demand for safe bike storage exists at several stations.

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66. Rebecca Roush (Sound Transit bicycle coordinator), e-mail message to author, April 21, 2016.

Table 3 – Current Bicycle Parking Capacity at Link Light Rail Stations

Half of Link’s sixteen stations currently have secure bike parking, with Sound Transit providing a mix of leased lockers and bike cages. The number of secure bike parking subscribers at each station includes locker lessees and those signed up for bike cages. Note that the number of subscribers is not an indication of the need for secure bike parking at stations that currently offer none – it is likely that these stations have significant unmet demand. Data source: Rebecca Roush (Sound Transit bicycle coordinator), e-mail message to author, April 21, 2016

Station	Locker Spaces	Bike Cage Spaces	Parking Subscribers	Non-Secure Rack Spaces
University of Washington	0	0	0	130
Capitol Hill	0	0	0	40
Westlake	0	0	0	0
University Street	0	0	0	0
Pioneer Square	0	0	0	0
International District / Chinatown	0	0	0	0
Stadium	0	0	0	0
SODO	16	0	12	0
Beacon Hill	4	48	17	24
Mount Baker	24	0	6	16
Columbia City	37	0	15	56
Othello	0	0	0	48
Rainier Beach	20	0	11	16
Tukwila International Boulevard	8	0	4	24
SeaTac / Airport	24	0	5	16
Angle Lake	8	40	4	14

Sound Transit’s method of bike parking allocation assumes that 2% of the projected 2030 boardings for a given station will occur via bike access. Parking is built to accommodate less than half the expected number of bike-accessed trips, including class I bike parking (secure parking) and class II parking (standard bike racks). Additional space is reserved during station design for additional bike parking space, with parking availability increased as demand warrants. Recently-adopted policy at Sound Transit will provide for 60% of bike parking built at new Link

stations to be class I secure parking, provided through a mix of bicycle cages and leased lockers.⁶⁷ While this represents an improvement for future Link stations, the existing stations will be left with a small supply of secure bike parking. Most notably, the University of Washington and Capitol Hill stations that opened in 2016 have no secure bike parking spaces at all. The Transit Cooperative Research Program recommends bike parking at transit stops be scaled to accommodate at least 5% of boardings at the given stop.⁶⁸ Some transit agencies are building even higher levels of bike parking capacity at their transit stations, with Portland, Oregon's TriMet building parking for bike access shares of 10-25% along the MAX Orange light rail line, which opened in late 2015.⁶⁹

Bike Parking at Sound Transit's Peer Transit Agencies

Several North American transit service operators provide high levels of secure bicycle parking at transit stations, including major bus transit centers and rail stations. These agencies and their programs and practices can serve as models for Sound Transit to expand its own nascent secure bike parking program. Peer agencies with effective programs for providing secure bike parking were identified through a combination of literature review and consultation with Andrea Clinkscales at Cascade Bicycle Club, a non-profit bike planning and advocacy agency based in Seattle. The following reports were particularly useful for identifying agencies to highlight: TCRP Synthesis 62 *Integration of Bicycles and Transit* (2005), TCRP Report 153 *Guidelines for Providing Access to Public Transit Stations* (2012), and Brand Koster's 2014 master's thesis *How Transit Agencies Handle Bicycles: An Analysis of Nine North American*

67. Rebecca Roush (Sound Transit bicycle coordinator), e-mail message to author, April 21, 2016.

68. Coffel, "Guidelines for Providing Access to Public Transportation Stations," 69.

69. Ibid., 66.

Transit Agencies. Selected agencies provide large, effective, and innovative secure bicycle parking facilities, including leased and on-demand bike lockers, bike cages, and attended bike parking stations.

Bay Area Rapid Transit (BART)

Agency Profile

BART's transit service is comprised of five heavy-rail rapid transit lines in the San Francisco Bay Area. The BART system includes 44 stations and reaches several major cities in the Bay Area, including Berkeley, Oakland, and San Francisco.⁷⁰ This agency ranked as the tenth largest transit agency in the United States in 2013 in terms of passenger boardings.⁷¹ BART is widely recognized as being at the forefront of planning for and accommodating bicycle access, and in 2012 the agency had a bike access mode share of 4%.⁷² Like Sound Transit, BART's service is limited to regional rail transit. Local public transit service in the San Francisco Bay Area, including buses and light rail, is provided by a mix of other agencies within the BART service area, primarily the San Francisco Municipal Transportation Authority and Alameda County Transit.

Bicycle Program and Practices

BART's bicycle parking program is guided by two major documents. The first is the BART Bicycle Plan, last updated in 2012. This document established BART's current goal of doubling the system's bicycle access mode share to 8% by 2022.⁷³ The BART Bicycle Plan also identifies

70. "Station List," Bay Area Rapid Transit, accessed April 15, 2016, <https://www.bart.gov/stations>.

71. John Neff, "2015 Public Transportation Fact Book," American Public Transportation Association, November 2015, 8.

72. "BART Bicycle Plan," v.

73. *Ibid.*

several strategies for achieving this goal, including making access easy with bike route and circulation improvements, increased capacity on BART trains for bikes, promotional programs to encourage bike access, and expanded and improved bike parking facilities at BART stations. The other guiding document for BART's bicycle parking program is the BART Bike Parking Capital Program, last updated in 2015. This document details plans for upgrading and expanding the bicycle parking available at BART stations to support the BART Bicycle Plan's goal of increased bike access to the BART system. The BART Bike Parking Capital Program heavily favors the use of secure bike parking facilities, primarily on-demand lockers and attended bike parking stations. The plan further proposes removing standard bike racks at 12 BART stations to make space for additional secure bike parking facilities.⁷⁴

Secure Bicycle Parking Facility Inventory

Currently, three of BART's 44 stations offer staffed bike parking facilities, with two located in Oakland and one in Berkeley. All three staffed bike parking facilities are open for 14 hours per day on weekdays, and the Berkeley facility is also open for limited hours on Saturdays. BART's staffed bike parking facilities are operated by BikeHub and are free to use for BART passengers.⁷⁵ Capacity at these staffed parking stations ranges from 130 to 200 bikes. Bicycle repair services and bike accessory sales are offered at all three of BART's staffed bike parking facilities.

Four BART stations provide controlled-access bike rooms, which are known as "self-serve bike stations" in BART's bike program. These bike rooms can be accessed at all hours using a BikeLink electronic key card. A fee is charged through the BikeLink card for use of bike

74. "BART Bike Parking Capital Program," 3.

75. "Bike Station Details," Bike Hub, accessed March 24, 2016, <http://bikehub.com/bartbikestation/>.

rooms, though fees are quite low – costs range from 1 to 3 cents per hour depending on time of day. BART bike rooms use either double-decker racks or vertical racks to maximize the number of bikes that can fit inside, and capacity ranges from 89 to 128 bikes. Like the staffed parking, BART’s bike rooms are run by BikeHub.⁷⁶

In addition to staffed parking and bike rooms, BART offers leased bike lockers and on-demand electronic bike lockers at many of its stations. A 2011 inventory of BART bike parking listed fourteen stations that offered on-demand electronic lockers and twenty-seven that provided leased lockers.⁷⁷ Like the bike cages, electronic bike lockers are accessed using BikeLink cards and charge small hourly fees, ranging from 3 to 5 cents per hour.⁷⁸ Leased bike lockers cost \$30-\$40 per year.⁷⁹ These facilities combined with staffed parking and bike cages for a total of 1,688 secure bike parking spaces in 2011, roughly 37% of BART’s bike parking capacity at that time.⁸⁰ BART has since more than doubled the number of electronic lockers in the system, opening 336 lockers at 19 stations in early 2012.⁸¹ Work on expanding secure bicycle parking availability is ongoing.

76. Ibid.

77. “BART Bicycle Plan,” 15.

78. “Bike on BART,” Bay Area Rapid Transit, accessed April 21, 2016, <http://www.bart.gov/guide/bikes>.

79. “Bicycle Locker Application,” Bay Area Rapid Transit, accessed April 15, 2016, <http://www.bart.gov/sites/default/files/docs/riderLockersForm.pdf>.

80. “BART Bicycle Plan,” 15.

81. “BART more than doubles number of electronic bike lockers,” Bay Area Rapid Transit, January 30, 2012, <http://www.bart.gov/news/articles/2012/news20120130>.

Example Secure Bicycle Parking Facility

Berkeley Bike Station

The Berkeley Bike Station, located in downtown Berkeley, California, is BART's largest bike parking facility and the second largest bike parking facility in the United States.⁸² The Berkeley station has capacity for 288 bikes provided by two types of secure parking facilities: a controlled-access bike room and staffed bike parking. The bike room provides 113 bike parking spaces, while the staffed parking area has room for 175 bikes.⁸³

Figure 6 – Staffed Bike Parking Inside BART's Downtown Berkeley Bike Station



The Downtown Berkeley Bike Station's staffed parking facility has capacity for 175 bikes using triple-decker bike racks. This secure bike parking is located behind the counter at the Downtown Berkeley Bike Station's repair and retail sales area. Image source: "The Berkeley Bike Station," Your Berkeley, accessed April 30, 2016, <http://yourberkeley.com/2014/10/24/berkeley-bike-station/#sthash.mOlRm9el.I20ADChr.dpbs>.

82. "BART Bike Parking Capital Program," 19.

83. "New Berkeley Bike Station nearly quadruples bike storage capacity," Bay Area Rapid Transit, July 13, 2010, <http://www.bart.gov/news/articles/2010/news20100713>.

The Berkeley Bike Station is not incorporated into a BART transit station. Instead, it is a separate facility that operates in a retail storefront on the ground floor of a mixed-use building. The Berkeley Bike Station serves BART's Downtown Berkeley Station, which is an underground station with an entrance located roughly 150 feet to the north of the Berkeley Bike Station entrance. While placing the bike parking facility outside of the transit station may slightly inconvenience cyclists accessing BART, the siting of the Berkeley bike station was chosen for two reasons. The first of these is that the Downtown Berkeley Bike Station replaced a previous bike parking facility that was located inside the BART station and was well over its designed capacity.⁸⁴ The new location outside of the station nearly quadruples bike capacity. The second reason for the Berkeley bike station location is that it provides access to the staffed parking and the bike room for cyclists who are not using BART. This bike parking facility thus benefits the surrounding Berkeley community, including those not using BART, by providing a bicycle repair and accessories shop that is accessible to the general public. It also allows access to the controlled-access bike room 24 hours a day, so it can be used for secure bike parking even when the BART system is closed.⁸⁵

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84. Ibid.

85. Ibid.

Figure 7 – The Downtown Berkeley Bike Station Entrance



The Downtown Berkeley Bike Station is located in a storefront 150 feet from BART's Downtown Berkeley Station entrance. This allows the facility to serve retail customers who are not riding BART and also enables 24-hour access to the secure bike room that is incorporated into the facility. Image source: "Berkeley BART Bicycle Station," Kaufman Construction, accessed April 18, 2016, <http://www.kaufmanci.com/portfolio/commercial/berkeley-bart-bicycle-station>.

Los Angeles County Metropolitan Transportation Authority (LA Metro)

Agency Profile

LA Metro is both a public transit agency and Los Angeles County's regional transportation planning agency. This uncommon arrangement places LA Metro in charge of planning and operating transit service as well as planning highway and bicycle projects and managing and dispensing transportation funding throughout the county. With 9.6 million people, LA County is the largest county in the United States. The agency's public transit service

is extensive, including 173 bus routes, four light rail lines, and two subway lines.⁸⁶ LA Metro was the third largest transit agency by passenger boardings in 2013.⁸⁷

Bicycle Programs and Practices

LA Metro has a distinct advantage in planning for bicycle access to transit as both a public transit agency and a countywide transportation planning agency. In 2006, the agency completed a countywide bicycle strategic plan in consultation with several transportation planning consulting firms. The plan's primary goal was doubling bike ridership in LA County, but several of the plan's policy objectives dealt with creating an expanded network of bike and transit hubs by providing more bike parking at LA Metro transit stations.⁸⁸ 167 transit stations were evaluated on several criteria for suitability for bike improvements, and twelve stations were identified for bike-transit hub planning. Stations located at the end of transit lines are given high priority for bike improvements and parking in LA Metro's planning process. LA Metro's bike planning is guided by policy documents in addition to the bicycle strategic plan. A 2010 decision by the LA Metro governing board doubled funding for bicycle and transit integration projects, ordering that all new transit projects incorporate bicycle facilities with a goal of increasing bike access.⁸⁹ The order specifically calls out providing higher levels of bike parking at high-demand transit stations.

86. "Facts at a Glance," Los Angeles County Metropolitan Transportation Authority, accessed April 21, 2016, <https://www.metro.net/news/facts-glance/>.

87. Neff, "2015 Public Transportation Fact Book," 8.

88. "Metro Bicycle Transportation Strategic Plan FINAL DRAFT," Los Angeles County Metropolitan Transportation Authority, January 2006, 7-14.

89. "Enhanced MTA Bicycle Policies & Programs," Motion by Mayor Antonio Villaraigoso, LA Metro, September 16, 2010, http://media.metro.net/riding_metro/bikes/images/Bikes_Mayors_Board_Motion_September_2010_16_EMAC.pdf.

Secure Bicycle Parking Facility Inventory

LA Metro's secure bike parking is primarily provided in the form of leased bike lockers. Of the 115 stations in LA Metro's rail and bus rapid transit system network, 47 have bike lockers. Locker rentals cost \$24 for a six-month period.⁹⁰ Three bicycle cage facilities are either open or under construction in the LA Metro system.⁹¹ These are known as bike hubs and incorporate staffed repair service during limited hours of operation to provide a high level of service to cyclists. Two of the three bike hubs are located at end-of-the-line transit stations. LA Metro's bike hubs have capacity for 56 to 72 bikes and users are charged a fee for various access periods ranging from one week to one year.

Example Secure Bicycle Parking Facility

El Monte Bike Hub

The El Monte Bike Hub opened in 2012 and is the first in a series of bike hubs planned by LA Metro.⁹² While not serving one of the agency's rail transit stations, the bike hub is located at a large bus station in El Monte, California, approximately 12 miles east of downtown Los Angeles. The El Monte Bus Station serves as the primary transfer point between LA Metro's Silver Line BRT service and several other transit agencies and sees roughly 22,000 passengers per day – one third the total number of daily Link light rail riders.⁹³ While not the only secure

90. "Metro Bike Locker Program Registration," Los Angeles County Metropolitan Transportation Authority, accessed April 29, 2016, http://blrs.metro.net/mobile/blr_public.aspx.

