University Link Light Rail Extension; Seattle, WA

The University Link Light Rail (LRT) Extension (U-Link) extends the initial segment of the Central Link LRT system in Seattle, Washington. The project consists of a 3.15-mile northward extension from northeast of the Westlake Station in Downtown Seattle to a new terminus at the University of Washington (UW). The U-Link project span was included as a component of the original Central Link LRT system which emerged from an alternatives analysis completed in 1999. Due to fiscal constraints, Sound Transit identified three operable segments for implementation, the first of which extended from just south of downtown Seattle north to UW. FTA awarded a Full Funding Grant Agreement (FFGA) for this project in January 2001.

Work stopped later that year due to significant increases in the estimated costs of tunneling from downtown Seattle north to UW. Instead, Sound Transit chose to construct the initial segment of the Central Link LRT from Westlake Station in Downtown Seattle to Tukwila. This project was implemented under a FFGA in October 2003. This FFGA was later amended to include a 1.7-mile extension south from Tukwila to SeaTac International Airport in December 2008. Sound Transit and FTA completed the Before and After Study for the Downtown Seattle to SeaTac International Airport segment in 2013.

Sound Transit returned to the planning process for extending the Central Link north from downtown Seattle to Northgate in December 2003. The Sound Transit Board of Directors selected the 3.15-mile U-Link project as the first phase in August 2005. The project entered Preliminary Engineering in December 2005, entered Final Design in December 2006, and was awarded a Full Funding Grant Agreement by FTA in January 2009. The project opened to service in March 2016.

Sound Transit operates the Link LRT system in the Seattle metropolitan region. Figure 1 provides a map of the U-Link LRT project and the inset shows the scope of the project with respect to the entire Link LRT system. In this Before-and-After Study of the project, sections documenting its physical scope, its capital costs and ridership on the project focus on the new 3.15-mile light rail extension.

