Sound Transit Fare Gates Study

Exploring Fare Gates on the Rail System

prepared for

Sound Transit

prepared by

Cambridge Systematics, Inc.

December 2022

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Executive Summary

Sound Transit is interested in exploring installation of fare gates on its rail system. This analysis is a high-level assessment of the feasibility, costs, and considerations for transitioning the current open-access system to one where fare gates and barriers are used to increase fare payment rates.

Approach

To see what operating a completely closed system might look like for Sound Transit, Cambridge Systematics:

1) Reviewed existing conditions at Sound Transit and conducted interviews with staff;
2) Interviewed peer agencies about the fare gating process;
3) Asked fare gate venders about their offerings; and
4) Conducted a site visit review of nine stations to scope out conceptual arrangements of fencing and fare gates.

Using this information, a Return-on-Investment (ROI) model was developed based on estimated capital and operating costs as compared to additional revenue that may be realized from a closed system.

Peer agencies and fare gating vendors cautioned that estimating the cost of installing fare gates on an existing open system is challenging because many variables can influence final capital and operating costs. Notably, the cost estimates presented in this report:

- Use averages by station type developed by Sound Transit staff to estimate costs. These estimates are designed to give the Board of Directors enough information to decide if they want to devote resources to a more detailed engineering and construction cost analysis;
- Reflect costs in nominal 2022 dollars;
- Assume reduced Fare Ambassador Program needs under each scenario proportional to the number of gated stations;
- Assume that gated stations increase fare compliance to 95 percent (or, conversely, reduce fare evasion to 5 percent of boardings), in line with gated peer systems;
- Assume some level of fare gate replacement after 10 years of useful life; and
- Do not consider locally specific pricing, which may increase or decrease the cost relative to peers.

Scenario Results

The scenarios developed for evaluation in the model are:

- **Scenario 1: All Stations** – All Link and Sounder stations (including Link stations under construction) are retrofitted with fare gates. This is the most capital-intensive option, at an estimated capital cost of over $305 million.
- **Scenario 2: All Link Stations** – All Link stations are retrofitted with fare gates, while Sounder stations remain proof-of-payment. This would require building fare gates at 50 Link stations (including existing stations and those under construction) at a capital cost of approximately $214 million. This scenario assumes the current 85 percent fare compliance rate at Sounder stations, which remain ungated.
- **Scenario 3: Top 5 Stations** – The top 5 ridership stations (Capitol Hill, Northgate, University Street, University of Washington, and Westlake) are retrofitted with fare gates. This requires the lowest capital investment at just over $34 million. In this scenario, non-gated Link stations retain their current 55 percent fare compliance rate, and Sounder stations are assumed to keep their current 85 percent fare compliance rate.

Based on the assumptions used for this analysis, all three scenarios showed a positive return on investment over a 20-year time horizon in both the low- and high-ridership projections. Scenario 1 (All Stations) was the most capital intensive and broke even after 6 years (7 years using low-ridership projections), netting a 227 percent (177 percent in low-ridership projection) ROI by year 20. Scenario 3 (Top 5 Stations) was the least capital intensive and had a 12-fold ROI after 20 years. The results of the ROI analysis are found in Table 1.

Table 1 Scenarios Summary with 55 Percent Fare Payment Rate

	Scenario 1 – All Stations Gated	Scenario 2 - All Link Gated	Scenario 3 - Top 5 Link Gated
# of Current Stations Affected	62	50	5
Total # of Fare Gates Needed	500	341	58
Installation Costs	$305,800,000	$214,000,000	$34,200,000
Annual Operations Costs	$5,000,000	$3,991,000	$3,338,000
Results Under High Ridership			
ROI in 20 years (2043)	227%	381%	1209%
Years to Break Even	6	5	2
Net Revenue vs. No-Build (10 Years)	$183,100,000	$275,400,000	$149,200,000
Net Revenue vs. No-Build (20 Years)	$642,600,000	$754,600,000	$381,400,000
Results with Low Ridership			
ROI in 20 years (2043)	177%	308%	1037%
Years to Break Even	7	5	2
Net Revenue vs. No-Build (10 Years)	$116,100,000	$208,400,000	$128,200,000
Net Revenue vs. No-Build (20 Years)	$501,400,000	$610,700,000	$328,700,000

The ROI analysis showed a high sensitivity to input variables, chief among these being the fare evasion rate. For instance, the non-fare boarding rate assumed for Link service in this analysis was 45 percent, relatively high compared to reported fare evasion rates at other peer agencies. Decreasing the Link fare evasion rate to 15 percent—on par with Sounder service—decreases the additional revenue captured by installing fare gates. Using that new assumption, Scenario 1 (All Stations) does not break even over the 20-year analysis and Scenario 2 (All Link Stations) takes at least 18 years to break even.

Table 2 Analysis with 85 Percent Link Fare Payment Rate

	Scenario 1 – All Stations Gated	Scenario 2 - All Link Gated	Scenario 3 - Top 5 Link Gated
# of Current Stations Affected	62	50	5
Total # of Fare Gates Needed	500	341	58
Installation Costs	$305,800,000	$214,000,000	$34,200,000
Annual Operations Costs	$5,000,000	$3,991,000	$3,338,000
Results Under High Ridership			
ROI in 20 years (2043)	-27%	18%	275%
Years to break even	> 20	18	8
Net Revenue vs. No-Build (10 Years)	-$186,300,000	-$93,900,000	$11,500,000
Net Revenue vs. No-Build (20 Years)	-$76,900,000	$35,000,000	$87,200,000
Results Under Low Ridership			
ROI in 20 years (2043)	-39%	-1%	224%
Years to break even	> 20	> 20	8
Net Revenue vs. No-Build (10 Years)	-$202,800,000	-$110,400,000	$6,300,000
Net Revenue vs. No-Build (20 Years)	-$111,900,000	-$2,500,000	$71,000,000

Other considerations, such as the potential for reductions in crime, were not monetized for inclusion in this analysis. A broader ROI analysis or benefit-cost analysis (BCA) that includes this and other considerations may yield different results, but would also require additional assumptions incorporated into the model.

Another way to think about the scenarios is through net revenue. While Scenario 3 has the lowest net revenue generation (Figure 1), it still has the highest return on investment of all the scenarios (Figure 2).

Figure 1 Net Revenue – High Ridership

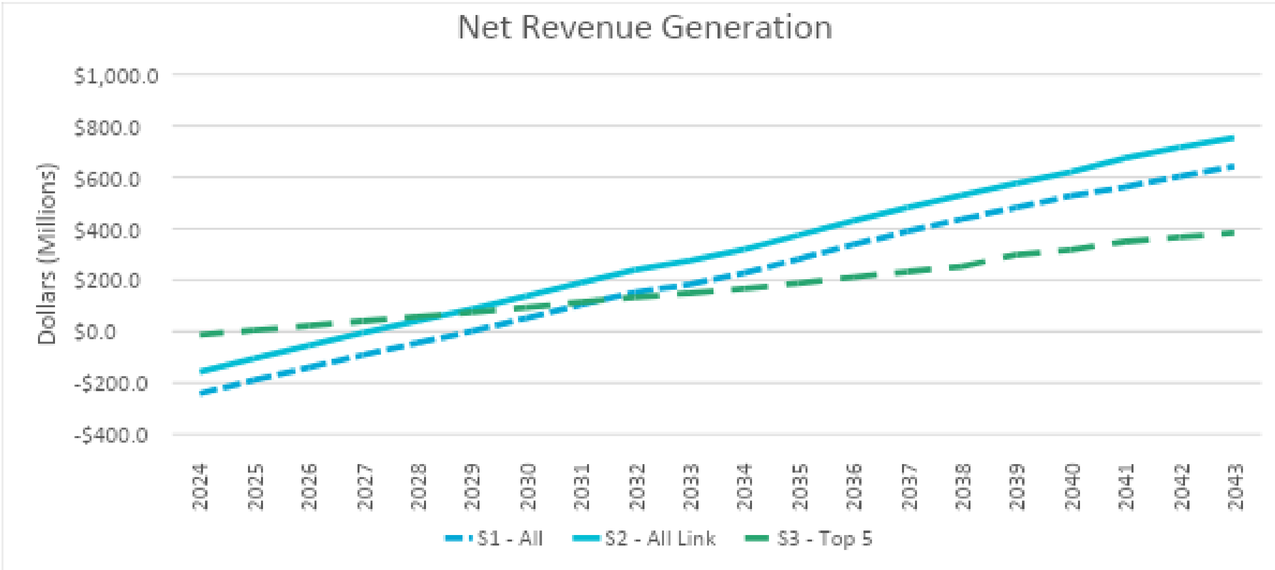
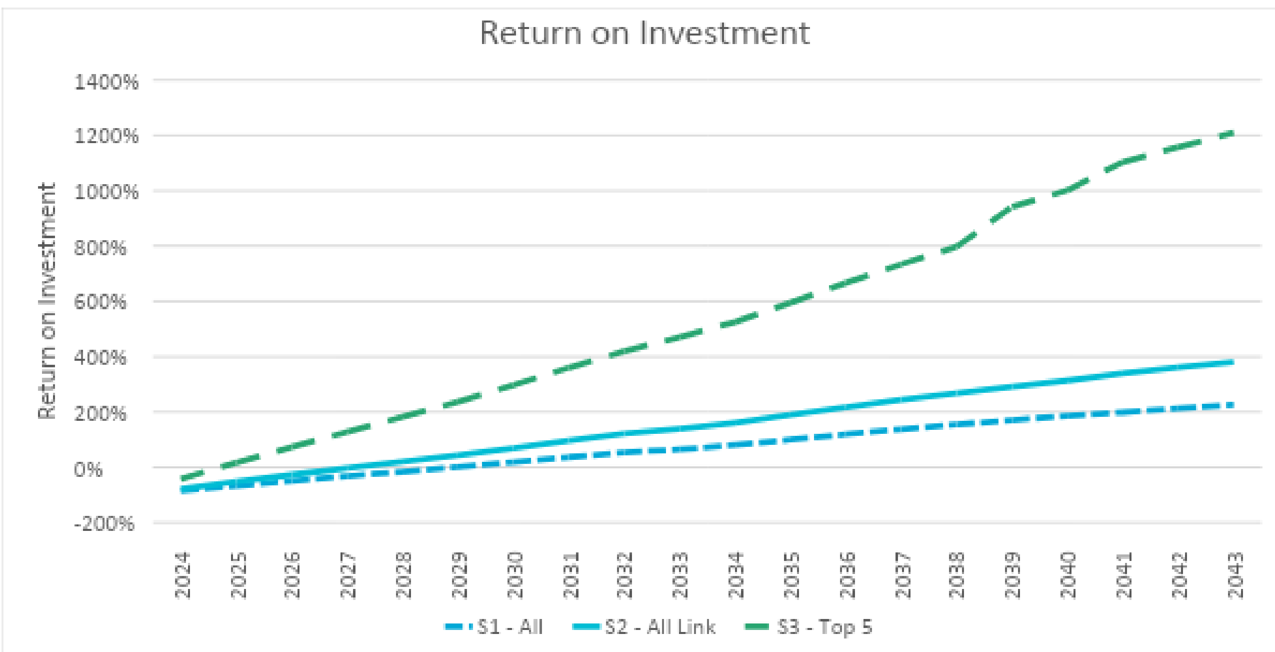