91. "Introducing Metro Bike Hub," Bike Hub, accessed April 29, 2016, <http://bikehub.com/metro/>.

92. David Sotero, "El Monte Bike Hub opens, featuring Metro's first secure bike parking station," *The Source* (Los Angeles County Metropolitan Transportation Authority), September 14, 2015, <http://thesource.metro.net/2015/09/14/el-monte-bike-hub-opens-featuring-metros-first-secure-bike-parking-station/>.

93. "El Monte Station," Los Angeles County Metropolitan Transportation Authority, accessed April 30, 2016, <https://www.metro.net/projects/elmonte/>.

bike parking facility serving the LA Metro transit system, it is the first one built by LA Metro and integrated directly into one of their facilities.

Figure 8 – Inside LA Metro’s El Monte Bike Hub



The El Monte Bike Hub incorporates retail sales and repair services, staffed part-time, into a secure bicycle room with space for 56 bikes. Access to secure bike storage is available at all hours. Image Source: “Bicycle Facilities Help Commuters with First and Last Mile Connections to Transit Hubs,” Dero Bike Racks Blog, accessed May 3, 2016, <https://www.dero.com/projects/transit-hubs/>.

The El Monte Bike Hub is a hybrid between the bike room and staffed parking facility concepts for secure bike parking. Like most bike rooms and cages, the El Monte Bike Hub uses controlled entry as the main form of security, supplemented by security cameras. Access to the facility is available twenty-four hours per day and bicycles must be locked to racks inside the bike hub. Between 7 am and 11 am on weekdays, the facility is staffed by bicycle mechanics and the El Monte Bike Hub incorporates a small bike repair shop for the bike hub’s users.⁹⁴ Like

94. “Introducing Metro Bike Hub,” Bike Hub, accessed April 29, 2016, <http://bikehub.com/metro/>.

BART's staffed bike parking, the private company BikeHub staffs and operates the El Monte Bike Hub.⁹⁵ Membership fees for the El Monte Bike Hub range from \$5 per week to \$60 per year. The facility has capacity for 56 bikes using double-decker racks.⁹⁶

Tri-County Metropolitan Transit District of Oregon (TriMet)

Agency Profile

TriMet is the public transit provider for three counties in the Portland, Oregon metropolitan area. The agency runs 79 bus routes, five light rail lines, and one commuter rail line. TriMet was ranked fifteenth in the United States by passenger boardings in 2013, though it should be noted that the Portland metropolitan area has a significantly smaller population than that of the other agencies profiled in this thesis.⁹⁷ Despite being the 24th-largest metropolitan area in the country, the Portland metro currently ranks 9th in transit ridership per capita.⁹⁸ TriMet's five MAX light rail lines together saw an average of 125,000 weekday boardings in January of 2016.⁹⁹

Bicycle Program and Practices

Prior to 2016, TriMet's bike program had primarily been administered on an ad-hoc basis, with bicycle access and parking improvements provided as funds became available or needs for improvements arose. The Portland Metro Regional Active Transportation Plan identified the need for bicycle access to the transit system as important at a broad policy level

95. Ibid.

96. Sotero, "El Monte Bike Hub opens."

97. Neff, "2015 Public Transportation Fact Book," 8.

98. "2016 TriMet At-A-Glance," Tri-County Metropolitan Transportation District of Oregon, February 1, 2016, <http://www.flipsnack.com/trimet/2016-trimet-at-a-glance.html>.

99. Timothy Kea, "January 2016 Monthly Performance Report," TriMet Memo, February 18, 2015, <https://trimet.org/about/pdf/2016-01.pdf>.

but did not provide more specific guidance. However, the draft version of TriMet's first comprehensive bicycle plan was released on May 2, 2016. The draft document identifies three priorities for bike planning, in order: secure bike parking, accommodating bikes on transit vehicles, and identifying cycling route improvements that would aid access to transit stations.¹⁰⁰ The Draft TriMet Bike Plan establishes criteria for identifying bike access focus areas and includes preliminary recommendations for bike infrastructure improvements around several transit stations.

Secure Bicycle Parking Facility Inventory

54 of TriMet's stops and stations offer secure bike parking, with a mix of leased lockers, electronic lockers, and bike cage facilities.¹⁰¹ Leased lockers are available at over forty stations and are rented for six-month periods at a cost of \$25 per period.¹⁰² However, TriMet is not building new leased lockers, instead favoring the expansion of their electronic locker and bike cage programs. Electronic lockers are provided at fourteen locations in the TriMet system and, like BART and King County Metro, TriMet's electronic lockers are run by BikeLink. Electronic lockers charge five cents per hour, in line with BART and KC Metro.¹⁰³ Bike cages in the TriMet system are known as Bike & Ride facilities and are also run by BikeLink. Bike & Ride facility use costs three cents per hour or less, depending on time of day. TriMet has installed Bike & Ride

100. "Draft TriMet Bike Plan 2016," Tri-County Metropolitan Transportation District of Oregon, May 2, 2016.

101. "Bike Parking," Tri-County Metropolitan Transportation District of Oregon, accessed April 30, 2016, <http://bikeparking.trimet.org/>.

102. "Reserved Bike Lockers," Tri-County Metropolitan Transportation District of Oregon, accessed April 30, 2016, <http://trimet.org/bikes/lockersavailable.htm>.

103. "Electronic Bike Lockers," Tri-County Metropolitan Transportation District of Oregon, accessed April 30, 2016, <http://trimet.org/bikes/electroniclockers.htm>.

facilities at five high-ridership locations in outlying areas of the TriMet system, including three suburban transit centers and two MAX light rail stations outside of central Portland.¹⁰⁴

Example Secure Bike Parking Facility

Beaverton Transit Center Bike & Ride

The Beaverton Transit Center (TC) in Beaverton, Oregon is home to TriMet's largest Bike & Ride facility. The facility opened in 2011 and has space for 100 bicycles inside the secure area, primarily in the form of double-decker racks. The Beaverton TC Bike & Ride is in a separate structure on the Beaverton TC property, built as a shed with open-air cage walls and a roof to keep bikes protected from rain. The Bike & Ride also provides standard bike racks under shelter outside of the secure area for cyclists who do not have a BikeLink card to access the facility. A bike repair stand is provided outside of the secure bike parking area. The Beaverton TC is a major transit hub in the area west of Portland and includes a bus terminal, a MAX light rail station, and a commuter rail station. It was chosen as a Bike & Ride location because the Beaverton TC has the highest rate of bike access in the MAX light rail system, with 12% of MAX riders arriving to the station by bike.¹⁰⁵ Construction of the Beaverton TC Bike & Ride was funded by federal stimulus funds in the American Reinvestment and Recovery Act.¹⁰⁶

104. "Bike & Ride," Tri-County Metropolitan Transportation District of Oregon, accessed April 30, 2016, <http://trimet.org/bikes/bikeandride.htm>.

105. Jonathan Maus, "TriMet's Largest Bike & Ride Opens in Beaverton," BikePortland.org, July 18, 2011, <http://bikeportland.org/2011/07/18/trimets-largest-bike-ride-opens-in-beaverton-56439>.

106. Joseph Rose, "TriMet will use \$1 million of federal stimulus for bike parking," *The Oregonian*, March 9, 2009, http://blog.oregonlive.com/commuting/2009/03/trimet_will_use_1_million_of_f.html.

Figure 9 – TriMet’s Beaverton Bike and Ride Facility Location



The Beaverton Bike and Ride (highlighted in yellow) was built as a separate structure within a vegetated patch in the Beaverton Transit Center. The facility provides bike access to commuter rail, light rail, and several bus lines and sees a bike access rate of 12%, the highest in the TriMet system. Image source: Google Maps, May 8, 2016.

Other Institutions and Agencies Providing Significant Secure Bicycle Parking

BikeStation

Organization Profile

BikeStation is a private company that designs, builds, and operates secure bike parking facilities at transit stations in several locations in the United States. BikeStation’s operating concept is based on bike parking facilities at transit stations in Europe and Japan. BikeStation’s Long Beach, California facility was the first implementation of secure bike parking other than

lockers for transit users in the United States and opened in 1996 in partnership with LA Metro. BikeStation has since opened several other locations, including a facility in Seattle's Pioneer Square neighborhood which is now closed. The details of operation at BikeStation's locations vary, but many offer repair and retail services, bike rentals, lockers for clothing, and changing rooms with showers in addition to secure bike parking. While these services can help cover operational costs, all BikeStation locations rely on funding through partnership with public agencies, usually public transit agencies that serve the BikeStation location. In addition to building bike parking facilities, BikeStation has consulted on the design of several bike parking projects at transit stations and transit-oriented development projects, including three of BART's secure bike parking facilities.¹⁰⁷

Secure Bike Parking Facility Inventory

There are eight BikeStation locations in operation, with seven of them located in California and one in Washington, D.C. Full-service facilities providing bike repairs, rentals, and showers are in downtown Long Beach, the Palo Alto Caltrain Depot, downtown Santa Barbara, and at Union Station in Washington, D.C. The Santa Barbara location is the smallest with capacity for 78 bikes; the others each have space for 100 bikes or more.¹⁰⁸ BikeStation's other facilities are smaller bike cages and rooms, providing controlled-access bike parking and repair stands for customer use. These are all located in Southern California at LA Metro's Oceanside commuter rail station, the Claremont and Covina stations on the LA Metro San Bernadino

107. "Past and Current BikeStation Projects," BikeStation, accessed April 28, 2016, <http://home.bikestation.com/bikestation-projects>.

108. "BikeStation Locations," BikeStation, accessed April 28, 2016, <http://home.bikestation.com/locations>.

commuter rail line, and a supplemental bike parking station in downtown Santa Barbara. These facilities are smaller than the full-service BikeStations, providing space for 23 to 36 bikes.¹⁰⁹

Example Secure Bike Parking Facility

BikeStation Long Beach

BikeStation opened their first facility in downtown Long Beach, California in 1996. The original location was successful enough to warrant the construction of a new, larger facility, which opened in 2008.¹¹⁰ Located 500 feet from LA Metro light rail and bus lines, the current iteration of BikeStation Long Beach offers a wide range of services to support bicycle and transit use. The general public has access to free staffed bicycle parking during operating hours, and the BikeStation staff provides repair services, information, and bike rentals. Members also have 24-hour access to bike parking, shower and changing rooms, and lockers.¹¹¹ In 2007, operation costs for the Long Beach facility were approximately \$130,000 annually. The majority of BikeStation Long Beach's operating costs are covered by bike repairs, rentals, and membership fees, while \$48,000 was provided by the City of Long Beach in 2007.¹¹² BikeStation Long Beach demonstrates that combining secure bike parking facilities with bicycle retail and service can generate substantial operating funding while providing a high level of service to cycling transit users.

109. Ibid.

110. Upton, "Grand ol' opening for Long Beach Bikestation."

111. "BikeStation Long Beach Services," BikeStation, accessed May 24, 2016, <http://home.bikestation.com/bikestation-long-beach-services>.

112. "BikeStation Long Beach," Pedestrian and Bicycle Information Center, accessed May 24, 2016, <http://www.pedbikeinfo.org/cms/downloads/ENC.BikestationLongBeach.pdf>.

Figure 10 – The New BikeStation Long Beach Facility



BikeStation Long Beach’s new facility opened in 2008, replacing the first secure bike parking facility in the United States. It represents a significant investment in supporting bicycle access to transit, providing secure bike parking near LA Metro light rail and bus service. The project is jointly funded by BikeStation and the City of Long Beach. Image source: “Bike Infrastructure Ride,” Bike Long Beach, accessed May 24, 2016, <http://www.bikelongbeach.org/infrastructure-ride>.

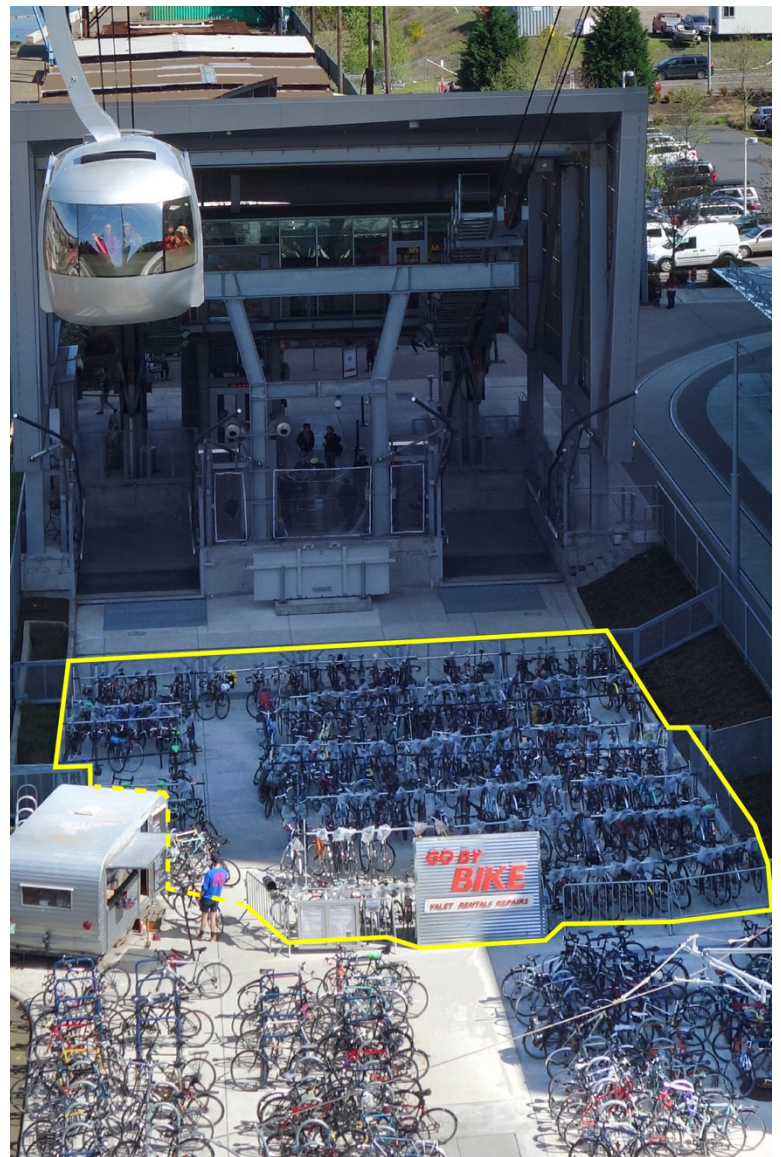
Oregon Health & Science University (OHSU)

Organization Profile

OHSU is a major hospital facility in Portland, Oregon, and serves as the only medical school in the state. OHSU's main hospital campus is located atop the steep Marquam Hill, which has created serious transportation challenges for its 14,000 daily visitors.¹¹³ In response, OHSU has developed a transportation program that is heavily focused on alternatives to automotive access to the hospital. The centerpiece of this strategy is the Portland Aerial Tram, which carries passengers between the main OHSU campus on Marquam Hill and their expansion campus site along Portland's riverfront.