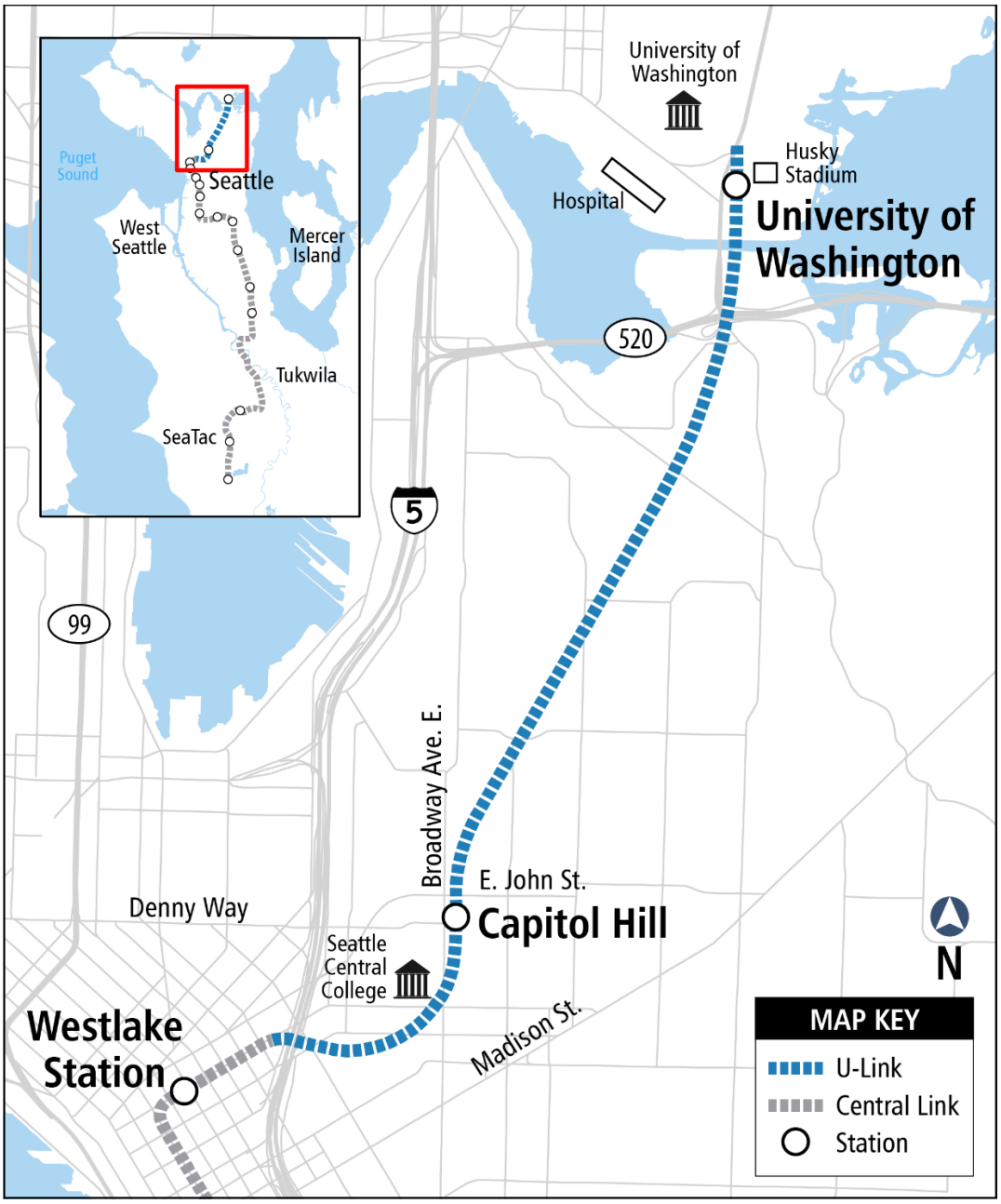

Figure 1. U-Link LRT Project Map

Physical scope

The U-Link project is a 3.15-mile, double-track light rail line which operates on an underground dedicated guideway. The project consists of parallel bored tunnels between the Pine Street stub tunnel northeast of the Westlake Station and between new station boxes constructed at the two new underground project stations: Capitol Hill and UW. Both project stations include a 380-foot long platform, enough to accommodate a four-car train set. Included in the project is a set of double cross-over tracks just south of the UW Station.

The Capitol Hill station is sixty-five (65) feet deep and has three station entrances from street level. The Capitol Hill station design uses a station mezzanine level as an intermediate point between the street and the platform level. The connection between the station platform and mezzanine is made using escalators and elevators for ADA compliance. Between the mezzanine and the street level, the three station entrances are connected by a combination of escalators, elevators and stairs.

The UW Station is ninety-five (95) feet deep and has three stations entrances at street level. Two of the station entrances are at street level providing access to the local on-street locations including Huskie Stadium, while the third entrance connects to an elevated pedestrian bridge which connects the central UW campus to the station. Elevators connect the station platform to street level and the elevated pedestrian bridge.

The U-Link project scope modified and expanded the existing Link Light Rail Operations and Maintenance Facility (OMF) located in the south downtown industrial district in Seattle. The project constructed five additional storage tracks with the additional capacity for 27 light rail vehicles, constructed 4,000 feet of additional track and additional infrastructure to support the storage and maintenance of the expanded vehicle fleet. In addition, the project constructed a new Maintenance of Way building at the OMF.

The project scope included the demolition and clearing of a limited number of residential and commercial buildings in areas of the two project stations. Utility work included capping, protecting in place, replacing and relocating of storm water drainage, water and gas lines, electrical conduit and street lighting. Hazardous materials were removed and disposed including asbestos, lead paint and underground storage tanks found on site.

The project scope included purchasing real estate properties for the stations and construction staging area, the purchasing of tunnel easements for two bored tunnels, purchasing of a land easement from the UW and cost of residential and commercial relocations. The scope also included payment for the cost of replacement parking that was provided to the UW to mitigate the loss of approximately 600 parking spaces temporarily during construction and the permanent loss of 100 parking spaces.

The vehicle scope encompassed the procurement, manufacture, delivery, testing and commission of 27 low-floor light rail vehicles. The procurement included the vehicles, spare parts and warranty support.

The anticipated scope identified at each project-development milestone was consistent with the as-built project in terms of its length and general alignment. At PE-entry, the anticipated scope was different from the as-built outcome for five elements of the project: (1) both project stations assumed two station entrances, instead of three that were constructed; (2) a ventilation shaft was assumed to be needed south of the UW station, which was later determined to be not needed; (3) the project was assumed to build a multi-story parking structure to replace displaced parking at the UW which was not constructed, instead a payment was made by Sound Transit to UW; (4) the project planned to purchase 30 light rail vehicles and the OMF was sized to accommodate this number of vehicles (instead of 27 vehicles actually purchased); and (5) a maintenance of way building was not included at the OMF.