Figure 2 Return on Investment – High Ridership



The main driver for a positive return on investment of installing fare gates is Link's current low fare payment rate. As seen in Figure 3 and Figure 4, increasing the fare payment rate to 90 percent in the system as is (without gates) results in a negative ROI except at the highest ridership stations.

Figure 3 Years to Break Even by Non-Gated Fare Payment Rate - High Ridership

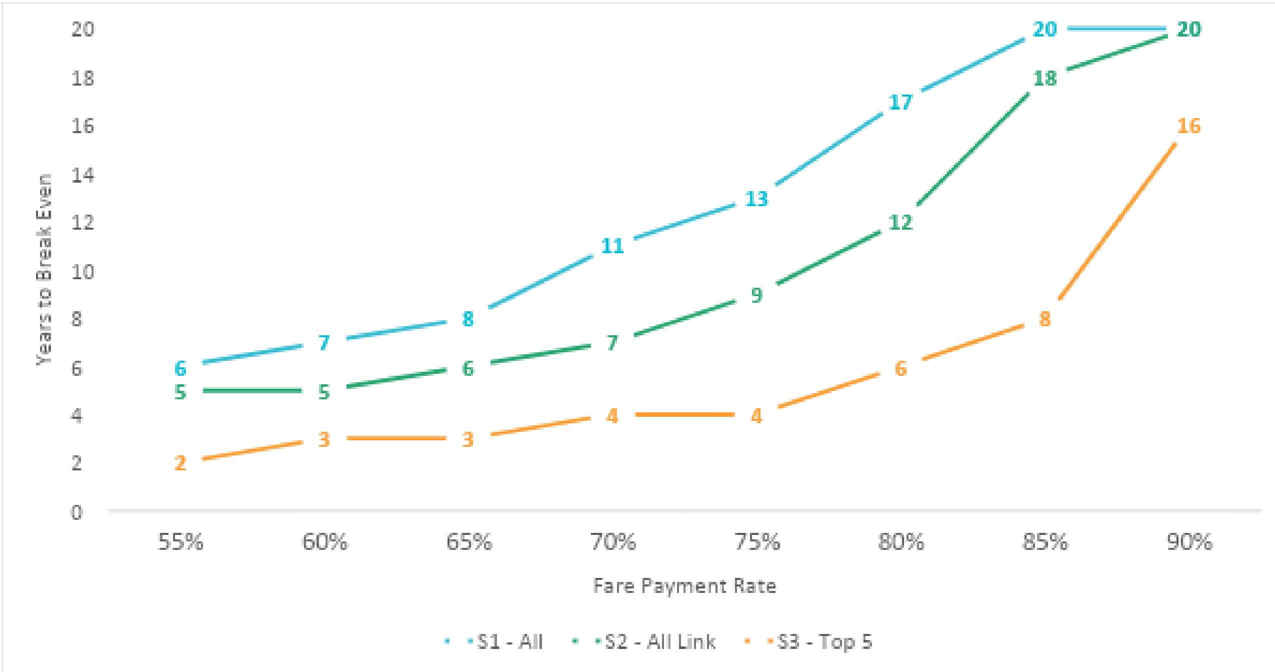
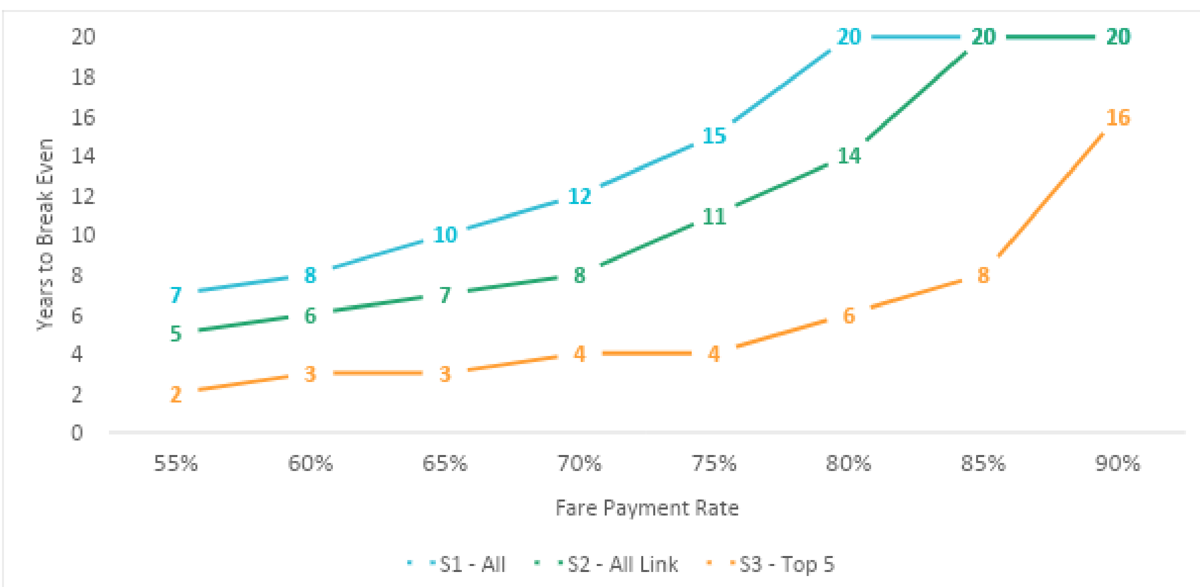


Figure 4 Years to Break Even by Non-Gated Fare Payment Rate - Low Ridership



While beyond the scope of this study, Sound Transit could pursue non-infrastructure approaches to improving fare compliance that are not already being employed, such as innovative public education campaigns, alternative fare ambassador approaches, and other low- or no-capital alternatives. This could be an interim step while fare gates continue being studied.

1.0 Existing Conditions

This section provides relevant information about Sound Transit's existing system and the fare collection challenges it faces. Sound Transit was designed as a proof-of-payment service, which is reflected in station design, fare collection approach, and fare technology. The financial plan supporting the agency's ambitious 32-station system expansion, ST3, has been impacted by the decline in ridership since 2020 and the increase in non-fare boardings. The variety of station types and existing fare payment infrastructure make the transition to a gated system complex.

1.1 About the System

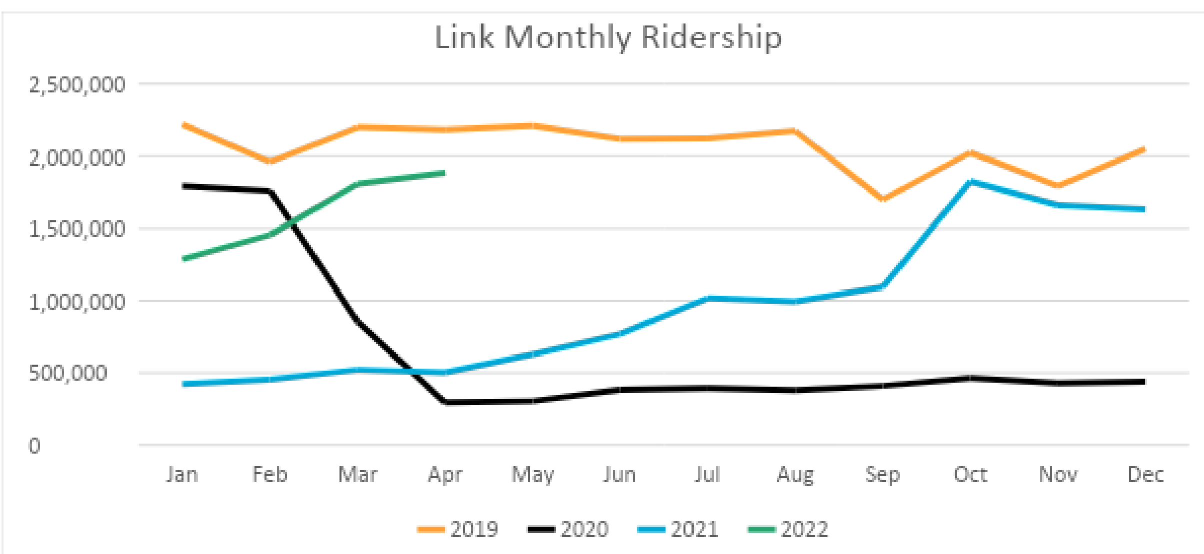
Sound Transit currently operates two light rail lines (Link Line 1 and T Line), two commuter rail lines (N Line and S Line), and express bus service. In 2016, voters approved an ambitious expansion of its light rail system (Sound Transit 3, or ST3) as well as development of a new bus rapid transit line and an extension of its commuter rail, the Sounder. A variety of revenue sources support the financial plan for this expansion, with fare revenue being an important element.