Construction of the tram was mainly funded by the hospital, and use of the tram is free for employees, students, and

Figure 11 – OHSU's Bike Valet at the Portland Aerial Tram



The Portland Aerial Tram bike valet is shown outlined in yellow. The valet area contains over 200 bikes in this photo. Standard bicycle racks outside of the valet area provide additional capacity and allow parking outside of the valet's operating hours. Image source: "Portland Aerial Tram," OHSU, accessed May 18, 2016, <http://www.ohsu.edu/xd/about/services/transportation-and-parking/tram/>.

113. "About Us – Transportation and Parking," Oregon Health & Science University, accessed April 18, 2016, <http://www.ohsu.edu/xd/about/services/transportation-and-parking/About/index.cfm>.

patients at OHSU.¹¹⁴

OHSU offers employees incentives to commute by bike, and several cycling routes connect OHSU's riverfront campus area with the rest of Portland. However, bikes are not allowed on the Portland Aerial Tram. This has created a concentrated need for bike parking at tram's base. In response, OHSU has partnered with a local bike repair shop to offer a free staffed bike parking facility immediately adjacent to the Portland Aerial Tram's waterfront tower.

Secure Bicycle Parking Facility Example

Portland Aerial Tram Bike Valet

The staffed bike parking facility at the base of the Portland Aerial Tram is OHSU's only secure bike parking facility. The bike valet opened in August 2012 and is run by the private firm Go By Bike, which also provides repair service for cyclists using the bike valet. Go By Bike's staffed parking facility is built into the plaza next to the base of the Portland Aerial Tram along Portland's south waterfront area. The facility is enclosed by permanent fences on three sides, but is not covered, and thus it does not provide bikes protection from the rain. Temporary fencing is used to provide the secure area's fourth wall. The bike valet has capacity for 350 bikes inside the secure area, and overflow parking is provided via standard bike racks outside of the bike valet fence.

Go By Bike staffs the bike valet from 6:00 am to 7:30 pm on weekdays.¹¹⁵ Outside of this time period, the valet is closed and only standard bike racks are available for cyclists accessing

114. "Portland Aerial Tram – About," Portland Aerial Tram, accessed April 18, 2016, <http://www.gobytram.com/about/> accessed.

115. "Valet," Go By Bike, accessed April 30, 2016, <http://www.gobybikepdx.com/>.

the tram. This arrangement suffices because the bike valet's hours of operation roughly correspond with regular working and commuting hours for OHSU's students and staff. Use of the valet bike parking is free for all users. Go By Bike's operations are partly funded by repair and rental fees, but the majority of the cost of running the tram's bike valet is paid for by OHSU as part of their employee transportation fund. This amounts to approximately \$80,000 in annual subsidy from the hospital according to Go By Bike's owner.¹¹⁶

Go By Bike maintains a daily tally of the number of bikes using the secure parking. This data provides an interesting insight into the demand for secure bike parking: demand can grow significantly with time. Go By Bike's data shows that daily use averaged over the year (shown in Figure 12) has increased 64% between 2012 and 2015. According to Go By Bike owner Kiel Johnson, this increase matches the increase in the observed rate of bike commuting to the Portland Aerial Tram, suggesting that the availability of secure parking has actually induced an increase in bike commuting.¹¹⁷ Though not scientific, this observation provides some validation to the notion that secure bicycle parking encourages bicycle use.

116. Kiel Johnson (owner of Go By Bike), e-mail message to author, April 11, 2016.

117. Kiel Johnson (owner of Go By Bike), e-mail message to author, April 1, 2016.

Figure 12 – Yearly Averages of Daily Users at the Portland Aerial Tram Bike Valet 2012-2015



The average number of daily users of the Portland Aerial Tram bike valet has increased each year from 2012 to 2015, with a 64% increase in average yearly use in that period. Data source: Kiel Johnson (owner of Go By Bike), e-mail message to author, April 1, 2016.

Summary of Peer Agency Review

Examination of the way other transit agencies have provided secure bicycle parking reveals several similarities that can serve to develop general guidelines for adding secure bike parking to Sound Transit's Link light rail stations. All agencies and organizations examined have moved away from using leased bicycle lockers at their transit stations due to low occupancy rates and the large space requirements. Instead, more flexible forms of secure bike parking are preferred. Several agencies are using electronic bike lockers in locations where demand for bike access is low. These lockers are able to accommodate small numbers of cyclists without requiring long-term lease agreements, and the electronic locker format makes a small number of lockers available to a larger number of users than with leased lockers.

For transit stations with demand for more than twenty bike parking spaces, however, agencies are using higher-capacity secure bike parking facilities. Most of these are in the form

of bike rooms or bike cages, which are in use by all agencies examined except OHSU. Several bike cages incorporate part-time staffed repair and retail space to offer customer service and support to cyclists. Full-time staffed bike parking facilities are less common, provided only by BART and OHSU. These facilities are only used in cases where demand for bike parking is very high; the smallest of them has space for 130 bikes. Staffed bike parking facilities have high operating costs due because they must be staffed at least five days per week, and require a large total amount of space.

Recommendations for Secure Bicycle Parking Implementation Based on Best Practices at Peer Agencies:

- Discontinue the addition of leased lockers at Link light rail stations. Use electronic lockers if less than 20 bike parking spaces are needed. Consider converting existing lockers to the electronic type to allow lockers to serve a larger number of users.
- If 20 to 100 bike parking spaces are needed, use a bicycle cage or bicycle room parking facility. This allows for a more efficient use of available space compared to lockers.
- Integrate electronic locker and bike cage access methods. This allows cyclists to use secure bike parking at multiple stations without having to register for multiple types of facilities, allowing a more flexible combination of bikes and light rail.
- For Link stations where more than 100 bike parking spaces will be needed, use either a bicycle cage/room or a staffed bike parking facility. Consider available space, available funding, and the need for 24-hour access to secure bike parking at the station. Staffed parking can make more efficient use of space, but requires ongoing operational funding and cannot feasibly be staffed at all hours.

Chapter 4: Estimating Demand for Bicycle Access to Link Light Rail Stations

The overall objective of this thesis is to develop an improved approach to providing secure bike parking at Sound Transit's Link light rail stations. One intermediate objective is to assess the level of demand for bicycle access to each Link station in the existing Central Link system. This is an important step in the planning process for two reasons. One, this can provide an estimate of the number of secure bike parking spaces that may be needed at each light rail station which is required for effective facility planning. The second reason for assessing demand for bike access is that it allows prioritization of both funding for providing and effort for planning secure parking. Sound Transit has limited funds available to make non-motorized access improvements to its existing light rail stations, and thus it is important to make the best use of this funding by targeting the stations with the highest demand for bike access. This is also useful for prioritizing the planning effort in this thesis, as creating detailed bike parking plans for all 16 Link stations would be beyond the scope of a master's thesis. Instead, detailed plans will be prepared for the two light rail stations with the highest level of demand for bike access and for secure bike parking.

Review of the Literature on Estimating Bicycle Travel Demand

The field of non-motorized travel demand forecasting has seen significant advancement in recent years. The National Cooperative Highway Research Program's (NCHRP) Report 770, *Estimating Bicycling and Walking for Planning and Project Development: A Guidebook*, was published in 2014 and details the state of the art in modeling walking and biking as travel modes. The NCHRP reports that while most regional travel demand forecasting models only

incorporate walking and biking at the most rudimentary levels, if at all, the Puget Sound Regional Council's activity-based travel model is able to provide a high level of detail on all travel modes. The decision to walk, bike, use transit, or drive is modeled at the individual level, resulting in more accurate prediction of cycling rates than any other travel forecasting model currently allows.¹¹⁸ The activity-based model is even able to model the choice to access specific sites, including transit stations. However, there are major obstacles to using PSRC's activity-based travel model to assess bike parking demand for this thesis. First, the modeling tool relies on a very large amount of data, including household travel survey results, parcel-level land use, and extremely detailed street network information, none of which is readily available.¹¹⁹ Second, the tool requires access to and expertise with PSRC's proprietary modeling software, which is not freely available.¹²⁰

Aside from PSRC's activity-based travel model, relatively few methods are available for estimating demand for bike access to transit stations. Several studies have been published relating various environmental, land use, demographic, and economic factors to rates of bicycling, which suggest that such factors could be used to generate a rough estimate of bicycle use rates in a given area. In particular, several studies have confirmed that a correlation exists between rates of cycling and population density, household density, employment density, and street connectivity.¹²¹ A greater mix of land uses, proximity to retail, traffic speed, and volume

118. J. Richard Kuzmyak, "NCHRP Report 770 – Estimating Bicycling and Walking for Planning and Project Development: A Guidebook," National Cooperative Highway Research Program, 2014, 10.

119. *Ibid.*, 84.

120. "Travel Demand Forecast," Puget Sound Regional Council, accessed April 15, 2016, <http://www.psrc.org/data/forecasts/travel-demand-forecast/>.

121. Brian E. Saelens, James F. Sallis, and Lawrence D. Frank, "Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literatures," *Annals of Behavioral Medicine* 25 no. 2 (2009).

have also been found to be correlated with cycling rates, while the relationship between cycling rates and some other factors like household income and car ownership have been shown to be mixed.¹²² Using these relationships to predict rates of cycling runs into several complications, however. The relationships between land use, demographic factors, and cycling rates vary between different metro areas, which suggests that underlying cultural differences between regions may have an important impact on cycling rates.¹²³ Studies have also shown that land use and demographic factors have varying effects on cycling rates in urban versus suburban environments within the same metro area.¹²⁴ This indicates that aggregate measures of demand like land use, economic, and demographic factors may serve better as indicators of relative levels of bicycle use between locations in one region, rather than predictors of actual cycling rates. Using these aggregate measures of demand is unlikely to generate accurate predictions of the level of demand for bicycle access to a given location.

Instead, sketch planning efforts offer a more accurate way to estimate the level of bicycle demand at a given location.¹²⁵ Stuart Goldsmith was one of the first to apply Census Journey to Work data on bicycling to the question of bicycle demand while working on a Seattle Department of Transportation Project in 1997.¹²⁶ This basic method has continued to be employed in the Puget Sound region for bicycle planning purposes. Two agencies, King County Metro and the Puget Sound Regional Council, have used sketch planning methods based on the

122. Yuchen Cui, Sabyasachee Mishra, and Timothy F. Welch, "Land use effects on bicycle ridership: a framework for state planning agencies," *Journal of Transport Geography* 41 (2014): 221.

123. Gary Barnes and Kevin Krizek, "Estimating Bicycling Demand," *Transportation Research Record* 1939 (2005): 45.

124. Cui, "Land use effects on bicycle ridership," 227.

125. Barnes, "Estimating Bicycling Demand," 45.

126. Stuart Goldsmith, "Draft: Estimating the Effect of Bicycle Facilities on VMT and Emissions," Seattle Engineering Department, 1997.

bicycle commuting rate in Census Journey to Work data specifically for planning secure bike parking. These methods are discussed further in the following section.

Prior Sketch Planning Methods for Estimating Secure Bicycle Parking Demand in the Puget Sound Region

Puget Sound Regional Council – Central Puget Sound Regional Bikestation Project

Overview of Project and Methodology

As discussed in Chapter 3 of this thesis, in 2002 the Puget Sound Regional Council prepared a detailed study of the potential for building secure bike parking facilities at six major transit stations throughout the Puget Sound region. This study was conducted with several partner agencies, including King County Metro Transit, Sound Transit, and the City of Seattle, as well as multiple consulting firms, including Alta Planning & Design and BikeStation. The study included both an assessment of demand for secure bike parking at transit stations and a method for determining the best type of secure bike parking facility to provide at a given location.

PSRC's method of estimating the demand for bike stations involved looking at three separate markets: bicycle commuters working near the bike parking station, transit commuters who switch to a bicycle at a bike parking station at the end of their transit trip, and transit commuters who ride to a bike parking station to access transit (bike and ride users).¹²⁷ These three markets were assessed using different techniques, but all three were sketch planning techniques that used the Census-derived rate of bicycle commuting within three miles of the bike station site and the number of transit boardings at the site as key inputs. The number of

¹²⁷ "Central Puget Sound Regional Bikestation Project," Puget Sound Regional Council, July 2002, 8.

jobs within ¼ mile of the bike station site also served as an input in assessing the bike parking demand from bike commuters working near the bike parking station. Rates of bicycle parking use at two existing facilities were used to verify the accuracy of the demand assessment methodology.¹²⁸

The PSRC bike station study used the estimated demand for bike parking as one input into a site assessment for each potential bike station site to determine whether it warranted a low level of investment, such as bike lockers, or a higher level of investment in the form of bicycle cages or staffed bike parking. Site assessments also considered nearby cycling conditions, surrounding commercial and employment density, community benefit, and the potential for the bike parking facility to generate revenue.¹²⁹

Critique of Project Methodology

The Central Puget Sound Regional Bikestation Project was an ambitious effort to integrate bicycling and transit in the Seattle area. Unfortunately, the one project that was implemented as a result of the study was BikeStation Seattle near King Street Station in Seattle's Pioneer Square neighborhood, which closed after less than three years of operation. As discussed in Chapter 3 of this thesis, this may have been due in large part to issues with BikeStation Seattle's siting relative to the major transit hub nearby, International District Station. However, the inclusion of surrounding employment likely inflated the estimated need for secure bike parking beyond realistic levels. While PSRC's demand estimation methodology was verified using two sites, neither was a site with the very high density of employment seen in Seattle's downtown neighborhoods. It is likely that the surrounding employment component

128. "Central Puget Sound Regional Bikestation Project," Puget Sound Regional Council, July 2002, 21.