Preliminary engineering did not materially change the project scope. Most of the differences listed above were carried forward to the FD-entry milestone. All but one of the scope differences

between the predicted and actual scope were resolved by the FFGA award. The only scope item that was different at the FFGA was the predicted scope did not include the Maintenance of Way building at the OMF.

Capital cost

The actual cost of the project was $1,674.8 million in year-of-expenditure (YOE) dollars – 58 percent for construction, 8 percent for land acquisition, 6 percent for rail vehicles, 18 percent for professional services and 10 percent for finance charges. Total YOE cost per mile was $476.2 million, $444.4 million per mile excluding the vehicles.

At PE-entry, the predicted cost was $1,557.3 million in YOE dollars, 7.0 percent less than the actual cost. This YOE estimate derived from a 3.8 percent underestimate of baseline (constant dollar) costs -- equivalent to $64.2 million YOE dollars. Projected inflation effects were marginally low because of small underestimates of annual inflation rates (equivalent to -$22.2 million YOE) and the length of the project-development schedule (-$31.0 million YOE).

At FD-entry, the predicted $1,645.9 million cost estimate in YOE dollars understated the actual project cost by $28.9 million (1.7 percent). An overestimate of baseline costs by the equivalent of $30.4 million YOE dollars was more than offset by an underestimate of inflation-related costs (equivalent to -$29.7 million YOE) and the length of the project-development schedule (-$29.6 million YOE).

At the FFGA, the predicted $1,947.7 million cost estimate in YOE dollars overstated the actual project cost by $272.9 million (16.3 percent). An overestimate of baseline costs by the equivalent of $255.6 million YOE dollars was the cause of the inaccuracy of the FFGA capital cost estimate. This occurred because Sound Transit substantially increased the capital cost estimate between FD-entry and the FFGA in response to tunneling cost underestimates that had occurred on other tunneling projects throughout the United States during the project development period. The FFGA cost estimate for the tunneling included a higher base cost plus a higher percentage of contingency than was assumed in the FD-entry cost estimate. Ultimately this increase in the predicted tunneling costs proved to be overly conservative in the FFGA cost estimate.

Transit service

Sound transit operates Link LRT service for 20 hours per day (5am to 1am) on weekdays and Saturdays. The service span is 18 hours on Sunday (6am to midnight). Weekday headways are 15 minutes in early mornings and late evenings, 6 minutes during peak-periods and 10 minutes during off peak periods. Trains operate with consist mix of two and three cars trains. End-to-end runtime on the Link LRT service (UW to SeaTac International Airport is 44 minutes at an average speed of 25.5 mph. The U-Link project segment (UW to Westlake) takes 6 minutes at an average speed of 31.5 mph.

Geographic constraints help define the project corridor. North Seattle is bounded on the east by Lake Washington and on the west by the Puget Sound. The south boundary is a series of waterways, both natural and manmade, collectively referred to as the Lake Washington Ship Canal. The Ship Canal serves to funnel bus service to use three bridge facilities: from west to east I-5 Freeway Bridge, the University Bridge and the Montlake Bridge.

The project corridor between UW and Downtown Seattle is a very densely developed residential and employment area within Seattle. King County Metro, the regional bus operator, operates

several bus routes in the project corridor, which compete with and provides connection to the U-Link project. This corridor is a transit rich environment where customers have multiple competitive choices to complete their trip including LRT and bus.

The I-5 Freeway Bridge is utilized by 25 express bus routes, many of which operate during the peak-period only. Most of these routes operate from locations outside the project corridor - North Seattle, the shoreline and Community Transit service from suburban Snohomish County to Downtown Seattle. I-5 operates peak-period, peak-direction reversible express lanes which facilitate faster travel times for these express buses. Only one route, Route 74 (15 min peak/30 min off-peak headway) serves the project corridor operates on the I-5 Freeway bridge.

The University Bridge is utilized by bus routes from the University District to the west side of Capitol Hill. Route 49 (12 min peak/20 min off-peak headway) serves Broadway on Capitol Hill, including the Capitol Hill station. Route 70 (8 min peak/12 min off-peak headway) continues along the western edge of Capitol Hill to Downtown Seattle.