Sound Transit uses a proof-of-payment system for its Link and Sounder services. Ticket Vending Machines (TVMs) allow customers to pay cash for fares or reload an ORCA tap card. Tickets are also available through the Transit Go Ticket app. Fare compliance is currently managed through its Fare Ambassador Pilot Project.

1.1.1 Ridership and Fares

Pre-pandemic ridership on the Link and Sounder systems grew as the system expanded. Ridership fell dramatically during the pandemic but has since rebounded to near pre-pandemic levels on Link light rail (Figure 5).

Figure 5 Link Monthly Ridership 2019 – 2022



Source: National Transit Database

Fare payment compliance has deteriorated significantly since 2020 (Table 3). Post-pandemic, the fare evasion rate on Link has increased from 3 percent to up to 30 percent based on the non-payment rate during fare checks. The non-fare boarding rate is a Sound Transit-defined metric which compares the number of fare purchases against automatic passenger counter (APC) data[1], and shows that non-fare boardings have increased to up to 60 percent. The Sounder has not seen the same increase in fare evasion as the Link system, though non-fare boardings have increased from 3 percent to up to 24 percent.

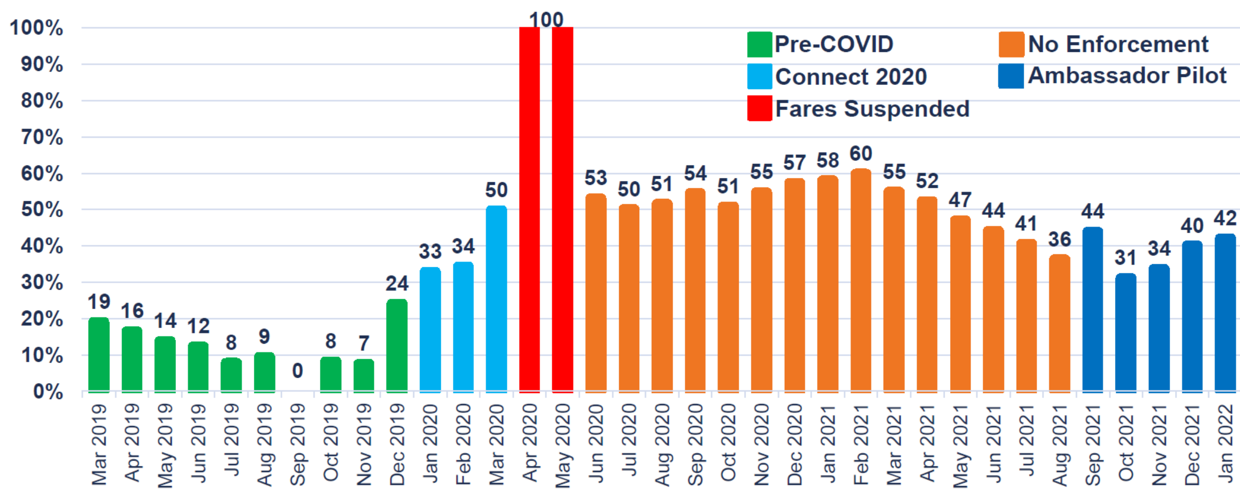
Table 3 Fare Evasion and Non-Fare Boarding Rate

	Link		Sounder	
	2018-2019	2020-2021	2018-2019	2020-2021
Fare evasion rate	3%	10-30%	1-2%	2%
Non-fare boarding rate	14%	31-60%	3%	3-24%

Source: Sound Transit

Fare noncompliance has remained relatively high compared to pre-pandemic statistics under the current Fare Engagement Pilot Project ("Ambassador Pilot"). Non fare payment increased during Connect 2020 project construction and accompanying partial Link closures. The Ambassador Pilot emphasizes directing income-qualified riders to discounted fare options as well as other alternatives to fines and penalties. Under the program, fare non-payment was up to 44 percent on the Link system, as shown in Figure 6.

Figure 6 Fare Non-Payment March 2019 – January 2022

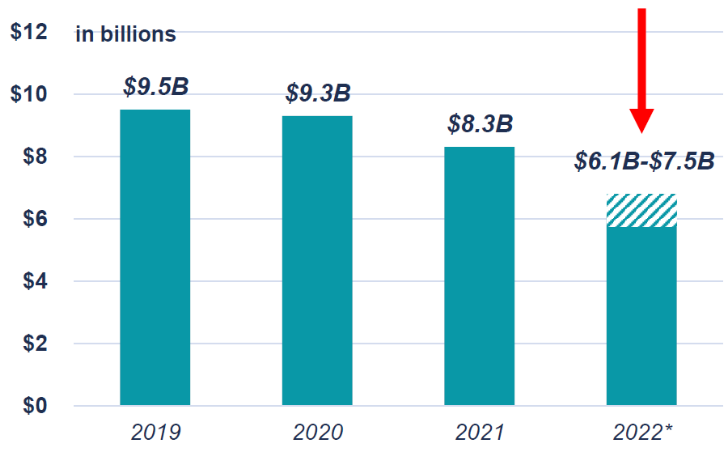


Source: Sound Transit

This increase in fare noncompliance reduces 30-year revenue projections by up to $3.1 billion, substantively impacting the financial capacity of Sound Transit to deliver and operate the planned expansions of the system in ST3 (Figure 7).

[1] APCs are pieces of equipment that automatically count the number of boardings and alightings from transit vehicles, typically using infrared or laser beams at vehicle entrances. Every time a boarding or alighting takes place, the computer will track that information. By comparing ridership as recorded by APCs against ridership as recorded by the fare equipment, the fare evasion rate can be estimated.

Figure 7 Change in Fare Revenue Projections in Finance Plan (2017 - 2046) since 2019



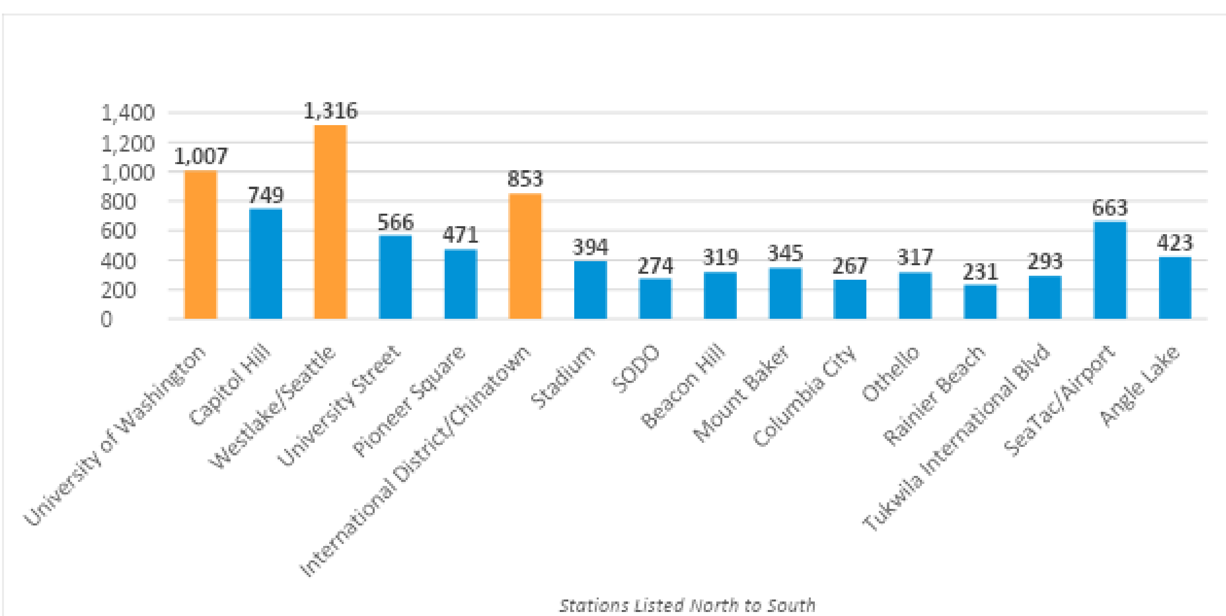
Source: Sound Transit

In this context, fare gates present a potential option for enhanced fare policy compliance without the need for increasing enforcement activities. As explored in Section 5, fare gates could be a capital investment up front that over time recaptures some or all of the lost revenue projected in Figure 7.