129. *Ibid.*, 24.

of the bike parking demand methodology is simply not appropriate for areas with large numbers of jobs. A subsequent review of bike parking demand methods found that the bike and ride portion of PSRC's approach was accurate when used without the other components originally included in the PSRC study.¹³⁰

Demand Analysis for Bicycle Lockers at King County Metro Park and Ride Lots

Overview of Project and Methodology

In 2006 King County Metro Transit received a federal grant to expand the number of leased bike lockers at Metro's park and ride lots and transit centers throughout King County. University of Washington Master of Urban Design and Planning student Hannah J. McIntosh prepared a master's thesis in 2007 examining methods of estimating the demand for bike parking as a way to allocate 60 new bike lockers to locations with the most need for bike parking spaces.¹³¹ Several prior methods of estimating bike parking demand were tested and evaluated, including King County Metro's bike parking planning methods and the PSRC bike station study methodology. After comparison, an improved methodology for determining bike locker demand was developed and used to recommend locker placements.

The final recommended and applied methodology for estimating the demand for bike lockers combined elements of King County Metro's existing bike planning 'rule-of-thumb' method and the PSRC bike and ride demand estimation method discussed above. The Census-derived bike commute mode share and the number of transit boardings at a given transit stop serve as the primary inputs to the model, with adjustments made based on local environmental and cultural factors. The resulting method produced bike locker demand estimates that differed

130. McIntosh, "Bicycle Parking and Transit," 60.

131. *Ibid.*, 5.

from known locker use rates by less than one locker on average, though the method was less accurate for high-demand sites.¹³²

Critique of Project Methodology

McIntosh's method for estimating the demand for bike lockers was both simple to apply and fairly accurate when tested against known levels of bike locker demand. Its main drawback is the use of adjustments to the cycling rate based on judgment calls for a given area. For example, areas that are deemed to have an "exceptionally strong biking culture" have a 1% boost added to their cycling commute rate.¹³³ These adjustments serve to distinguish areas with high rates of bicycle ridership from areas with lower cycling rates because the citywide bike commute rate is used as the starting point for a given location. This method avoids the use of geographic information system (GIS) software, which was an explicit goal of the study's author. However, using GIS would have allowed a more localized rate of cycling to be applied at each transit station location, avoiding the need for judgment calls. Additionally, this method may be limited in its applicability to secure bike parking demand in general, as it was specifically developed and calibrated for leased bike lockers.

Methodology Used in this Study for Estimating Secure Bike Parking Demand at Link Light Rail Stations

Four different methods were used to assess the level of demand for secure bike parking at Sound Transit's Link light rail stations. Both the PSRC and the McIntosh sketch planning methods were used, with some adjustments made to better match the level of demand for secure bike parking Sound Transit is currently seeing. These methods both serve to measure the

132. Ibid., 64.

133. Ibid., 62.

relative level of demand for bike access to each Link station as well as produce an estimate of the number of bike parking spaces that will be needed. Two indexes of bicycle demand were also used to analyze stations for relative levels of demand for bike access. One of these methods comes from a 2010 article in *Transportation Research Record* by Kevin Krizek and Eric Stonebreaker¹³⁴ while the other method was used by LA Metro in preparing their 2006 Metro Bicycle Transportation Strategic Plan.¹³⁵ Both methods are based on aggregate measures of demand and incorporate several demographic factors. While they are useful for comparing relative levels of demand for bike access to Link stations, they do not provide estimates of the number of bike parking spaces that might be needed at each site.

Link Station Areas Analyzed

All four bike demand analysis methods used Census block groups within a fixed biking range of two or three miles around selected Link light rail stations as the basis for analysis, with the distance depending on the demand method in use. Non-overlapping two- and three-mile bikesheds were generated using the network analyst tool in ESRI's ArcGIS software and represent the area that can be reached by bicycle from the given light rail station using bike-accessible segments of the street network (see Figure 13). Census block groups with their centroid inside a given bikeshed were assigned to the corresponding Link station and American Community Survey (ACS) 2010-2014 data was aggregated for the selected block groups (see Figure 14).

Only thirteen of the sixteen light rail station were analyzed due to the very close proximity of Link stations in the downtown Seattle area. The University Street, Pioneer Square,

134. Krizek, "Bicycling and Transit: A Marriage Unrealized."

135. "[LA] Metro Bicycle Transportation Strategic Plan."

and Stadium stations are each less than one-half mile from either the Westlake or International District/Chinatown stations and thus had very small bikesheds containing only a few block groups each when GIS analysis was initially performed. Since Westlake and International District/Chinatown stations have the highest numbers of Link light rail boardings of the downtown Seattle stations, the other three stations were dropped from the analysis and their Link boarding numbers were assigned to the closest station remaining in the analysis.

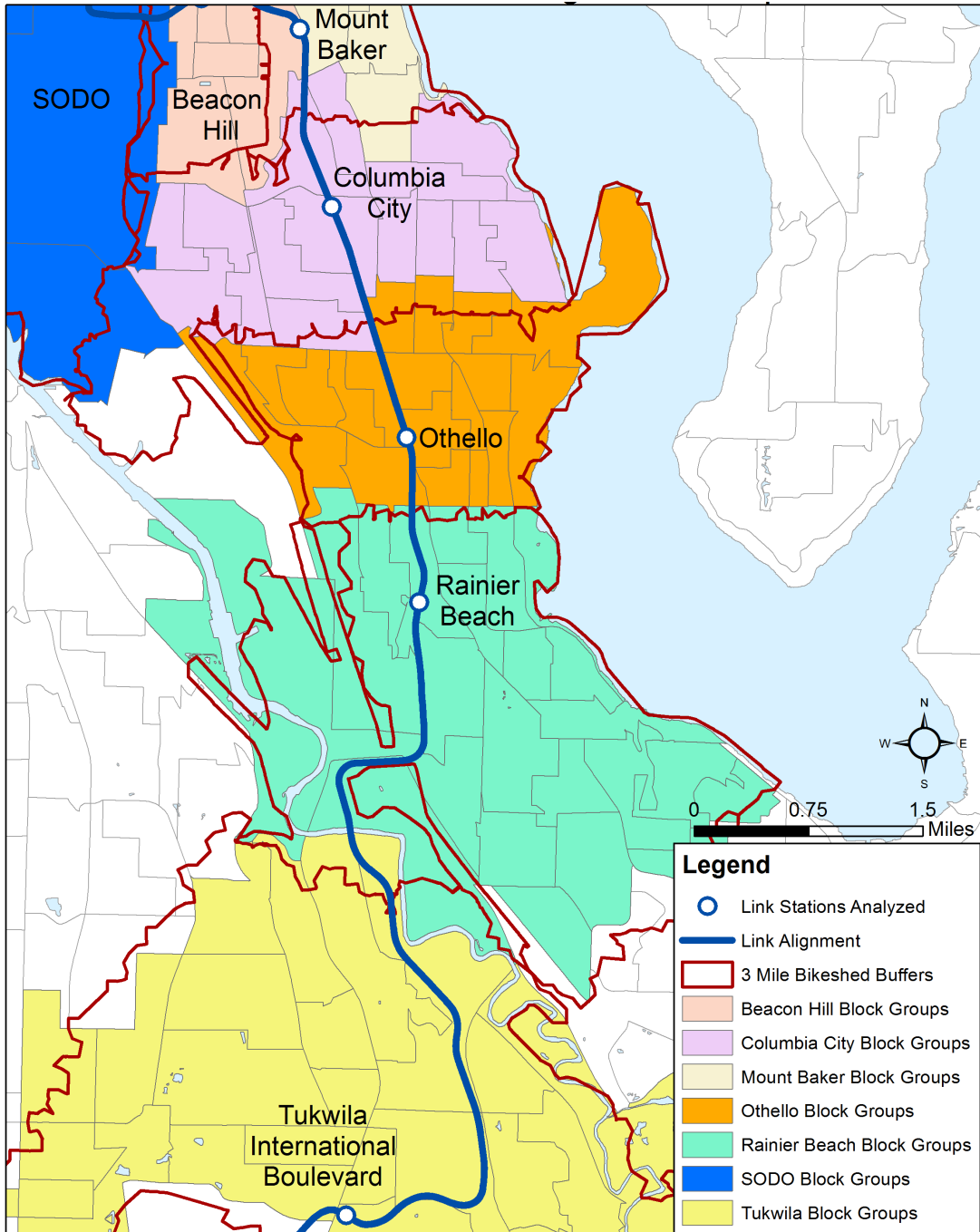
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Figure 13 – Three-Mile Bikesheds Around Link Stations



ESRI's network analyst tool in ArcGIS was used to generate non-overlapping three-mile bikesheds (shown in red) around each Link station analyzed for bike parking demand. These bikesheds were used to select Census block groups to aggregate ACS 5-year estimates for the area around each station.

Figure 14 – Example Three-Mile Bikesheds and Resulting Census Block Group Selections



Census block groups with their centroids inside each Link station’s three-mile bikeshed were assigned to that station for analysis. This process was repeated with two-mile bikesheds for the CTU index method.

Data Sources Used

Four major data sources were used in the process of analyzing bike demand at Link stations, though not all methods used all data sources. The data sources and their specific details are outlined below:

2010-2014 ACS 5-Year Estimates

All four analysis methods used data from the most recent 5-year estimate of the ACS. Data was collected at the block group level and aggregated over the extent of the bikeshed around each Link station as outlined above. Because data was collected from the ACS, all numbers are estimates rather than actual counts. The following measures were used:

- Bike commute mode share (%) – Calculated based on the number of bicycle commuters and the number of commuters of all types within each Link station's bikeshed.
- Transit commute mode share (%) – Calculated based on the number of public transit commuters and the number of commuters of all types within each Link station's bikeshed.
- Median household income (\$) – Because median incomes are not available for arbitrary geometries, median household income was averaged for all block groups within each Link station's bikeshed. This is not an accurate calculation of median household income, but should provide a close approximation. The underlying data necessary to perform a precise calculation is not available from the ACS.
- Share of population between ages 20 and 39 (%) – Calculated based on the number of people between 20 and 39 and the total population within each Link station's bikeshed.

- Housing unit density (housing units/acre) – Calculated based on the total number of housing units within each station’s bikeshed and the land area of all the corresponding block groups.
- Transit commuting population – The total number of people within each station’s bikeshed who commute by public transit.
- Population – The total number of people living within each stations’ bikeshed.
- Employed population – The total number of people within each station’s bikeshed who are employed.

Estimated Spring 2016 Link Station Boardings

The number of people boarding Link light rail at each station is a key input into the sketch planning methods for estimating the number of secure bike parking spaces needed at each Link station. A recent ridership update from Sound Transit stated that estimated total Link ridership in April 2016 was 58,000 boardings per weekday.¹³⁶ This report also included the proportion of boardings at each station, allowing the approximate number of daily boardings at each Link station to be calculated. An estimate of 5,400 weekday boardings was used for Angle Lake station per the estimate found on Sound Transit’s project website.¹³⁷ Boardings for University Street station were then assigned to Westlake and Pioneer Square and Stadium boardings to International District/Chinatown station because University Street, Pioneer Square, and

136. “Update – Light rail ridership is even better than earlier estimated since opening University Link,” Sound Transit, last modified May 19, 2016, <http://www.soundtransit.org/Rider-Community/Rider-news/light-rail-ridership-even-better-earlier-estimated-opening-university-link>.

137. “South 200th Link Extension,” Sound Transit, accessed May 2, 2016, <http://www.soundtransit.org/s200thstreet>.

Stadium stations were not included in the final analysis of Link stations. The estimated number of weekday boardings at each Link station used for analysis are shown in Table 4 below.

Table 4 – Estimated Spring 2016 Link Boardings by Station

The proportion of total Link boarding activity at each station in April 2016 and the estimated number of boarding at each station based on an estimated 58,000 average weekday boardings. Angle Lake station ridership is a projection from Sound Transit, as Link is not yet serving that station. Data source: “Update – Light rail ridership is even better than earlier estimated,” Sound Transit.

Station	Proportion of Total Boardings (%)	Estimated Weekday Boardings
University of Washington	15.5	8990
Capitol Hill	10.3	5974
Westlake	23.2	13456
International District/Chinatown	14.6	8468
SODO	2.4	1392
Beacon Hill	3.9	2262
Mount Baker	3.3	1914
Columbia City	3.8	2204
Othello	3.6	2088
Rainier Beach	2.5	1450
Tukwila International Boulevard	6.2	3596
SeaTac/Airport	10.6	6148
Angle Lake	N/A	5400

Link Station Boardings by Time of Day

The two methods for estimating the number of secure bike parking spaces needed at each Link station require a reduction of the number of boardings at each station to only the number that are likely to be home-based trips to work. These trips, when made by a combination of bike and transit, are most likely to require secure bike parking at the transit station. The proportion of commute trips being made from each Link station cannot be known without a major survey of Link riders. However, the PSRC method recommends making an assumption that boardings occurring in the morning are most likely to be home-based trips to work. Sound Transit has

published Link boardings at each station by time of day for the fall 2013 period, which was used to determine the proportion of boardings at each station occurring by time of day as seen in Table 5.¹³⁸ The proportion of home-based work trips was calculated by adding up early morning, morning peak, and half of the midday boardings and dividing by the total number of daily boardings at the given station. Since University of Washington, Capitol Hill, and Angle Lake station boardings were not available, estimates of 40%, 45%, and 60% home-based work trips were used, respectively. These are based on the proportion of home-based work trips at similar stations that had data available.

Table 5 – Proportion of Link Station Boardings Occurring by Time of Day

The number of boardings at each Link station for each period of the day in fall 2013 was divided by the total number of boardings at that station to determine the proportion of likely home-based work (HBW) trips, which includes all early morning and morning peak boardings and half of midday boardings. Home-based trips to work made by a combination of bikes and transit are most likely to require secure bike parking at Link stations. Data source: “2015 Service Implementation Plan,” Sound Transit, February 2015, 165.