The Montlake Bridge is used by bus routes from the UW Link Station to the east side of Capitol Hill. Route 43 (30 min all-day headway) bus travels from west of the UW campus and travels to the Capitol Hill Link station into Downtown Seattle. Route 48 (10 min peak/15 min off-peak headway) travels from west of the UW campus past the UW link station and operates on 24th and 23rd Avenues to the Mt. Baker Link station.

Sound Transit and King County Metro made changes to bus routes in the U-Link Corridor to reduce/eliminate bus service made redundant by the opening of the U-Link project. Prior to the U-Link project opening, King County Metro operated three local and three express buses (71, 72 and 73 are local routes and 71X, 72X and 73X are express routes) which were modified with the opening of the U-Link project. The express buses operated from the University district to Downtown Seattle via the I-5 bridge. King County Metro eliminated the 71X, 72X and 73X with the U-Link project opening because these routes duplicate U-Link service, with U-Link providing a faster and more reliable connection than the former express buses.

Prior to the U-Link project, the 71, 72 and 73 local bus services operated on surface streets from Northeast Seattle to Downtown Seattle. With the opening of the U-Link project, these routes were modified to truncate at the UW Station, meaning these routes no longer operate south of the Ship Canal into Capitol Hill and Downtown Seattle. This means that riders using these routes to travel to Capitol Hill or Downtown Seattle must transfer at the UW station.

The U-Link service plan in place through most of the project-development effort was an accurate representative of actual rail and bus service outcomes with very minor exceptions. The service span, weekday frequency of service, travel time on the project and supporting bus system changes were all accurately planned during project development. The only material difference pertaining to service was that Sound Transit planned to operate two-car trains on the Link LRT system, while the system operates a mix of two- and three-car trains. The lengthening of trains was in response to PM peak-period passenger crowding on-board trains departing Downtown Seattle, which exceeded Sound Transit loading standards. To ease this crowding, Sound Transit added a third car to a portion of the Link trains in operation.

O&M costs

The Link LRT O&M costs are reported for the entire length of the Link line. The year 2018 actual O&M costs for the SeaTac/Airport Station to the UW segment was $95.5 million. At the time of the FFGA, Sound Transit predicted year 2018 O&M costs of $74.6 million (an underprediction of 22 percent). The driver of this difference was a 40 percent under-prediction in the number of revenue-vehicle miles operated. As described in the service section, the FFGA service plan assumed the system would operate all two-car trains, while the as-built system operates a mix of two- and three-car trains to address capacity issues on the Link system.

As discussed in the transit service section, King County Metro bus service was nominally reduced with the opening of the U-Link project. However, King County Metro has since redeployed the reduced bus service hours which were eliminated with the opening of the U-link project to accommodate greater bus demand in the project corridor. As such, bus O&M costs were not materially impacted by the U-Link project opening.

Ridership

In 2018, two years after the U-Link project opened to service, weekday ridership on the project averaged 33,900 trips. This count includes all trips that used either the Capitol Hill or UW stations. An on-board rider survey collected in 2018 provides insights into the characteristics of U-Link riders and their trips. Forty (40) percent of all U-Link trips are made between home and work, 18 percent are made by students between home and a college campus, 20 percent are made between home and other activities, and 22 percent are between two non-home locations.

The large shares of non-work trips reflect both the diverse mix of land uses in the corridor and the multiple functions of U-Link service – as a commuter line for workers and college students in the U-Link Corridor, as a distributor of trips to the Corridor from outlying areas connecting to the Link system in Downtown Seattle, and as a circulator for both residents and non-residents of the Corridor among its various activity locations.

Fifty-seven percent of U-Link riders lived close enough to a Link station to be able to walk directly from home to the station while 21 percent used bus connections to travel between home and the Link system. The remaining 22 percent used another access mode: park-and-ride (8 percent), private automobile drop-off (7 percent), drop-off by Uber/Lyft/Taxi (2 percent) and bicycle (5 percent).