Peak Ridership by Station

One consideration for fare gates is the average and maximum passenger flow through stations, in particular in case of an emergency in which people must quickly exit a station. In general, boarding volumes at stations located at the north end of the Link light rail system have the highest peak hours, while those between SeaTac/Airport and Stadium stations have the lowest boarding volumes. In 2019, the station with the largest volume of peak boardings was the Westlake/Seattle Station (Figure 8).

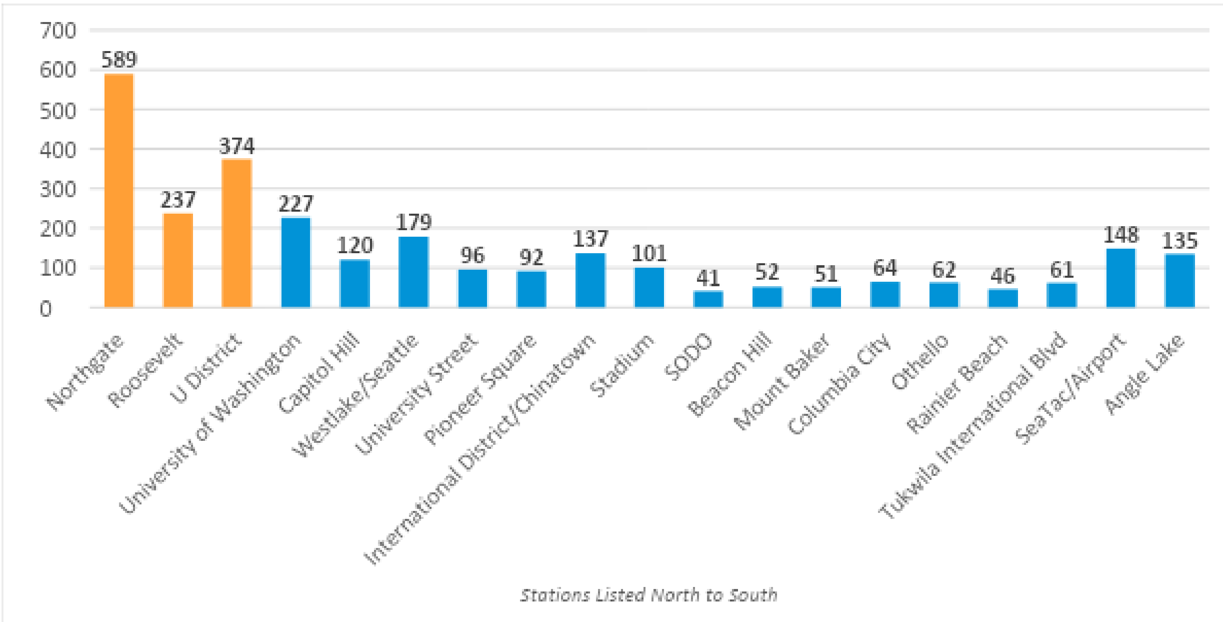
Figure 8 2019 Maximum Hourly Boardings



Source: Sound Transit

By 2021, three additional stations north of University of Washington had opened (U District, Roosevelt, and Northgate). That year Northgate Station, the northern terminus of the Link light rail system, had the largest volume of peak hour boardings (Figure 9).

Figure 9 2021 Maximum Hourly Boardings



Source: Sound Transit

It is not clear whether changes to commute habits or the opening of the three northern-most stations drove the northward shift of peak-hour ridership flows. The absolute number of boardings during peak passenger flows in 2021 are much lower than those observed in 2019; Northgate had a peak hourly number of boardings of 589 in 2021 compared to Westlake/Seattle Station's peak of 1,316 boardings in 2019. This suggests that changes in commute patterns due to the pandemic (e.g., more flexible work schedules) could have caused the change in peak passenger volumes.

1.1.2 Station Design

Sound Transit's station design guidelines specify materials, signage, bike parking, seating, and other features. Elements of this guide that could have direct bearing on the installation of fare gates include the following:

- **Surge Zones:** Elevator, escalator, and stair surge zones shall be free of all obstructions. The elevator surge zone is defined as a 10 by 10 foot area in front of the elevator door. Stair and escalator surge zones shall be 15 feet long (measured from end of handrail) and, where conditions permit, five feet wider in each direction than the width of the stair or escalator. Surge zones of elevators shall not overlap surge zones for stairs/escalators.[2]

[2] Sound Transit Station Design Criteria, page 9-18

- **Weather Protection:** Weather protection from the rain shall be provided for fare vending equipment and adjacent surge zones.[3]
- **Fare Vending Area Design:** Fare vending areas shall include:
  - Customer information panels
  - Two TVMs
  - Two smart card readers
  - Benches
  - Passenger Emergency Telephone
  - 30 by 48 inch surge zone in front of each TVM[4].

These guidelines are in addition to those required by the Americans with Disabilities Act (ADA), National Fire Protection Association (NFPA) 130: Standard for Fixed Guideway and Passenger Rail Systems, and Crime Prevention Through Environmental Design (CPTED) guidelines, discussed in more detail in Section 3.2.

1.1.3 Station Typologies

There are currently 25 Link stations and 12 Sounder Stations in service. Additionally, there are 26 Link stations under construction and slated to open by 2024. The voter-approved ST3 initiative will expand the Link light rail system to over 80 stations, in addition to expansions in Sounder commuter rail and express bus service. A bus rapid transit service will also be implemented as a part of ST3.

While yet-to-be designed future stations might be able to readily incorporate fare gates, existing stations and those under construction would have to be retrofitted with fare gates, fencing, and other associated infrastructure elements. Within the Sound Transit system, the diversity of station types would require customized solutions for fare gate implementation.

In general, stations are at-grade, underground, or elevated (with variations within those categories).

At-Grade

At-grade stations are the most common station type, with 11 out of the 25 operational Link stations and 10 of the 12 operational Sounder stations located at-grade. These stations are open-air and typically have direct access to the streets and sidewalks. Retrofitting these stations for fare gates may be challenging due to space constraints and right-of-way jurisdictions (e.g., space needed on city-owned sidewalks), in addition to other public safety and emergency access considerations described above.

Operational at-grade stations include:

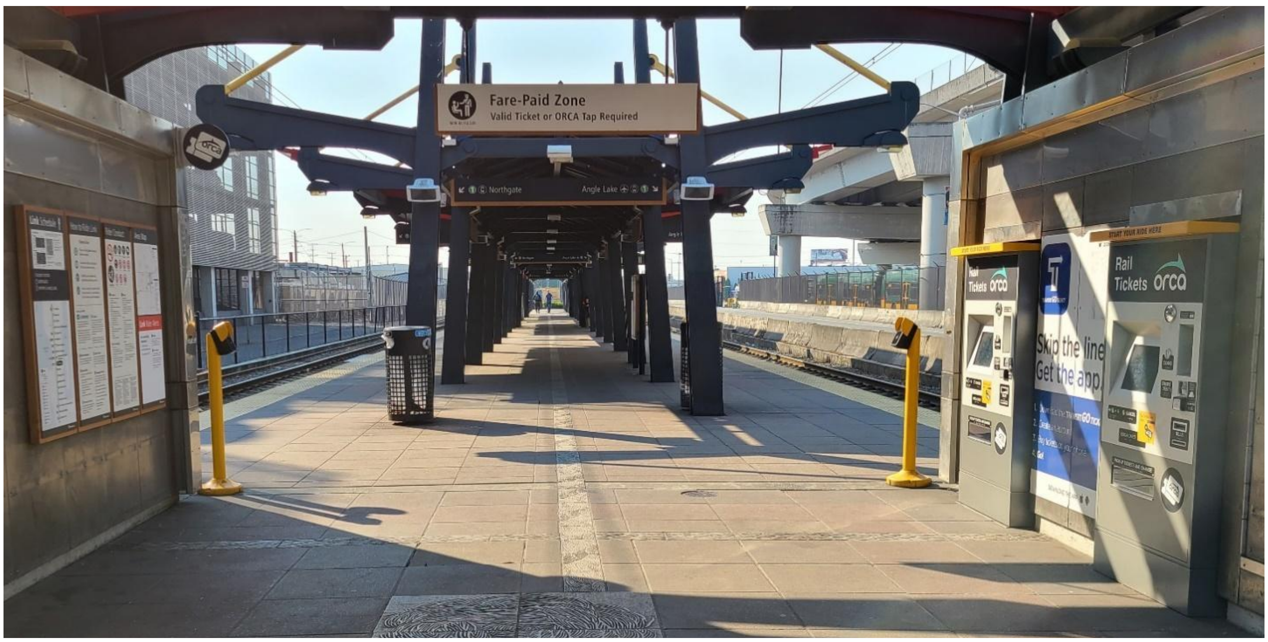
- Stadium (Figure 10)

[3] Sound Transit Station Design Criteria, page 9-25

[4] Sound Transit Station Design Criteria, page 9-35

- SODO
- Columbia City
- Othello
- Rainier Beach
- All six Tacoma Link stations (Commerce Street, Convention Center, Union Station, S 25th, Tacoma Dome Station, Theater District[5])

Figure 10 Stadium Station (At-Grade)



Underground

The second most common station type is underground, with nine stations being underground. Four of those stations are downtown; Beacon Hill is particularly deep and can only be accessed via elevator. Underground stations may be challenging to retrofit due to space constraints and the presence of difficult-to-move structural elements that could impede installation of fare gate infrastructure. Furthermore, the downtown tunnels are an older part of the system and so utility connections may be more complicated to retrofit.