Station	Early AM Ons	AM Peak Ons	Midday Ons	PM Peak Ons	Evening Ons	Night Ons	HBW Trips
Westlake	2%	10%	28%	36%	17%	7%	25.6%
International District/Chinatown	3%	22%	29%	28%	13%	6%	38.8%
SODO	2%	18%	26%	37%	12%	4%	33.6%
Beacon Hill	2%	35%	33%	20%	7%	3%	53.5%
Mount Baker	1%	20%	40%	26%	10%	4%	40.7%
Columbia City	3%	39%	30%	16%	9%	3%	57.6%
Othello	3%	35%	33%	18%	8%	3%	54.4%
Rainier Beach	4%	35%	31%	17%	9%	4%	54.3%
Tukwila International Boulevard	8%	34%	29%	17%	8%	4%	56.4%
SeaTac/Airport	3%	14%	42%	19%	12%	9%	38.4%

138. “2015 Service Implementation Plan,” Sound Transit, February 2015, 165.

Bicycle Facilities Within 3 Miles of Link Stations

Multiple bike demand analysis methods used GIS-based measures of the presence of bicycle facilities around Link stations as an input into the analysis process. Complete bicycle facility GIS datasets were available from SeaTac, Seattle, and Tukwila, though these three datasets did not cover the entire area needed for analysis. Bike lanes and bike paths were extracted from each dataset and appended into one shapefile. This shapefile was edited to include bike lanes and bike paths outside of SeaTac, Seattle, and Tukwila but within three miles of Link stations based on Google Maps data. The final shapefile containing all bike lanes and paths within three miles of Link stations was used for proximity analysis.

PSRC Bikestation Method

PSRC's sketch planning method for estimating demand for secure bike parking required little modification other than limiting the analysis to only potential bike and ride users, one of three components of the original PSRC bikestation study methodology. The inputs into this process were the bicycle commute mode share from the 2010-2014 ACS 5-year estimates, the estimated number of average weekday boardings at each Link station, and the proportion of home-based trips to work. This method produces a base estimate of the number of transit trips accessed by bike at each station, as well as a best-case (high) and a worst-case (low) estimate. The base estimate of transit trips accessed by bike is the number of boardings multiplied by the proportion of home-based work trips at the station and the bike commute rate around the station. A bike commute rate of 0.5% is used for stations that have an actual bike commute rate below that level. The best-case estimate doubles the base estimate except for stations with a bike commute rate below 0.5%. For those stations, a 1% bike commute rate is substituted.

Finally, the worst-case estimate substitutes a 1% bike commute rate for all stations that actually have a higher surrounding bike commute rate, and maintains the ACS value if it below 1%.

PSRC’s method recognized that not all transit riders reaching the station by bike will want to use a secure bike parking facility there if one is available. Though the proportion of cycling transit riders who will use secure bike parking at a station may vary depending on several factors, PSRC recommended a base assumption that 75% of those biking to the transit station would make use of a secure bike parking facility.¹³⁹ This rate was applied to the base, high, and low estimates of the number of the number of transit trips accessed by bike at each Link station to determine the number of secure bike parking spaces needed under each scenario. The inputs and results are presented below in Table 6.

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139. “Central Puget Sound Regional Bikestation Project,” 15.

Table 6 – Inputs and Results of PSRC Bikestation Method for Link Stations

PSRC’s bikestation project method produces base estimates of the number of secure bike parking spaces needed, as well as high and low estimates based on best-case and worst-case scenarios. Applied to the Link light rail system, PSRC’s method shows that University of Washington and International District/Chinatown stations have the greatest need for secure bike parking.

Station	Bike Mode Share	Estimated Link Boardings	% HBW Trips	Bike Spaces Needed (Low)	Bike Spaces Needed (Base)	Bike Spaces Needed (High)
University of Washington	6.44	8,990	45.0	27	174	348
Capitol Hill	4.72	5,974	45.0	20	95	190
Westlake	2.01	13,456	25.6	26	52	104
International District / Chinatown	4.46	8,468	38.8	25	110	220
SODO	4.44	1,392	33.6	4	16	31
Beacon Hill	5.57	2,262	53.5	9	51	101
Mount Baker	3.28	1,914	40.7	6	19	38
Columbia City	1.84	2,204	57.6	10	19	35
Othello	1.25	2,088	54.4	9	11	21
Rainier Beach	0.21	1,450	54.3	1	3	6
Tukwila International Boulevard	0.26	3,596	56.4	4	8	16
SeaTac / Airport	0.75	6,148	38.4	13	13	27
Angle Lake	0.67	5,400	60.0	16	16	33

McIntosh/King County Metro Method

Hannah McIntosh’s bike parking demand estimation method used bicycle commute mode share from the ACS, estimated boardings at Link stations, the proportion of home-based trips to work, and the presence of bike lanes as inputs. For each Link station, 1% was added to the bike commute rate if a bike lane or bike path was within ¼ mile of the station. This adjusted bike commute rate was then multiplied by the proportion of home-based work trips and the

number of boardings at each station to produce an estimate of the number of transit commute trips accessed by bike at each station. As in the PSRC method, it was assumed that 75% of such trips would use a secure bike parking facility to store their bike, giving the final estimate of the number of secure bike parking spaces needed at each station presented in Table 7. Once again, the University of Washington and International District/Chinatown stations were found to have the greatest need for secure bike parking.

Table 7 – Inputs and Results of McIntosh Method for Link Stations

McIntosh’s bike locker planning method produced estimates for the number of lockers needed at each Link station that was between the base estimate and the high estimate of the PSRC method in most cases. Both methods found that International District/Chinatown and University of Washington stations have the highest need for secure bike parking.

Station	Bike Mode Share	Bike Lane/Path Within 1/4 Mile	Transit Boardings	% HBW Trips	Secure Bike Spaces Needed
University of Washington	6.44	1	8,990	40.00%	201
Capitol Hill	4.72	1	5,974	45.00%	115
Westlake	2.01	1	13,456	25.60%	78
International District / Chinatown	4.46	1	8,468	38.80%	135
SODO	4.44	1	1,392	33.60%	19
Beacon Hill	5.57	1	2,262	53.50%	60
Mount Baker	3.28	0	1,914	40.70%	19
Columbia City	1.84	1	2,204	57.60%	27
Othello	1.25	1	2,088	54.40%	19
Rainier Beach	0.21	1	1,450	54.30%	7
Tukwila International Boulevard	0.26	1	3,596	56.40%	19
SeaTac / Airport	0.75	0	6,148	38.40%	13
Angle Lake	0.67	0	5,400	60.00%	16

LA Metro Bike Hub Project Method

LA Metro's bike hub assessment method was developed as part of LA Metro's 2006 Bicycle Transportation Strategic Plan to prioritize bicycle access improvements to transit stations throughout LA County. Though this method does not produce estimates of the number of bike parking spaces needed, it was included as an alternative way of assessing overall demand for bike access to Link stations. The LA Metro assessment is an index that uses total numbers of residents, workers, and transit commuters in the 3-mile bikeshed of each transit station derived from ACS data. Additional inputs are the median household income in each station's bikeshed, also derived from the ACS, and the number of transit lines serving each station. Lower median household income receives a higher score. Transit service information was gathered from an internal resource at King County Metro known as Remix, which keeps an up-to-date record of all transit service in the Puget Sound region. Though as many as 86 transit lines serve some Link stations, the maximum input value for this criterion was capped at 10 to produce a reasonable range. All values were then normalized to a scale from 0-5 to feed into the index. Each factor into the index was given a weight per LA Metro's assessment method. A small bonus was added to Angle Lake and University of Washington stations' index scores because the LA Metro method prioritizes stations at the terminus of a transit line. The inputs, weights, and final index scores for each station are shown in Table 8. University of Washington and Capitol Hill stations scored highest on this index.

Table 8 – Inputs and Results of LA Metro Bike Hub Method for Link Stations

LA Metro’s bike hub scoring index was developed as a way of prioritizing bicycle improvements to transit stations, including bike parking improvements. When applied to Link stations, University of Washington and Capitol Hill stations score highest on this index.

Station	Transit Riders	Population	Workers	HH Income	Transit Lines	Terminus	Index Score (out of 10)
University of Washington	13,678	105,621	61,842	82,331	23	Y	7.62
Capitol Hill	11,441	68,429	45,779	80,932	8	N	5.39
Westlake	8,459	61,489	40,834	67,210	86	N	5.19
International District / Chinatown	2,602	19,715	9,275	38,273	86	N	3.34
SODO	353	3,427	2,019	81,587	15	N	1.16
Beacon Hill	2,375	12,703	7,494	57,720	3	N	1.87
Mount Baker	1,029	11,052	5,734	77,685	7	N	1.36
Columbia City	2,138	22,105	11,379	64,544	3	N	1.93
Othello	2,415	23,461	10,596	52,854	4	N	2.43
Rainier Beach	2,077	29,010	13,316	59,792	5	N	2.45
Tukwila International Boulevard	2,623	36,137	17,235	46,522	5	N	3.18
SeaTac / Airport	893	8,954	4,367	46,846	4	N	1.87
Angle Lake	1,863	37,349	17,273	59,295	2	Y	2.9
<i>Factor Weight</i>	<i>25</i>	<i>25</i>	<i>15</i>	<i>25</i>	<i>10</i>	<i>5</i>	<i>—</i>

Krizek & Stonebraker CTU Index Method

The cycle-transit user (CTU) index is a method of assessing the demand for bike access to transit stations that was developed by Kevin Krizek and Eric Stonebraker and published in *Transportation Research Record* in 2010.¹⁴⁰ Like LA Metro’s method, this method rates the relative level of bike demand rather than providing an estimate of the number of bike parking

140. Krizek, “Bicycling and Transit: A Marriage Unrealized.”

spaces needed. The CTU index uses a 2-mile bikeshed in place of the 3-mile bikesheds used for the other analysis methods, though the bikesheds were derived in the same method. The inputs to this analysis method were median household income, the percent of the population between ages 20 and 39, housing unit density, the percent of commuters who use public transit, the percent of commuters who commute by bike, and the length of bike lanes and paths within each station's bikeshed. All inputs were normalized and weights were applied to produce a final CTU index score out of 10 as shown in Table 9. University of Washington and International District/Chinatown stations received the highest scores using this method.

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Table 9 – Inputs and Results of CTU Index Method for Link Stations

Krizek and Stonebraker’s CTU index incorporates several demographic factors to assess the demand for bike access to transit stations. University of Washington and International District/Chinatown stations scored highest on this index.

Station	HH Income (\$)	% Population Age 20-39	Housing Unit Density	% Transit Commuters	% Bike Commuters	Km of Bike Facilities	Index Score (Out of 10)
University of Washington	73,469	46.16	6.037	22.25	6.58	23.32	6.47
Capitol Hill	75,375	52.66	14.25	26.67	4.88	7.4	5.63
Westlake	66,240	53.38	21.07	21.42	1.97	14.4	5.77
International District / Chinatown	38,273	39.49	11.02	28.46	4.46	13.93	5.98
SODO	98,990	27.68	0.27	14.84	1.52	5.1	1.28
Beacon Hill	55,243	36.08	5.83	32.71	5.27	6.48	4.99
Mount Baker	77,685	23.63	4.99	18.23	3.28	6.03	2.67
Columbia City	64,544	30.00	4.57	19.17	1.84	8.93	2.93
Othello	52,854	30.07	4.39	23.37	1.25	19.93	4.11
Rainier Beach	57,232	28.12	3.32	21.64	0.34	8.06	2.44
Tukwila International Boulevard	47,428	33.32	3.08	21.24	0.31	9.75	2.89
SeaTac/Airport	46,846	32.60	3.79	21.00	0.75	3.69	2.51
Angle Lake	46,931	34.74	2.51	13.00	0	8.75	2.27
<i>Factor Weight</i>	<i>-0.64</i>	<i>0.931</i>	<i>0.797</i>	<i>0.912</i>	<i>0.945</i>	<i>0.947</i>	<i>—</i>

Summary of Bike Parking Demand Analysis Results

In general, all four methods produced broad agreement on the relative level of demand for secure bike parking at each Link station. University of Washington, International District/Chinatown, and Capitol Hill stations received the highest scores, with International District/Chinatown station ranking highest in the sketch planning methods and University of Washington station ranking first in the index methods. Some variation is seen between the

sketch planning and index methods in which stations will have the lowest level of demand for secure bike parking. SODO station received the lowest score in both index methods, while Rainier Beach was ranked lowest in the two sketch planning methods due to very low rates of bicycle commuting in the ACS data. This may indicate that stations receiving low scores in the sketch planning methods but higher index scores have the greatest potential for increasing the proportion of their transit trips that are accessed by bicycle, though the absolute numbers would likely still be small. The most pressing need for secure bike parking is at the highest-scoring stations, which are all estimated to need over 100 secure bike parking spaces. Summarized results are presented in Table 10.

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Table 10 – Summary of Bike Parking Demand Analysis Results

Results for four methods of assessing the demand for secure bike parking at Link stations are presented both as scores and ranked from highest to lowest scores. The meaning of scores varies depending on the method used, but all indicate the relative level of demand for bike parking. University of Washington, International District/Chinatown, and Capitol Hill stations all scored highly using all four methods of analysis.

Station	Scores				Rank				
	PSRC (base estimate)	KC Metro	LA Metro	CTU Index	PSRC (base estimate)	KC Metro	LA Metro	CTU Index	Overall Rank
University of Washington	174	201	7.62	6.47	1	1	1	1	1
Capitol Hill	95	115	5.39	5.63	3	3	2	4	3
Westlake	52	78	5.19	5.77	4	4	3	3	4
International District / Chinatown	110	135	3.34	5.98	2	2	4	2	2
SODO	16	19	1.16	1.29	9	10	13	13	13
Beacon Hill	51	60	1.87	4.99	5	5	10	5	5
Mount Baker	19	19	1.36	2.67	6	9	12	9	9
Columbia City	18	27	1.93	2.93	7	6	9	7	6
Othello	11	19	2.43	4.11	11	8	8	6	8
Rainier Beach	3	7	2.45	2.44	13	13	7	11	12
Tukwila International Boulevard	8	19	3.18	2.89	12	7	5	8	7
SeaTac / Airport	13	13	1.87	2.51	10	12	11	10	11
Angle Lake	16	16	2.9	2.27	8	11	6	12	10

Sound Transit’s current figures for bike locker and bike cage subscriptions do not provide a full account of the demand for secure bike parking. Only eight of the sixteen Link stations have secure bike parking, and several stations have no bike parking available at all. Most of the existing secure bike parking spaces are in the form of leased lockers, which are likely less appealing to users than other forms of secure bike parking, as discussed in chapter 3.