Three individual travel markets together represent nearly 90 percent of the 33,900 trips on the U-Link project. The largest market comprises the 16,100 trips (47 percent of project trips) that occur within the Seattle Core. These are trips that occur within the University District, Capitol Hill and the Seattle CBD. This pattern reflects the more residential characteristic of the Capitol Hill area and the mixed nature of the University District. Fifty-four percent of these trips (8,700) are residents of the University District and Capitol Hill traveling to the Seattle CBD. Twenty-five percent (4,000) are residents of the Seattle CBD traveling to the University District and Capitol Hill. The remaining 21 percent (3,400) are riders who travel locally between Capitol Hill and the University District. This market comprises 44 percent home-to-work trips, 11 percent home-to-university trips, 17 percent home-to-other trips and 28 percent non-home based trips. The trips within the Seattle core are significantly more walk oriented (71 percent) and less auto access oriented (3 percent park-and ride and 5 percent drop-off) than the project overall.

The second-largest market are trips attracted to Seattle Core from the south of the Seattle Core. This market includes 8,800 project trips (26 percent of project trips). The South of the Seattle Core area is part of the region where pre-U-Link the Central Link LRT system operated to the Seattle CBD. These project trips are riders using Link LRT system to access Capitol Hill and the University District. Thirty-two (32) percent of these trips are made between home and work, 39 percent are made by students between home and a college campus, 16 percent are made between home and other activities, and 14 percent are between two non-home locations. Because these trips are produced from more suburban parts of the region, these trips tend to be more oriented to auto-access (13 percent park-and-ride and 11 percent drop-off) and less walk oriented (43 percent) as compared to the project overall.

The third-largest market are trips produced from the Seattle Core to locations outside the Seattle Core. This market represents a reverse-commute market and totals 5,500 trips (16 percent of project trips). Over 80 percent of these trips are attracted to areas South of the Seattle CBD along the Link LRT system with notable concentrations in the Rainer Valley and Sea-Tac International Airport.

Ridership forecasts prepared for the FFGA milestone predicted 48,100 weekday trips on the U-Link project in its opening year, an overprediction by 14,200 trips (42 percent) of the actual 33,900 ridership.

The overprediction had three principal causes. First, the project forecast used transit networks that significantly overstated the accessibility of the U-Link project stations in the travel forecasting model. The station access coding for the project stations used a course street network combined with nominal station access/egress time to represent the time required for customers to travel between the street and the U-Link platforms. As described in the physical scope of the project, these project stations are deep and require riders to spend several minutes to connect between street and platform levels. Sound Transit's review of the transit networks showed that the forecasts understated station access/egress time by between four and six minutes of walking time in the travel forecasts. Sound Transit performed a test that corrected this misrepresentation and found that it accounted for more than half of the overprediction in project ridership (7,500 of 14,200 trips).

Second, the forecasting model software struggled to evaluate the highly competitive rail and bus options in the corridor. Travel forecasting software programs identify the best transit routing (path) for a rider to complete a trip. However, the algorithm employed on U-Link was discreet between modes, meaning that if the best path boarded transit first at a bus stop, the program will continue to look for alternative paths boarding at the same bus stop. If the best path first boarded at a rail station, the program would not consider any competing bus options. Sound Transit and FTA's analysis revealed that this both 1) over-stated rail trips on zone-to-zone movements served by competitive bus and rail paths and 2) over-stated bus-to-rail transfers to the project because the model tended to include non-competitive bus-to-rail with bus-only paths. An investigative analysis revealed that the forecasting model assigned approximately 4,000 trips to the project, where the bus only path was found to be superior to using rail.

Lastly, when the U-Link travel forecasts were developed, the initial Central Link LRT service had not opened. There was no experience with how riders trade off attributes of bus and LRT service. As Sound Transit continued to develop their LRT system and their travel forecasting methods, they have used more recent ridership data to inform and validate their models to better

represent customer behavior. Since the U-Link forecasts were made, Sound Transit have used their customer data to improve the performance of their travel forecasting procedures in the following fashion: 1) improved the underlying regional transit trip-tables through use of their ORCA fare media and 2) used their improved data on actual customer behavior to better represent transit rider behavior in the Seattle region.

Sound Transit prepared a test of the U-Link forecast with their current travel forecasting model calibrated to 2015 conditions prior to the U-Link opening. This version of the model addresses the issues identified with the U-Link forecasts and includes 1) improved representation of the U-Link project and transit network attributes, 2) uses an updated version of the travel forecasting software, which performs better at evaluating competing bus and rail paths and 3) utilizes updated model parameters based on current, observed bus and LRT customer behavior. This test revealed that the current model predicts 31,200 riders on the U-Link or an underestimate of project ridership by 8 percent.