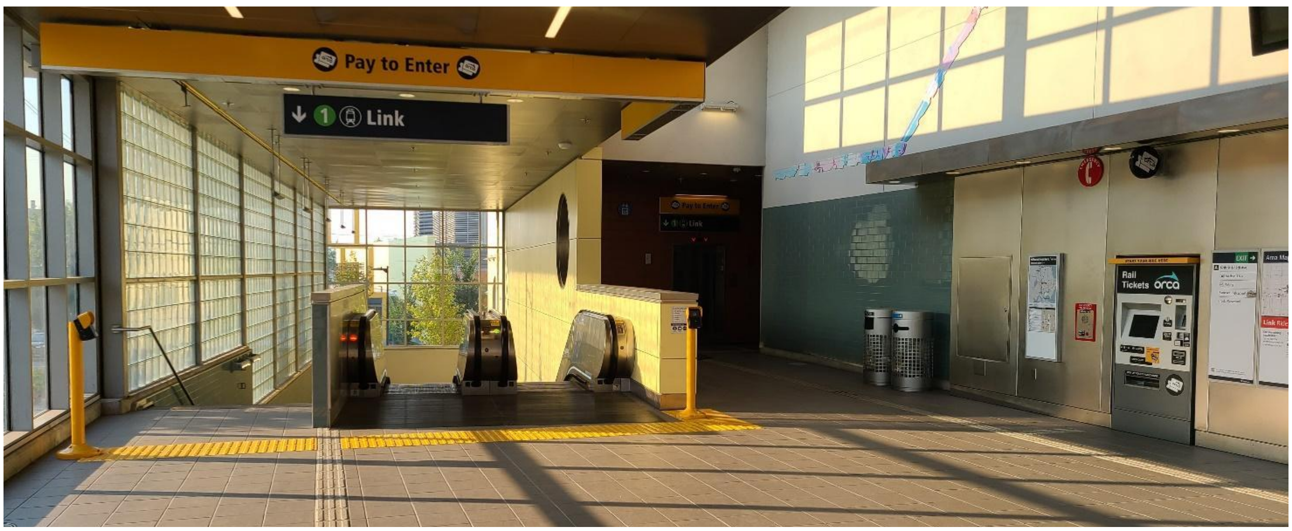
Underground stations currently operational include:

- Roosevelt (Figure 11)
- U District
- University of Washington

[5] As of August 2022, this station closed and is being relocated. For the purpose of this study, 6 at grade stations were assumed for the Tacoma area.

- Capitol Hill
- Westlake (Downtown Tunnel)
- University Street (Downtown Tunnel)
- Pioneer Square (Downtown Tunnel)
- International District / Chinatown (Downtown Tunnel)
- Beacon Hill (Elevator only)

Figure 11 Roosevelt Station



Elevated

Elevated stations are the least common station type, with five elevated stations in the Link system. However, of the 26 stations currently under construction, 10 will be elevated. Elevated stations may be the easiest to retrofit with fare gates due to the availability of open space underneath the structures and well-defined entrance and egress points. However, the presence of pedestrian bridges and stairs can present challenges to retrofitting these stations.

Elevated stations currently operational include:

- Northgate (Figure 12)
- Mount Baker
- Tukwila International Boulevard
- Airport / SeaTac
- Angle Lake

Additionally, Tukwila Sounder station is elevated.

Figure 12 Northgate Station

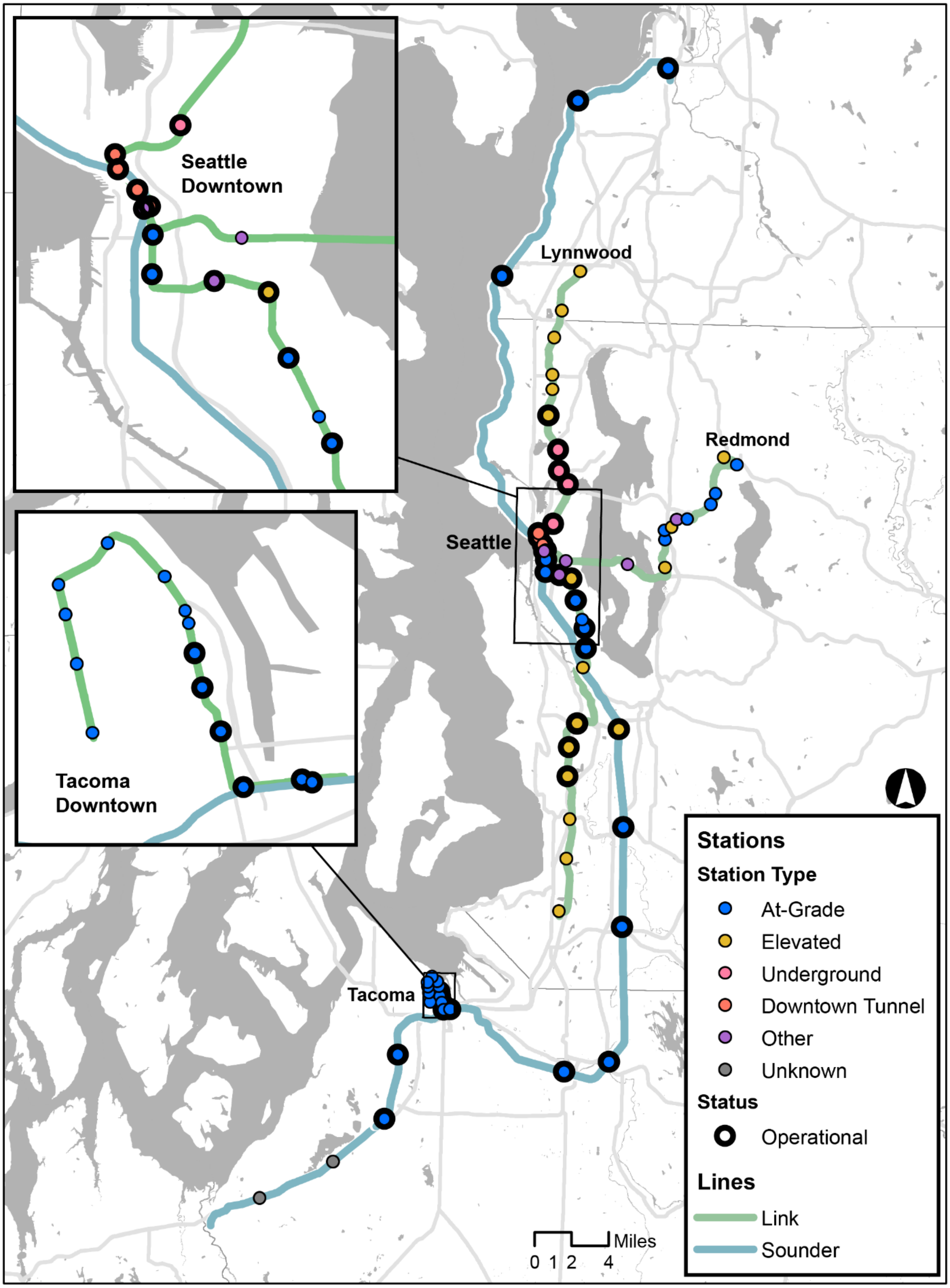
All stations in operation or under construction are shown by station type on the following page (Figure 13). Stations classified as "Other" are below grade (such as King Street Sounder Station), either wholly or partially, due to topography.

There are 69 Link and Sounder stations, 39 operational, 26 in construction, and 6 planned (Table 4). As described above, at-grade stations are by the far the most common station type. While there are several underground stations currently in operation, there are none in construction or planned, meaning that elevated stations will be the second-most common once those under construction or in planning are completed.

Table 4 Link and Sounder Stations by Type and Status

Station Type	Operational	In Construction	Planned	Total
Elevated	6	10	5	**21**
At-Grade	21	13	1	**35**
Underground	9	0	0	**9**
Other	1	3	0	**4**
Total	**37**	**26**	**6**	**69**

Figure 13 Stations by Type (Operational and In-Construction)