However, it is still useful to compare the current numbers of secure bike parking users to the predicted numbers of secure bike parking spaces needed according to the two sketch planning methods. The numbers are shown in Table 11. The PSRC method's base estimate was closest to the number of actual subscribers to lockers and cages, though the predictions differ greatly from the actual number of subscribers at several stations. Rainier Beach station has 11 locker users, but all estimates under-predicted demand for secure bike parking at this location. Beacon Hill, Mount Baker, SeaTac/Airport, and Angle Lake stations all have less than half the number of subscribers that would be expected based on the PSRC base estimate or the McIntosh/KC Metro method. Based on this incidence of over-prediction, using the relatively conservative PSRC base estimate of the number of secure bike parking spaces needed at other Link stations seems prudent versus the PSRC high estimate or the McIntosh/KC Metro estimate.

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Table 11 – Comparison Between Actual and Predicted Secure Bike Parking Needs

The number of secure bike parking spaces needed at Link stations by the PSRC and KC Metro sketch planning methods is compared with the current number of subscribers to bike locker and cages at Link stations and the number of existing secure bike parking spaces at each station.¹⁴¹ The PSRC method’s base estimate is closest to the actual number of subscribers, though all three estimates shown under-predict the need for secure parking at Rainier Beach station. Link stations without any secure bike parking spaces are not shown. Data source: Rebecca Roush (Sound Transit bicycle coordinator), e-mail message to author, April 21, 2016.

Station	PSRC Base Estimate	PSRC High Estimate	KC Metro	Current Bike Parking Subscribers	Current Secure Bike Spaces
SODO	16	31	19	12	16
Beacon Hill	51	101	60	17	52
Mount Baker	19	38	19	6	24
Columbia City	18	35	27	15	37
Rainier Beach	3	6	7	11	20
Tukwila International Boulevard	8	15	19	4	8
SeaTac / Airport	13	27	13	5	24
Angle Lake	16	33	16	4	48

Limitations of Demand Assessment

There are several limitations to both the accuracy and the broader applicability of the results of the bike parking demand assessment performed. Primary among these is the simple fact that all four methods used rely on indirect measures of demand for bike access, and therefore secure bike parking, at Link stations. In addition, some rough estimates had to be used for the sketch planning methods, such as the proportion of home to work trips seen at each Link station. More broadly, the use of ACS 5-year estimates at the block group level introduces a great deal of uncertainty into some values, particularly the bicycle commute rate around each station, which is based on a very small sample. However, the data used are the best and most current available in all cases. The general agreement between results from the

141. Rebecca Roush (Sound Transit bicycle coordinator), e-mail message to author, April 21, 2016.

various methods is a strong indicator that the relative magnitude of demand estimated for each station has been ranked correctly by the demand assessment methods. Additional predictive power may be available from the PSRC's activity-based travel model, which Sound Transit can access if desired. Results from even the best model would still need to be verified with real-world data on bicycle access rates to the Link system, which Sound Transit does not currently collect.

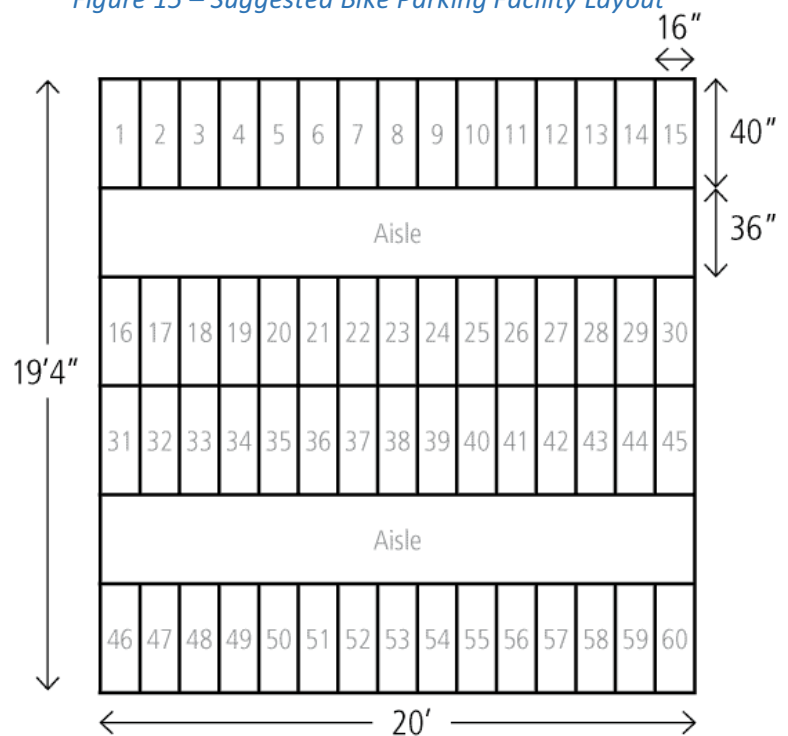
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Chapter 5: Possibilities for Implementation of Secure Bike Parking at Selected Link Light Rail Stations

The goal of this thesis is to provide preliminary recommendations for how secure bike parking can be provided at the Link stations with the highest predicted need. In the previous chapter, University of Washington station ranked highest in the level of demand for bike access in all four methods used to assess demand, while the second highest-scoring station was the International District/Chinatown station. This chapter will focus on these two Link stations for planning additional secure bike parking. While this thesis has found that several other Link stations also likely have a need for more bike parking facilities, planning more such facilities is outside the scope of a 9-credit thesis and would exceed the resources available to the author.

Several considerations were used when planning for secure bike parking facilities at the University of Washington and International District/Chinatown stations. The first of these is available space at the station. The bicycle rack manufacturer Dero provides a bike parking area design that can accommodate 60 bikes within a

Figure 15 – Suggested Bike Parking Facility Layout



Bicycle parking manufacturer Dero suggests secure bike parking use vertical racks to achieve maximum space efficiency. 60 bikes can fit into a 20x20 foot area. Image source: "Bike Parking Guide," Dero, accessed May 15, 2016, <https://www.dero.com/bike-parking-guide/>.

20 feet by 20 feet square using two rows of vertical parking (see Figure 15). Since both University of Washington and International District/Chinatown stations are estimated to need over 100 secure bike parking spaces, a minimum space of roughly 20 feet by 40 feet was assumed to be required for any bike parking facility at either station. An additional minimum clearance of 10 feet around any potential bike parking structure was specified to leave room for bike and pedestrian circulation since both stations can see very high levels of foot traffic. Where possible, using existing open space to avoid reconfiguring or reconstructing the station plaza is preferred to reduce construction cost and disruption. All parking facilities were assumed to need two entrances/exits for safety, though this comes at the cost of some space for bikes. Lastly, the possibilities for Sound Transit to partner with other agencies to fund or operate secure bike parking facilities were considered.

University of Washington Station

Sound Transit's University of Washington Link station received the highest score in all four bicycle demand assessment methods. Predictions of the number of secure bike parking spaces needed at this station, produced in chapter 4, range from 27 to 348. The base estimate from PSRC's method produced the closest results to the existing numbers of subscribers for secure bike parking at several Link stations, and indicated a need for 174 secure bike parking spaces at the University of Washington station. This is a very large number of bike parking spaces, but this estimate is plausible for several reasons. First, the University of Washington station had the second-highest number of average weekday Link boardings in April 2016 at approximately 8,990. This was 15.5% of the total Link system boardings and only slightly less

than the 9,396 boardings seen at the busiest downtown Seattle station, Westlake.¹⁴² Second, while University of Washington station lacks secure bike parking, it does have standard bike rack space for 130 bikes.¹⁴³ Anecdotally, the author has frequently observed these racks at or near capacity since the opening of University of Washington station, and bikes are also frequently brought onto the train at this location. Lastly, the station is connected by a bike and pedestrian bridge to the Burke Gilman Trail, a major bicycle route in North Seattle, which is likely to make this an attractive location for multimodal bike and transit commutes.

University of Washington Station Plaza Layout

Finding space to securely store 174 bikes at University of Washington station is a challenge. The station plaza is a triangle constrained by Montlake Boulevard on the west side, parking lots to the south, and Husky Stadium to the east as shown in Figure 16.

Figure 16 – UW Station Plaza Layout and Potential Bike Parking Facility Locations



The UW station plaza is bounded on the west by Montlake boulevard and on the south and east by parking lots. Sites large enough for bike parking facilities are shown in yellow and labeled A through D.

142. “Update – Light rail ridership is even better than earlier estimated,” Sound Transit.

143. Rebecca Roush (Sound Transit bicycle coordinator), e-mail message to author, April 21, 2016.

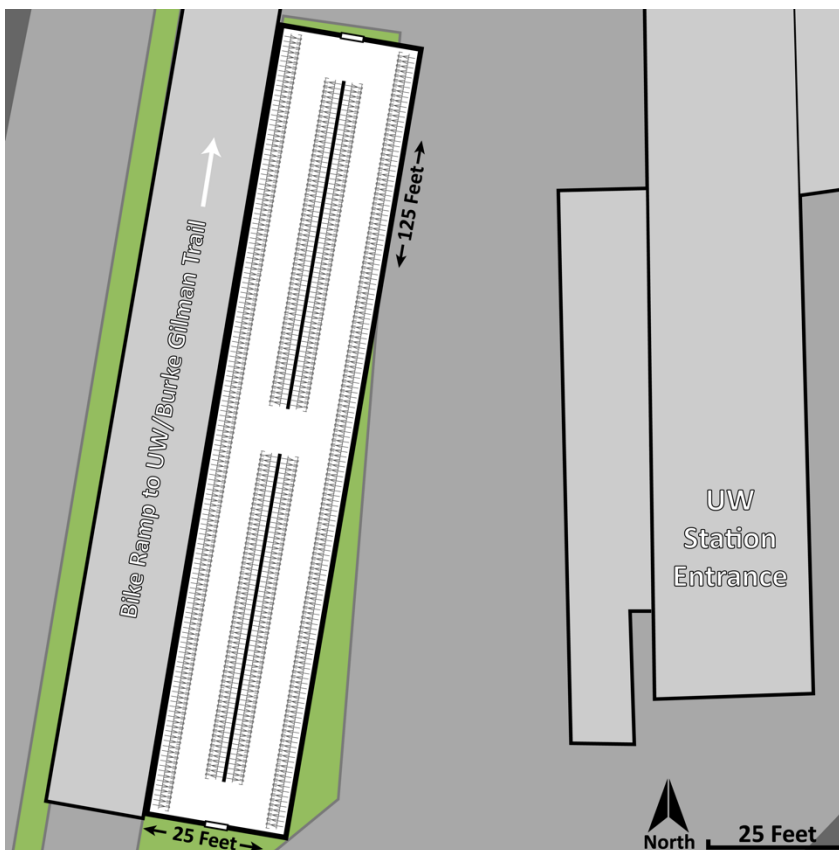
Several structures are located within the plaza, including a building containing the escalators and elevators to the train platform below, a ventilation shaft at the north end, and ramps and staircases connecting the station plaza with the Montlake Boulevard bike and pedestrian overpass. The overpass is the main bike and pedestrian link between the Link station and the University of Washington campus and Burke Gilman Trail. Four open areas are large enough to accommodate a potential bike parking facility while still allowing for bike and pedestrian circulation, labeled sites A-D in Figure 16.

Site A is just east of the bicycle ramp leading from the station plaza to the Montlake overpass and is the largest available space for a new facility. The site is currently host to a large landscaped area, though it may be possible to remove the landscaping to install a new structure. Site B abuts the Link station entrance and is on the southeast corner of the station plaza. This site is completely empty at present, containing nothing but bare concrete. Sites C and D are located underneath the elevated pedestrian and bike pathways out of the station and currently host the bike racks Sound Transit has installed at University of Washington station. Site visits revealed that several potential conflicts exist within these sites that render them unusable as locations for bike parking facilities. Site C contains several utility access doors that Sound Transit would likely be unwilling to block, while site D has several concrete support columns in it. Both sites also contain drainage features for the plaza. Sites C and D were excluded from further analysis for these reasons.

University of Washington Station Site A – East of Bicycle Ramp

The largest available space at University of Washington station, this site is an irregular quadrilateral running roughly north-south with a minimum width of 20 feet and a minimum length of 126 feet. Any structure built here would require extensive modification or removal of the existing planter box that covers most of the available space. While altering the planter box would likely add to the construction cost, the tradeoff is that this site provides ample space for bikes. A secure bike parking facility that makes the maximum use of the available space here would measure approximately 25 feet wide and 125 feet long. Shown in Figure 17, a bike cage

Figure 17 – Potential Bike Parking Layout at UW Station Site A



Space is available just east of UW station's bicycle ramp for a bike parking facility large enough to accommodate 350 bikes, significantly more than the estimated need.

built to these dimensions could accommodate as many as 350 bikes in vertical racks. This significantly exceeds the expected need for 174 bike parking spaces, and matches the highest estimate produced in chapter 4. The length of the facility could be reduced to scale the bike parking down as needed – a 25-by-65-foot structure should be sufficient to accommodate 174 bikes. In addition to space, this site

benefits from close proximity to University of Washington station's bicycle ramp. This would allow cyclists to ride directly to the entrance of the secure bike parking facility, minimizing any potential conflict with pedestrians.

Figure 18 – Rendering of Potential Bike Parking Facility at UW Station Site A



A secure bike parking facility in this location would have direct access to the bike ramp over Montlake Boulevard connecting to the Burke Gilman Trail and the University of Washington campus. Modification or removal of an existing planter box would be required.

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University of Washington Station Site B – East of Station Entrance

Site B is currently an empty paved area of the University of Washington station plaza just east of the escalators down to the Link platform and south of the station’s elevators. This site is smaller than site A and very irregularly shaped, significantly reducing the size of structure that will fit and thus the number of bikes that it can accommodate. Unlike site A, a bike parking facility could be added to this site without removing or modifying any existing structures, which may reduce costs and preserves

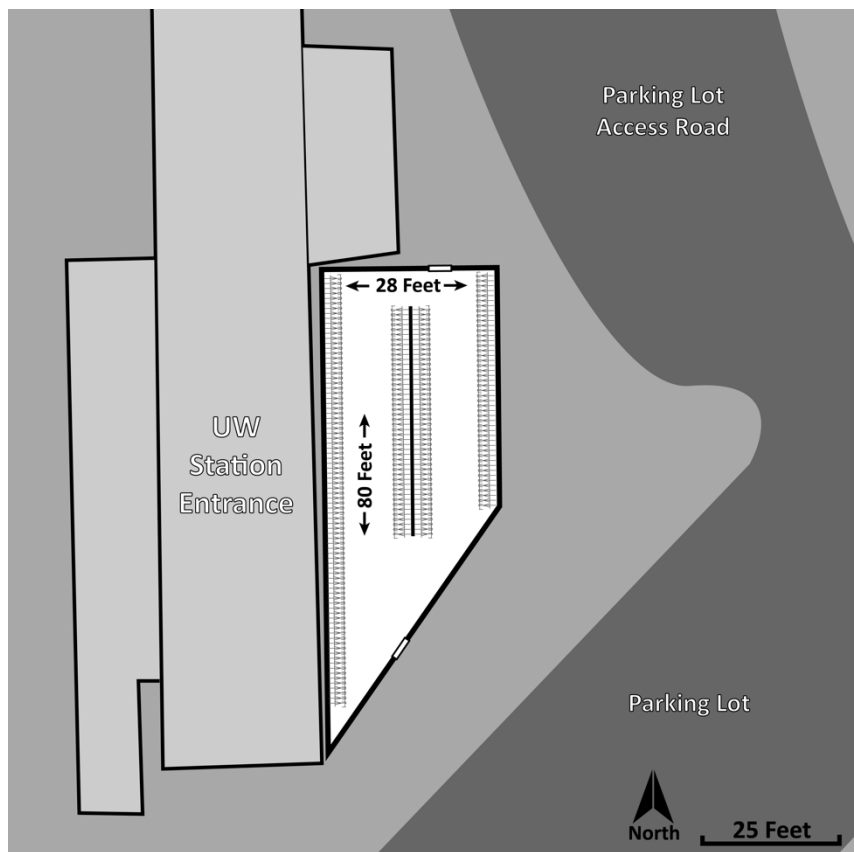
Sound Transit’s original station plaza layout. A building on this site, as shown in Figure 19,

could be built to dimensions of 28 feet wide from east to west.

Due to the site’s irregular shape, an angled wall would be required to avoid intruding into the pedestrian path, resulting in north to south length varying from 40 feet to 80 feet. This layout would provide space for

155 bikes, slightly less than the target of 174.

Figure 19 – Potential Bike Parking Layout at UW Station Site B



The space east of the entrance to UW station is considerably more constrained, though the layout shown would be able to hold 155 bikes, just short of the estimated need of 174 bike spaces.

Figure 20 – Rendering of Potential Bike Parking Facility at UW Station Site B



A secure bike parking facility just east of the UW station entrance would provide easy station access, though it is located farther from the bike trail. Some bikes are shown for illustrative purposes, though if filled to capacity significantly more bikes would be within the parking facility.

Partnership Opportunities at University of Washington Station

As its name might suggest, Sound Transit’s University of Washington Link station is built on University of Washington property.¹⁴⁴ This means that any project to improve bike access to this station, including providing bike parking, would need the University’s permission and involvement. Fortunately, the University of Washington may serve as an ideal partner for such projects, as they have an extensive program to support transportation alternatives. Bicycles are a major focus of UW’s transportation strategy, and the University already offers over 5,000 bike parking spaces on campus. While most are in the form of bike racks, UW also offers secure bike

144. “Parcels for King County with Address; Property and Ownership Information [parcel_address],” King County GIS data, last modified May 17, 2016, <http://www5.kingcounty.gov/gisdataportal/>.

parking using over 600 lockers, 26 limited-access bike rooms, and 6 bike cages.¹⁴⁵ With the University of Washington Medical Center and Husky Stadium located very close to the Link station, a secure bike parking facility could serve the University's transportation needs at the same time that it allows cyclists to reach Link. UW could be a source of some ongoing operational funding for a staffed bike parking facility at this location if willing.

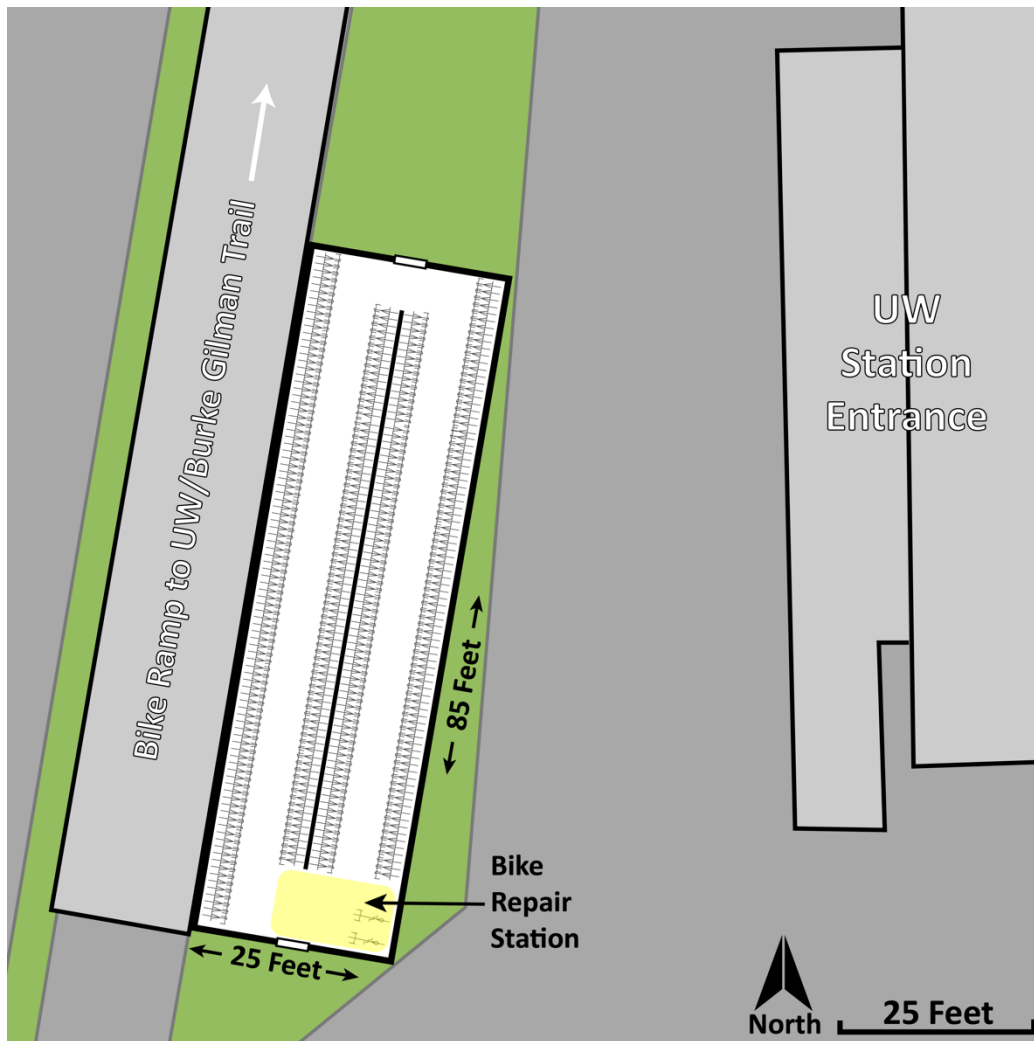
Recommended Secure Bike Parking Approach at University of Washington Station

Between the two available sites at the University of Washington Link station, the site located just east of the bike ramp and Montlake Boulevard (site A) is preferred for building a secure bike parking facility. Though it requires removal of the existing landscaping features, this site offers enough space to meet the projected capacity need of 174 bikes and leaves room for additional services like a small bike repair shop. In addition, this site is directly adjacent to the bike ramp to the Burke Gilman trail, allowing easy access for arriving cyclists.

The high level of demand for secure bike parking and the opportunity to partner with the University of Washington makes this station ideal for providing staffed bicycle parking. Providing repair staff during working and commuting hours would allow a large bike cage to offer additional service to bicycle commuters and added security, as repair staff can monitor the bike parking during working hours. Using a partially-staffed bike cage in the model of LA's bike hubs and the various BikeStation locations still allows 24-hour access to secure bike parking. The proposed facility layout is shown in Figure 21. A structure measuring 25 feet by 85 feet should provide enough space for approximately 200 bikes and a bicycle repair area.

145. "Transportation Services – Bike parking," University of Washington, accessed May 22, 2016, <https://www.washington.edu/facilities/transportation/bike-parking>.

Figure 21 – Recommended Secure Bike Parking Facility Layout at University of Washington Link Station



University of Washington station's high level of demand for bike access warrants a significant investment in secure bike parking. The proposed facility would operate as a bike cage with 24-hour access and space for 200 bikes. Partnership between the University of Washington and Sound Transit could provide operating funding for part-time staffing of the facility, offering repair service and an additional level of security.

International District/Chinatown Station

The International District/Chinatown station is the southern end of the Downtown Seattle Transit Tunnel and is currently owned by King County Metro, though it is located immediately adjacent to Sound Transit's offices in the Union Station complex. In addition to Link light rail, several bus routes serve this tunnel station and many more make stops on surface streets surrounding this station. This makes the station an important regional transit

hub, offering transit connections to several major destinations throughout the Puget Sound region. Average weekday Link boardings at this station were 4,524 in April 2016, about half the number seen at University of Washington station. However, Pioneer Square and Stadium stations are within ½ mile of International District/Chinatown station and the three were combined for the purposes of bike demand analysis under the assumption that cyclists within the bikeshed of any of the three stations would be willing to ride an extra five minutes or less to a secure bike parking facility. The combined ridership at these three stations in April 2016 was 8,468, almost at the level of the University of Washington and Westlake stations.

International District Chinatown station received second-place scores in three of the four bicycle demand assessment methods and fourth-place in one. Predictions of the number of secure bike parking spaces needed at this station range from 25 to 220, with 110 spaces needed in the base estimate from PSRC’s method. While less than the predicted need at the University of Washington station, this is still a significant need for secure bike parking, particularly in light of the fact that almost no bike parking of any kind exists at this station. Only a single standard bike rack exists currently, providing space for six bikes at most. The International District/Chinatown station is not located near any major bicycle routes and has a very high level of public transit service.

A previous effort at providing secure bike parking, BikeStation Seattle, was opened near International District/Chinatown station in 2003 as a result of PSRC’s bikestation project.¹⁴⁶ BikeStation Seattle’s location at 311 3rd Ave S was over 800 feet from the entrance to International District/Chinatown station and separated by several signalized intersections,

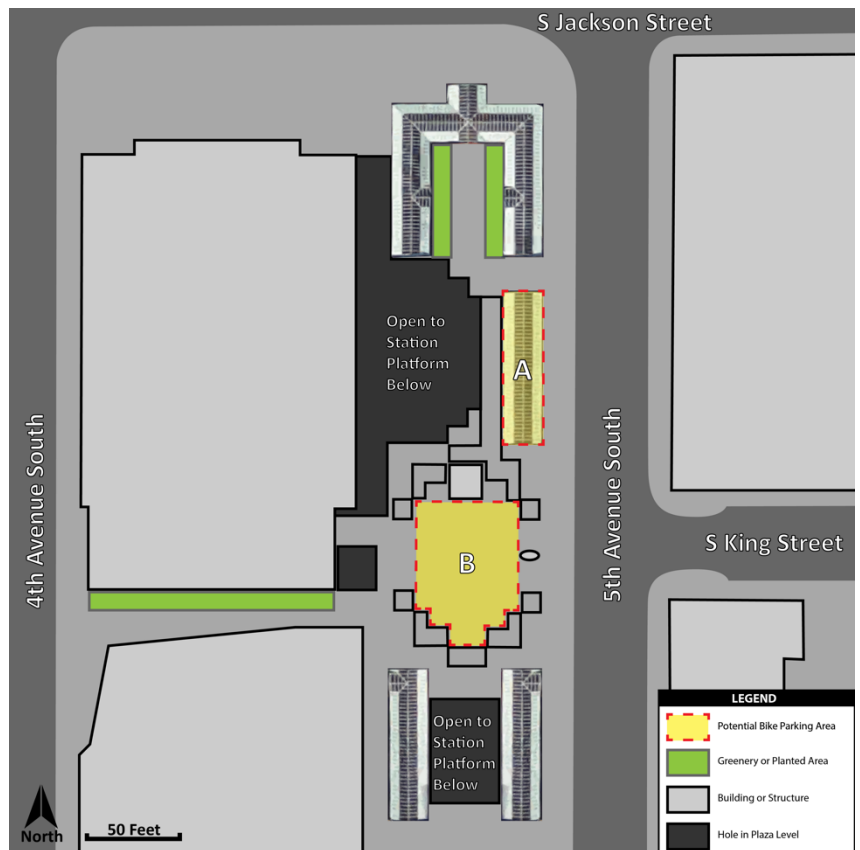
146. “Central Puget Sound Regional Bikestation Project.”

resulting in long walks from the bike parking location to the station. This likely contributed significantly to BikeStation Seattle’s closure in 2006, though it is also possible that there is simply limited demand for secure bike parking at International District/Chinatown station despite strong projections. Considering BikeStation Seattle’s failure, building a smaller demonstration facility with capacity for less than 110 bikes would likely be prudent at this location, particularly if space can be reserved for future expansion if needed.

International District / Chinatown Station Plaza Layout

International District /
Chinatown station’s plaza is constrained by Jackson Street to the north, 5th Avenue South to the east, and Union Station offices to the west and the south, as shown in Figure 22. In addition, the subterranean station platform is open to the sky above in several locations, resulting in large holes in the station plaza that constrict pedestrian movement and available space. Despite these constraints, two sites at the station

Figure 22 – ID/C Station Plaza Layout and Potential Bike Parking Facility Locations



The UW station plaza is bounded on the west by Union Station and on the north and east by S Jackson St and 5th Avenue S. Sites large enough for bike parking facilities are shown in yellow and labeled A and B.