1.1.4 System Expansion

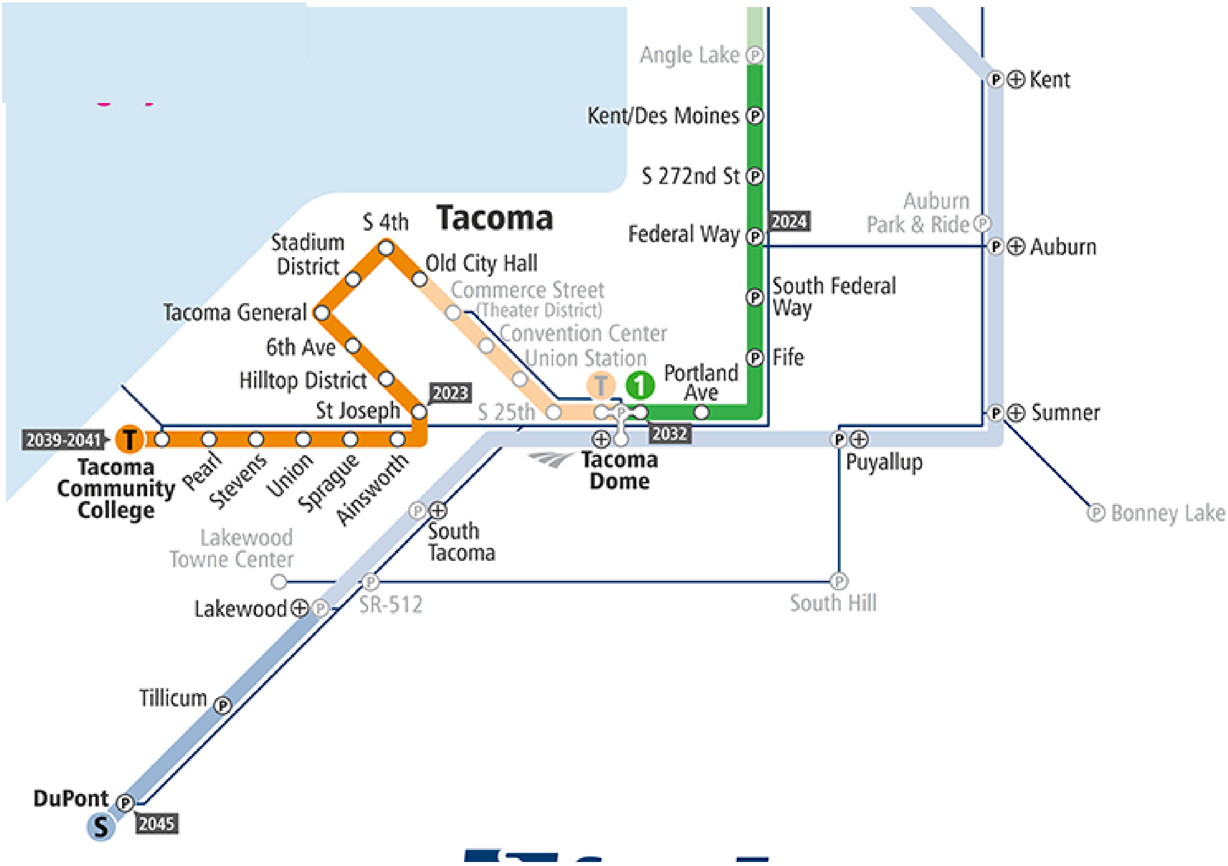
With the passage of ST2 (the predecessor bond referendum to ST3) and ST3, Sound Transit has committed to significantly expand the geographic scope of its services. The northern part of the system is envisioned to have light rail extending north to Everett, east to Redmond and Issaquah, and west to Alaska Junction (Figure 14). In addition to the rail expansions shown on the next page, there are also plans for bus rapid transit lines from Lynnwood to Redmond and Shoreline to Bothell.

Figure 14 System Expansion - North

Source: Sound Transit

There are also plans to expand the system further south. Link will extend from Federal Way to Tacoma Dome, and the Sounder would extend to Dupont (Figure 15).

Figure 15 System Expansion - South



Source: Sound Transit

Sound Transit plans to build these extensions over the coming decades. As of October 2022, stations currently in design assume proof of payment as the fare compliance mechanism and thus do not incorporate fare gates. It is possible that some stations planned for construction further out in the future could be designed to accommodate fare gates, should Sound Transit decide to begin implementing them.

1.2 Fare Collection Technology

Sound Transit has transitioned from Scheidt & Bachmann to INIT as their fare system vendor for the ORCA card, a tap payment card that is used by Sound Transit as well as local bus service providers. ORCA cards are accepted across modes with a base card cost of $3. Numerous discounts are available to customers, including the ORCA Lift program for low-income riders; discounted fares for seniors and people with qualifying disabilities; and free rides for youth 18 and under. Customers can add money onto the ORCA card online or at ticket vending machines located at the stations.

Use of the Bytemark's Transit GO Ticket mobile app allows fare payment on a smart phone; the app uses visual inspection to confirm that the fare has been paid. While fare payment is typically done through credit card or other digital payment method, there is also the option to add cash to an account at local retailers. However, it is anticipated that this fare medium will be phased out at Sound Transit.

Finally, one-way or all day/round trip tickets are available through ticket vending machines (TVMs). TVMs accept cash, credit, and debit cards and are located at all Link and Sounder stations.

2.0 Peer Agency Review

This section provides an overview of how eight peer systems use barriers and barrier-free zones to control for fare evasion at transit stations (Table 5). Interviews were conducted between June and July of 2022.

Table 5 Agencies Contacted during Peer System Research

Agency	Location	Fare Gate Status
Regional Transportation District (RTD)	Denver, Colorado	Plan to install fare gates at their primary downtown station
Los Angeles County Metropolitan Transportation Authority (LA Metro)	Los Angeles, California	Currently in use at some stations (elevated and underground station platforms)
Metro St. Louis	St. Louis, Missouri	Currently open system without gates; Plan to retrofit all stations with fare gates
Massachusetts Bay Transportation Authority (MBTA)*	Boston, Massachusetts	Currently in use
Bay Area Rapid Transit (BART)	San Francisco Bay Area, California	Currently in use, seeking to “harden” or upgrade gates
San Francisco Municipal Transportation Agency (SFMTA)	San Francisco, California	Currently in use
TransLink	Vancouver, B.C.	Retrofitted a completely open system with fare gates
Tri-County Metropolitan Transportation (TriMet)	Portland, Oregon	Not in use, but studied at one platform

*MBTA was not able to engage in our questionnaire, but publicly available information was added to this report.

Research was conducted on previous studies, supplemental board reports, and project specifications to provide a more complete picture on the costs and benefits of fare gating systems.

This section covers the following content:

- **Overall Agency Perceptions of Fare Gates** – Overarching benefits, challenges, and customer experience considerations for installing fare gates.
- **Operational and Design Considerations** – An overview of the different types of barriers and fare gates used by agencies and design considerations for installing these gates.
- **Capital and Operating Costs** – Information about the cost of installing and maintaining fare gate systems.
- **Fare Evasion at Stations** – Fare evasion statistics and considerations.

2.1 Overall Agency Perceptions of Fare Gates

The agencies surveyed for this project range from completely closed rail systems (e.g., BART, with fare gates in operation at all stations) to completely open systems (e.g., TriMet, where payment is required but not enforced by physical barriers). As of October 2022, two agencies (RTD and Metro St. Louis) were in the early phases of installing gating systems at some or all of their stations and one agency (Translink) had migrated from an open system to a completely closed system. In addition, one agency is operating a mix of open and closed stations (LA Metro).

As a result, the agencies ranged in perspective about the benefits and challenges of having fare gates. This section provides an overview of the major themes that emerged from these conversations.

2.1.1 Purpose of Fare Gates

At the most basic level, fare gates regulate access to station platforms or paid fare zones. They are intended to collect fare payment, reduce the amount of loitering at stations, assist in regulating flow of passengers onto platforms, and allow transit agencies to collect ridership data.

Interviewees noted that these physical barriers are not impenetrable. Riders who seek to evade fare payment do so by jumping gates, tailgating (following someone inside), pushing gates open, and entering through emergency exit zones. Examples of different types of fare gates are shown in Table 6 found in Section 2.2.

2.1.2 Benefits of Fare Gates

Fare gates are a way to collect fare payment and ridership data. According to the transit agencies interviewed, the main benefits of installing and operating fare gates include:

- **Reducing fare evasion.** Fare gates increase revenue collection by minimizing entry of non-paying passengers.
- **Data collection.** Fare gates help agencies collect more accurate ridership data that allows for better planning of service.
- **Creating a more efficient and secure system**. Physical gates help regulate the flow of customers onto the system, which is especially helpful at stations near event venues that experience crowd surges. Fare gates can also enhance security when installed in a way that does not reduce visibility.
- **Reducing conflict with customers.** Fare gates are a passive way for the agency to enforce fare payment. In addition, physical barriers remove a potential conflict point between agency staff and customers since the machine is performing the fare enforcement activities.
- **Keeping non-riders out of stations.** Some agencies felt their fare gates helped prevent non-riders from accessing and loitering in station areas. Opinion on this topic was mixed with other agencies asserting that non-riders can find a way to get past the gates.

2.1.3 Challenges of Fare Gates

Agencies also cited challenges of fare gates including expense of installation, operation, and maintenance. Other issues are split into two categories: **general challenges** of operations and maintenance and **specific challenges** for retrofitting existing stations with fare gates.

From a transit agency's perspective, **general challenges** of installing and operating fare gates include:

- **Capital and operating costs.** Cost to purchase, install, and maintain fare gates may exceed additional fares collected as compared to proof-of-payment systems.
- **Maintenance response times.** Any gate that is not functioning can prevent people from accessing transit services and disrupt their journeys. Ensuring a smooth customer experience means any gate that is broken must be quickly repaired.
- **Inconvenience to customers.** Physical barriers can lead to slower throughput of customers (especially during peak hours) and make it more cumbersome for people with strollers, groceries, bikes, wheelchairs, and other mobility devices to access the station platform.
- **Customer support**. Additional operational and capital costs are incurred providing customer support in the event of technical difficulties (e.g., a call button for when gates are not operating correctly and/or customers are confused about how to use fare payment equipment). More details on the cost implications for providing customer support can be found in Section 3.

From a transit agency's perspective, **specific challenges** of retrofitting stations with fare gates include:

- **Space requirements.** Fare gates take up additional space and impact egress requirements. Stations that were not designed with fare gates in mind may not have sufficient space for fare equipment and expected passenger movement needs, including ADA space requirements. These constraints may be particularly challenging for stations directly abutting sidewalks, roadways, and connected to pedestrian and bike bridges.
- **Hard-to-estimate costs.** Installation processes may vary station to station, and may necessitate additional utilities to support the fare gates. Existing stations – especially older existing stations – have more unknowns about their as-built conditions and less flexibility in fare gate design and placement. Utilities availability, structural elements, and state-of-good-repair issues are all more uncertain for retrofitting stations compared to designing new stations, and therefore complicate cost estimation.
- **An imperfect solution.** Installing fare gates may make it harder for people to evade fares, but will not stop all fare evasion and crime on the system. This may create a cycle of constantly trying to retrofit stations with new fare gates or 'harden' the system as people find new innovative ways to evade paying fares. For example, BART has had fare gates since its inception but continues to upgrade their gating system in order to reduce fare evasion.

2.1.4 Customer Experience Perspective

Ensuring a smooth customer experience is important when installing new (or upgrading existing) fare gates. Clear communication and user testing can help avoid rider frustration around gates (see sidebar on LA Metro's Tap Lab). Things to consider from a customer experience perspective include:

- **Wayfinding.** Installation of fare gates should come with wayfinding and signage that explains how to use them and what to do in the event of issues.

- **Consistent design.** Installing fare gates in a similar area at all stations can avoid user confusion about how to access the station area. A confusing example is LA Metro's 7th Street / Metro Center station; there are secondary fare payment consoles inside the paid area for people transferring from one train to another. The location of these devices leads many customers tap their fare payment twice after entering the 7th & Metro station and prior to boarding a train. While they do not pay more, it does create ridership data collection challenges for LA Metro.
- **Marketing.** Agencies should treat installing fare gates like a service change and allow for ample time to raise awareness and prepare customers to ride successfully.
- **Logistics.** Having fare gates adds a level of complexity to one-time events like free-fare days.
- **Safety.** People can run into some fare gates (like turnstiles) expecting them to spin and hurt themselves in the process.
- **Physical appearance.** The visual condition of fare gates can reflect negatively on transit agencies if they appear damaged, are covered in graffiti, or work poorly. Fare gates should be designed to be durable and able to sustain regular use and abuse without showing wear and tear.

LA METRO: TAP LAB

To help ensure a smooth customer experience with fare payment, LA Metro operates and maintains an in-house lab where they can test how fare gates are working.

This lab includes every type of fare gate and payment station in use. This allows them to test fare payment software updates before releasing them to the public to minimize service disruption and enhance the customer experience.

- **ADA accessibility.** The payment process, physical passage through the fare gates, and calling for technical assistance should be accessible to passengers of all abilities. Examples of accessible services are detailed in Section 2 under "Station/Barrier Selection and Sizing Methodologies"

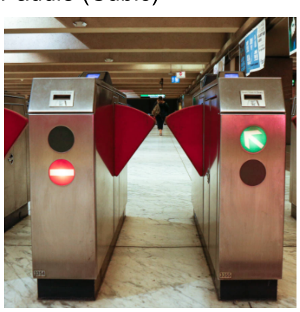
2.2 Operational and Design Considerations

Selecting the ideal type and size of fare gate is crucial. This section presents a summary of the fare gates used by each agency and important factors that influence the design process.

2.2.1 Types of Barrier or Fare Gates Used

Types of fare gates varied across agencies (Table 6). However, station technology and utility needs were similar and include: power to support the gates, network connectivity to communicate with the ticket validation system and unlock gates, resistance to the environmental conditions, and power and network redundancy to reduce disruption of service in case of failure.

Table 6 Fare Gates used by Agencies Interviewed

Agency	Type of Fare Gates used (Vendor)	Fare Media accepted
Metro St. Louis*	Full height turnstiles (Hayward Turnstiles) 	Closed loop[6] fare media – Gateway card, paper passes
LA Metro	Turnstile (Cubic) 	Closed loop fare media – mobile app via Apple and Android/Google payment and TAP card
Translink	Paddle (Cubic) 	Closed loop fare media – Compass Card/Ticket Open loop fare media – Contactless credit card or virtual cards provisioned in mobile wallet
BART	Paddle (Cubic) 	Closed loop fare media – mobile app via Apple and Android/Google payment and Clipper card

[6] Closed Loop fare payments are smart cards (like TAP, Clipper, ORCA) that can only be used to pay on the transit agency's private ticketing system.

Agency	Type of Fare Gates used (Vendor)	Fare Media accepted
SFMTA (MUNI)	Paddle (Cubic) 	Closed loop fare media – Clipper Card, MuniMobile App, Muni Ticket
MBTA	Paddle (Cubic) 	Closed loop fare media – CharlieCard, CharlieTicket, mTicket app

*Still in the process of procurement, actual fare gate may differ.

2.2.2 Station/Barrier Selection and Sizing Methodologies

Suitable barrier selection and sizing varies with station type and existing street geometry. Nevertheless, there are a few common considerations and regulatory standards noted by the agencies interviewed when addressing fare gate sizing and design. These align with the design considerations that Sound Transit uses when building stations as noted in the Existing Conditions section:

- **CPTED.** Crime Prevention Through Environmental Design (CPTED) is a multi-disciplinary approach of crime prevention that uses urban and architectural design and the management of built and natural environments. CPTED strategies aim to reduce victimization, deter offender decisions that precede criminal acts, and build a sense of community among inhabitants so they can gain territorial control of areas, reduce crime, and minimize fear of crime. A CPTED screen of fare gates would consider things like line of sight. For example, opaque paddle barriers could create blind corners, hindering law enforcement response to a potential threat. In contrast, turnstile barriers are visually permeable and do not impede line of sight.

Agencies have enlisted the assistance of local law enforcement in the design process to implement CPTED design considerations. The American Public Transit Association published *Crime Prevention Through*

Environmental Design (CPTED) for Transit Facilities[7], which lays out principles for deterring criminal activity through careful design. Those include:

- **Natural Surveillance** – Bringing as much of the public space into open view as possible to deter criminal activity.
- **Natural Access Control** – Creating barriers between public and restricted areas.
- **Territoriality** – Clearly delineating public spaces and restricted areas.
- **Activity Support** – Encouraging permitted uses of public space to crowd out and discourage criminal activity.
- **Maintenance** – Consistent care and upkeep of the space to show ownership and discourage unsanctioned activities.

- **Fire and Life Safety Requirements.** The National Fire Protection Association (NFPA) has specified NFPA 130 as the Standard for Fixed Guideway Transit and Passenger Rail Systems. It requires that passengers on the platform and in vehicles can evacuate in a timely manner. Designers must determine the occupant load on the transit vehicle and on the station platform, the egress capacity at egress points including ramps, escalators, elevators and fare barriers, and the evacuation time from the platform and the station.

Fare barriers have additional requirements that must be met to be allowed in the means of egress. For a fare barrier to be allowed in the means of egress, it must either be designed to release in the direction of travel during an emergency or be able to open by providing 15 pounds (or 66 Newtons) of force in the egress direction. To meet the NFPA 130 requirements, the occupant load must be able to evacuate from the platform in under 4 minutes, and be able to evacuate from the station and reach a point of safety in under 6 minutes. There is also a requirement that the travel distance is 100 meters or less.

- **ADA Accessibility.** The Americans with Disabilities Act (ADA) requires public and private transportation services to follow accessibility guidelines that accommodate passengers with disabilities. Thus, many agencies have two types of gates at a station – standard fare gates and accessible fare gates, which are wider to accommodate entry for wheelchair users. In the LA Metro system, button-activated gate intercoms were installed to assist users who encountered technical difficulties, which also required a hands-free sensor for accessibility that activates the intercom when a passenger stands next to it for a few seconds.

  Stations retrofitted with fare gates may have newly installed conduit providing electrical service to the gates. Stations must maintain a smooth surface for people using mobility devices and, where there are any inclines or declines in the floor grade, tactile strips must be installed to provide warning. The gates themselves must be compliant with ADA Standards for Accessible Design, such as a 48-inch minimum width.

- **Appearance.** Physical barriers may appear unfriendly and uninviting to potential passengers, deterring use and adoption. In particular, full height turnstiles may seem especially unfriendly to a typical user. The inherent visual cues of a type of fare gate may also cause customer confusion. For example, while

[7] Found at https://www.apta.com/wp-content/uploads/APTA-SS-SIS-RP-007-10_Rev1.pdf

paddle gates show clear signs of whether passage is permitted, turnstile gates in the locked and unlocked states look identical. Thus, when an agency has fare-free days for special events, riders may see the turnstiles as locked and get confused or deterred. On the other hand, fare gates that are too accommodating may enable fare evasion tactics such as tailgating.

2.3 Capital and Operating Costs

As the benefits and challenges section indicates, installing and maintaining fare gates include a range of capital and operating costs. Agencies were asked about the major components that would impact the cost of retroactively installing fare gates. This section provides a summary of these costs broken out by capital and operating costs. Example budgets from different agencies are shown at the end of the section.

Capital costs:

- **Design.** A team is required to design the retrofit for each station, ensuring that the design regulations are met and take into account the aforementioned methodologies. This may be an extensive iterative process if other offices such as civil rights, maintenance, passenger experience, or law enforcement are involved in the design.

- **Construction.** Labor and materials costs vary depending on the region, design, location, and complexity of the project.

- **Canopies for fare gates.** Protection from the elements is needed to minimize disruption to service, increase passenger comfort, and protect the gate assets.