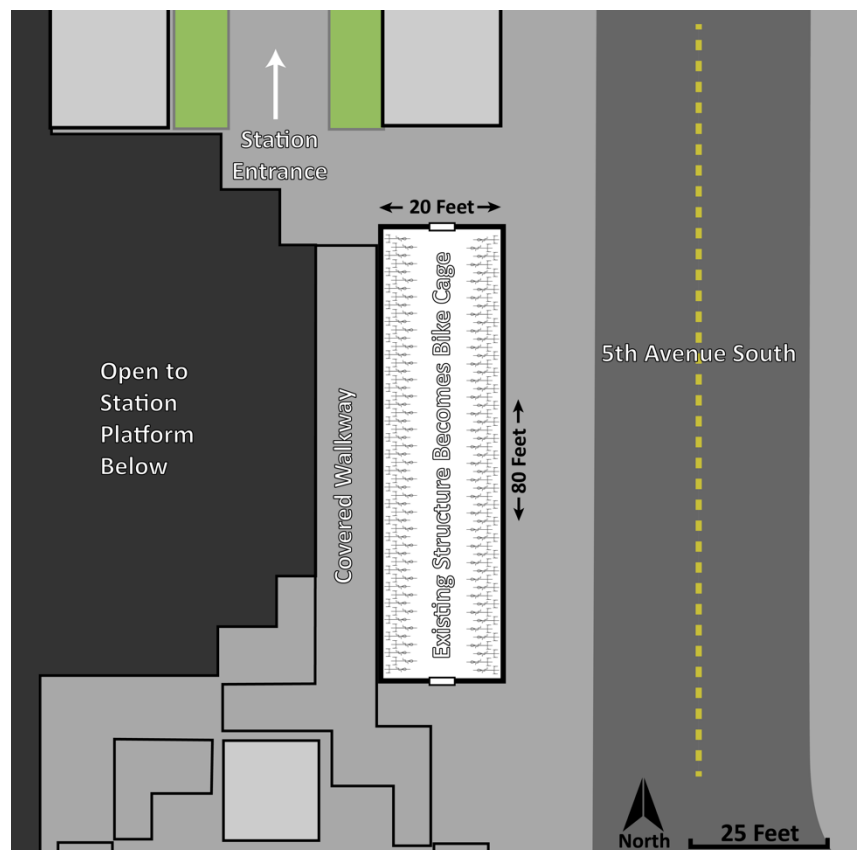
provide opportunities for secure bike parking facilities. Site A is an existing structure in the station plaza near the north entrance to the station which could be converted to bike parking use, while Site B is a large open space at the center of the station plaza.

International District/Chinatown Station Site A – Existing Shelter Structure

The International District/Chinatown station presents a unique opportunity for adding secure bike parking facilities: an existing structure in the plaza could be easily converted into a bike cage. Located just south of the station’s north entrance, this structure consists of several metal posts supporting a roof, presumably serving as a shelter from rain for bus passengers

waiting for a nearby stop on 5th Avenue South. Repeated site visits determined that this structure is rarely used by either waiting bus riders or pedestrians passing through the station plaza, meaning that its conversion to a new use would likely have little to no adverse impact on International District/Chinatown station. The shelter structure measures 20 feet wide by 80 feet long. This width would result in extremely narrow

Figure 23 – Potential Bike Parking Layout at ID/C Station Site A



ID/C station plaza is constrained by several features, but an existing structure in the ID/C station plaza could easily be converted to a bike cage with capacity for approximately 100 bikes.

aisles between hanging bikes if Dero's suggested vertical bike parking layout were used, leaving only 3 feet in which to maneuver bikes. However, this width is more than sufficient to accommodate the same layout Sound Transit has used in the Beacon Hill station bike cage. Using double-decker bike racks along both walls, the configuration shown in Figure 23 could hold an estimated 100 bikes. The layout of vertical posts in the existing shelter makes it possible to start with a 40- or 60-foot long bike cage and expand later if additional capacity is needed. An awning could be constructed on the 5th Avenue South side of the cage to provide shelter from the weather for waiting bus passengers.

Figure 24 – Rendering of Potential Bike Parking Facility at ID/C Station Site A



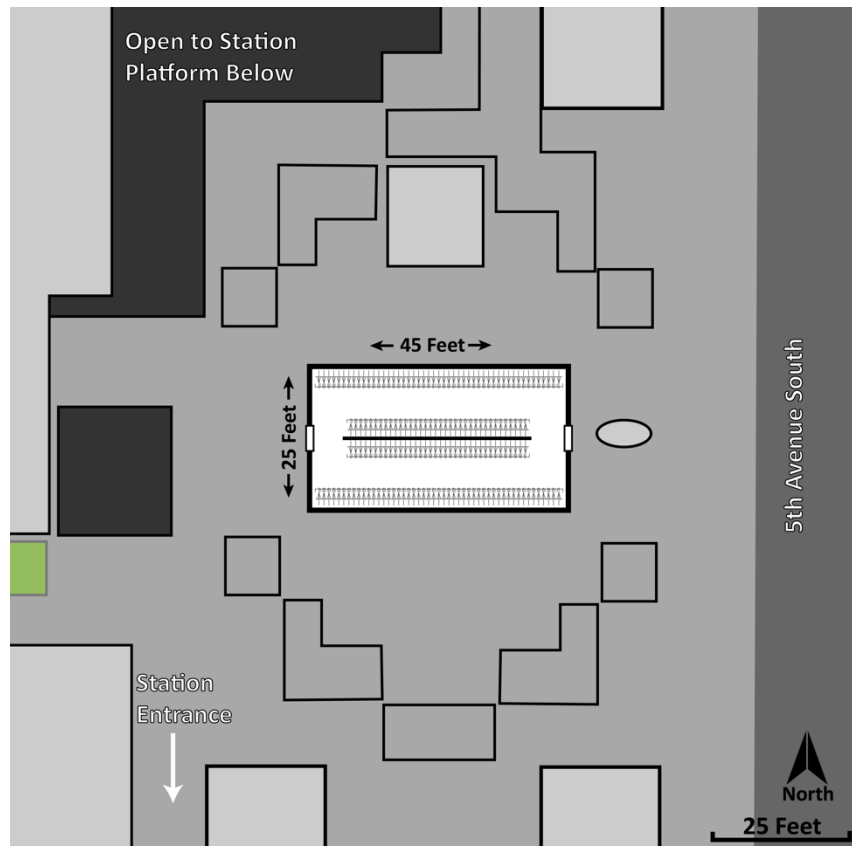
A little-used shelter in the ID/C station plaza is shown here converted to use as a bike cage with space for 100 bikes. This structure presents a unique opportunity to provide secure bike parking with minimal construction cost or disruption. Though not shown, an awning could be added to provide cover for the adjacent bus stop.

International District/Chinatown Station Site B – Center of Station Plaza

The second available site for secure bike parking at International District/Chinatown station is a large open expanse at the center of the station plaza. The open area is a rectangle measuring 50 feet by 60 feet with a small additional area open to the south. This plaza space is surrounded by decorative structures of no discernible purpose – metal posts hold up metal grates

above the station plaza, providing no protection from the elements. It is likely that these structures could be removed to build a very large bike parking facility, though for this exploration it was assumed that these structures would remain in place. A 25-foot by 45-foot bike parking facility, as shown in Figure 24, could provide secure space for approximately 100 bikes. This is just shy of the estimated need of 110 bike spaces, and may be sufficient to meet actual demand.

Figure 25 - Potential Bike Parking Layout at ID/C Station Site B



An open area near the center of the ID/C station plaza is large enough to accommodate a bike parking facility with room for approximately 100 bikes. The surrounding structures are decorative and could be removed to build a larger bike facility, though it is likely not warranted for this location.

Figure 26 – Rendering of Potential Bike Parking Facility at ID/C Station Site B



The open area near the center of ID/C station plaza is large enough to allow a new structure with capacity for 100 bikes. This open space sees little use, and a bike parking facility here would have little impact on circulation through the station plaza.

Partnership Opportunities at International District/Chinatown Station

As with the University of Washington station, International District/Chinatown is not currently owned by Sound Transit. As part of the Downtown Seattle Transit Tunnel, this station is owned, operated, and maintained by King County as part of their Metro Transit division. Sound Transit owns the surrounding Union Station property.¹⁴⁷ As with the University of Washington station, any secure bike parking facility here would require cooperation between multiple agencies. King County Metro has an extensive program to promote bicycle and transit integration and was heavily involved in the nearby BikeStation Seattle project in 2003. Metro's past and present involvement in bicycle planning makes them an ideal partner in all phases of a

¹⁴⁷ "Parcels for King County with Address," King County GIS data.

bike parking project at International District/Chinatown station, including planning, construction, and operation. Since Sound Transit and King County Metro already work together on planning and delivering transit service in the Seattle area, it should be feasible for Sound Transit to partner with King County Metro to provide secure bike parking in this location.

Recommended Secure Bike Parking Approach at International District/Chinatown Station

International District/Chinatown station is projected to have high demand for bicycle access and King County Metro is likely to be a willing partner in funding bike parking improvements at this station. However, the previous failure of a BikeStation nearby indicates that projections of high rates of bicycle access may be optimistic, precluding recommendation of a staffed bicycle parking facility. The availability of an existing structure for ready conversion to a bike cage in the International District/Chinatown station plaza further reinforces the recommendation of the proposed site A bike cage facility illustrated in Figures 23 and 24. This facility would provide 24-hour controlled access bike parking with a minimum of construction cost and low ongoing operational expense.

Chapter 6: Conclusion

Summary of Chapters 1-5

Sound Transit's Link light rail system is growing while bicycle use is increasing in the Seattle area. This provides both opportunity and motive for improving access to Link light rail by better integrating light rail with bicycles. A review of the literature on bicycle access to transit showed that providing bike share at transit stations, allowing bikes onboard transit, building bike paths to transit stations, and providing bike parking at transit stations are all methods of improving bike access to transit, which promotes cycling while helping people reach the public transit system. Of these options, Sound Transit is most able to provide increased bike parking as a means to support bike access to Link because Sound Transit has direct influence over the land use at most Link stations. However, Sound Transit provides a low level of bike parking generally, and of secure bike parking in particular. Examination of Sound Transit's peer agencies in chapter 3 showed that several transit agencies plan for bike access rates in excess of five percent. This has resulted in several large secure bike parking facilities in the San Francisco Bay, Los Angeles, and Portland areas, many of which accommodate over 100 bikes each at high-demand locations. Chapter 4 looked at available methods for assessing and estimating the demand for bike access to transit stations to determine which Link stations had the greatest need for secure bike parking. University of Washington and International District/Chinatown stations are expected to have the greatest demand for bicycle access and thus the greatest need for secure bicycle parking. Based on examination of these two stations in detail, a staffed bike parking facility with capacity for 200 bikes is recommended for University of Washington

station. A bike cage with space for 100 bikes is recommended at International District/Chinatown station.

Recommendations for Sound Transit Bicycle Parking

Based on the research completed in this thesis, there are several opportunities to improve bicycle planning and bicycle parking for Sound Transit's Link light rail system. These follow from literature review, observations of the practices at Sound Transit's peer agencies, evaluation of the demand for secure bike parking at Link stations, and examination of the possibilities for constructing secure bike parking facilities at the stations with the highest demand for bike access.

Address the need for secure bike parking at existing high-demand stations first.

This thesis has demonstrated that several Link stations, particularly University of Washington, International District/Chinatown, and Capitol Hill, have a high level of demand for bicycle access. Secure bicycle parking is an important component of supporting bicycle access to these stations, but they currently have no secure bike parking facilities at all. Sound Transit should direct their bicycle planning efforts and bicycle access funding to addressing this unmet need as soon as possible.

Prepare a system-wide bicycle plan.

BART and LA Metro have bicycle plans that guide all aspects of planning for bicycle access to their transit systems, including the provision of secure bike parking. TriMet is also in the process of completing their own bicycle plan, which is currently available in draft form. All of these documents incorporate an assessment of the level of need for bike access and parking at each transit station within each agency's system, as well as policies for the provision of

bicycle services and amenities. BART's bicycle plan also serves as the basis for their bike parking capital program, which allows for targeted and scheduled funding of bicycle amenities rather than an ad-hoc planning approach. This thesis has begun the work needed to prepare a bicycle plan for the Link light rail system. Sound Transit should continue this work and expand it into an agency-wide bicycle plan that includes bike parking as well as other bicycle access improvements where possible.

Scale secure bike parking capacity to demand.

While Sound Transit provides secure bicycle parking at several of its light rail stations, this thesis has demonstrated that no secure bike parking is available at the stations with the greatest need. Going forward, Sound Transit should be sure to build adequate bike storage capacity into new Link stations after working to address the need at the existing stations. The following general recommendations in scaling for demand should be applied to bike parking at future Link stations:

- If less than 20 bike parking spaces are needed, use electronic lockers to provide flexibility for those who need secure bike parking.
- If 20 to 100 bike parking spaces are needed, use a bicycle cage or bicycle room parking facility. This allows for a more efficient use of available space compared to lockers.
- For Link stations where more than 100 bike parking spaces will be needed, use either a bicycle cage/room or a staffed bike parking facility. Consider available space, available funding, and the need for 24-hour access to secure bike parking at the station. Staffed parking can make more efficient use of space, but requires ongoing operational funding and cannot feasibly be staffed at all hours.

Opportunities for Future Research

The available data on bicycle use is scarce, particularly in relation to transit. This lack of data makes planning for bicycles challenging. There are several ways that this situation could be improved with work from either transit agency staff or willing graduate students. First, collecting data on bicycle use to access the transit system in the Seattle area could provide a better picture of how bicycles currently integrate with the public transportation network. It is not currently known how often the existing leased lockers are used, how often bikes are brought onboard buses and trains, or how frequently transit vehicles reach or exceed their bike capacity. Second, a survey of transit riders or area residents could provide more insight into the need for bike access to transit stations. Lastly, discussion with Sound Transit and King County Metro staff revealed a keen interest in new techniques for tracking the use of bicycle amenities in the transit system. Gathering bicycle data is currently labor-intensive and thus costly, so transit agencies would benefit from automated data collection methods.

Another possible direction for future work on bicycle access to the Link system is the application of PSRC's activity-based travel model. Recent literature indicates that this model may be capable of predicting the rate of bicycle access to transit stations with much greater accuracy than the existing methods of estimating demand used in this thesis. However, PSRC's model has not been tested in this specific application. If it is found to be accurate, it could be a valuable tool for planning for bicycle access to transit facilities in the future.

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