- **CCTV upgrades.** Agencies may opt to install Closed-Circuit Television (CCTV) upgrades, especially if safety and fare evasion are concerns, which would increase complexity and require additional funding for procurement, installation, and monitoring.

- **Additional fencing.** Fencing may be necessary to ensure that the only entry and exit points to the transit system are at the fare gates, otherwise fare evasion may persist, and safety issues may arise if fare evaders walk on the trackway. St. Louis Metro noted that fencing was an unexpectedly large cost, especially when transforming an open system into a closed system.

- **Integration with fare payment systems.** Fare gate vendors may charge a premium to integrate with third party vendor payment systems. It is thus important to consider this when assessing proposals.

- **Facilities for staff assisting at gates.** If staff are stationed at fare gates, they may require the construction of service booths or additional restrooms. If this staff is available over intercom, that system must be installed and made accessible (including things like braille and appropriate height placement).

Operating costs:

- **Utilities.** Gates and validators require a constant power supply and network connection to function, adding to daily operating costs.

- **Maintenance.** Timely maintenance and repair are needed to ensure the system will provide continuous service.

- **Staffing for customer assistance at gates.** Assistance must be provided for any technical difficulties associated with the fare gates so that riders can still enter and exit the system. This could include staff at stations or call-center staff located off site (and the cost of the intercom system required to accommodate this).

2.3.1 Example Costs and Construction Timelines from Agencies

This section details financial information gathered from agency interviews. While these numbers provide useful information about the costs to purchase, install, and operate fare gates, many local factors influence costs including existing conditions at stations, labor costs, union contracts, and supply.

TransLink

The cost to upgrade all 53 stations was $195 million in 2012 dollars. The contract was awarded in 2010 and the first fare gate was installed in August 2012. The pilot run started in 2013, with a full launch in 2016. TransLink plans to spend $216.3 million later this decade on a substantial overhaul of the fare card system to increase its capacity and be able to support distance-based fares and other features.

St. Louis Metro

St. Louis Metro is upgrading all 38 of their stations at a $52 million project cost, $6.2 million of which is CCTV camera upgrades. They received $10.7 million in private funding from local business groups. The construction timeline is 24 months, with plans to upgrade station by station and provide bridge service via bus when stations are closed. Every station has a slightly different cost. The fixed costs that are consistent across all stations include the unit costs for turnstiles, turnstile shelters, and signage. Variable costs include new concrete (priced per square foot), decorative and chain-link fencing (cost varies by height and length), and utility upgrades (priced per linear foot).

The community is concerned about safety on the system, which was designed to be open. The St. Louis Metro oversight board (St. Louis Metro is run by Bi-State Development and governed by its Board of Commissioners) has directed staff to install fare gates throughout the system to make it completely closed – including fencing, tall turnstile gates, and CCTV upgrades. The agency has been able to secure additional private funds from the business community to complete this work, who expect that these upgrades will make the city a more attractive place to work and commute.

The agency is still in the process of procurement for retrofitting the system. As of the most recent correspondence with St. Louis Metro, the bids for the project came in “significantly higher” than the estimated $52 million cost, but no further details were forthcoming on cost.

RTD

RTD has allocated a budget of $10 to $15 million to create a fare-secured perimeter in the Denver Union Station bus transfer facility. This safety upgrade includes upgraded lighting, TV monitors with security camera feeds, barriers to restrict access to permitted entryways, smoke detectors in restrooms, turnstiles, and exit gates. Construction will take place in three phases varying from six months to three years. No impact to service is anticipated.

RTD is installing fare gates, upgraded lighting, and TV monitors at their main downtown central station, Union Station, to increase safety and deter loitering in the station. RTD is also working in tandem with local housing groups to address this issue.

BART

The BART Station Hardening Project is estimated to cost $90 million systemwide, which includes 50 stations and over 700 individual fare gates. This covers the installation of pneumatic swing gates to replace the existing paddle gates, which are expected to be more effective against fare evasion.

SFMTA

SFMTA replaced existing fare gates and installed new Ticket Vending Machines at all entry points at their Light Rail stations. The biggest driver of cost was the procurement, engineering, and testing of the equipment. Additionally, stations located outside of the underground subway in the open air required additional measures to protect the equipment from the elements, which made them more expensive to retrofit.

An expedited installation took approximately 18 months from planning to installation. Impact to service was limited by working on one bank at a time and leaving the others at the station in service. Ongoing maintenance costs are approximately $1.2 million per year.

LA Metro

LA Metro retrofitted all subway stations and select above-ground stations with 387 turnstiles for a cost of $46 million in 2010.[8] They were installed without being locked for two to three years so customers could acclimate to them (fare gates were latched for fare payment in 2013). They have included fare gates at new stations where feasible (underground and elevated stations typically have fare gates, but most at-grade stations do not). They estimate the cost of maintaining their current fare gates is about $20 million per year. A recent board report shows it would cost $9 million in construction costs and $157,000 in maintenance for installing fare gates at four stations.

From Metro's point of view, the cost of gates was not always worth the fares they collect. While not anti-gate, if a new station would be cost-prohibitive to build by including fare gates, the agency defaults to excluding gates. For example, they have added gates at elevated and underground platforms, but when it comes to at-grade stations they would rather fit a station into the existing right-of-way than spend the money and political capital to get the space needed to include fare gates.

2.3.2 Fare Evasion at Stations

Fare evasion occurs when a transit rider either does not pay for their ride or underpays for a ride. Physical fare gates are one way to deter fare evasion. Agencies had a different approaches to fare gates and fare evasion (Table 7). In some cases, installing fare gates was more about system security than improving revenue.

[8] LA Times. 2009. "Through the Turnstile and onto the Train" https://www.latimes.com/archives/la-xpm-2009-aug-17-me-turnstiles17-story.html

Table 7 Survey of Agency Fare Evasion Information

Agency	Fare Evasion Comments
Metro St. Louis	Planning to track fare evasion statistics after installation. Agency is more concerned with reducing other crime and improving perceptions of public safety.
LA Metro	After installing latched fare payment gates Metro noticed an immediate increase in fare payment on rail lines, fewer rail riders, and more “no fare” tabulations on parallel bus lines.
Translink	Fare evasion was 6.54 percent prior to installation. Agency staff says fare evasion has decreased since installation of gates, but they have not conducted an official survey.
BART	In 2019 BART estimated fare evasion at around $15 – 25 Million, or 5 percent of riders annually[9].
MUNI	SFMTA experimented with the automatic closure timing to ensure that customers could successfully pass-through, but also prevent tailgating.
TriMet	TriMet conducted an equity analysis of their fare enforcement policy in 2018. This report found approximately 16.6 percent of riders evade paying fares on their completely open system (but no evidence of systemic racial bias in the enforcement)[10].

[9] https://www.sfchronicle.com/bayarea/article/BART-official-5-of-riders-cheat-fares-not-15-14048946.php

[10] https://news.trimet.org/2018/08/independent-analysis-once-again-finds-no-systemic-racial-bias-in-trimet-fare-enforcement/

3.0 Fare Gate Technology Review

The purpose of this section is to provide an overview of fourteen fare gate vendors and their product offerings (including Sound Transit's current vendor, INIT). Four vendors were interviewed, with supplemental research conducted on the remaining ten (Table 8).

Table 8 Fare Gate Vendors Interviewed and Researched

Vendors		Key Clients
Interviewed	Scheidt & Bachmann	• CDOT, MTA Maryland
	Hayward Turnstiles	• SEPTA, NYCMTA
	Gunnebo	• Calgary, Montreal, Mexico City, many South American and Asian cities, Sweden ferry terminals, Disney Europe
	Cubic *(Vendor used by most peer agencies interviewed in Memo 2)*	• LA Metro, Translink, BART, SFMTA, MBTA, London
Researched	Conduent	• SEPTA
	Mikroelectronika	• Various major international cities: Santiago De Chile, Lagos
	Straffic	• WMATA, Seoul Metro
	INIT *(Sound Transit's Current Vendor)*	• Sound Transit, OCTA
	Thales	• Singapore's MRT Lines
	Indra	• Shanghai Metro, Cairo Metro, RENFE, Metro St. Louis, Brussels Metro
	Nippon Signal	• Not collected
	Omron	• Not collected
	Shanghai Humaing Intelligent Terminal Equipment	• Not collected
	Singapore Technologies Electronics	• Not collected

The purpose of these interviews was to understand product offerings, technical specifications, cost considerations, passenger throughput, maintenance and life cycle parameters, fare validation systems, and data management and reporting. In general the interviews were focused around ten topics:

1. Physical barrier types of product offerings
2. Fare collection and fare media
3. Passenger throughput metrics
4. Technical specifications

5. Use case recommendations
6. Installation timeline considerations
7. Installation process
8. Environmental considerations
9. Useful life benchmarks
10. Cost considerations

This section covers the following content:

- **Key Findings from Vendors.** The most important takeaways from initial research, interviews, and follow-up correspondence; also highlights topics for later research.
- **Overview of Product Offerings.** Summary of physical barrier types, fare collection, fare validation systems, fare media, and data management and reporting provided by vendors.
- **Installation and Design Considerations.** Overview of installation process, timelines, passenger throughput metrics, and technical specifications needed for fare gates.
- **Cost Considerations.** Key takeaways on costs of installation and operations, including useful life benchmarks.

3.1 Overview and Key Takeaways from Vendors

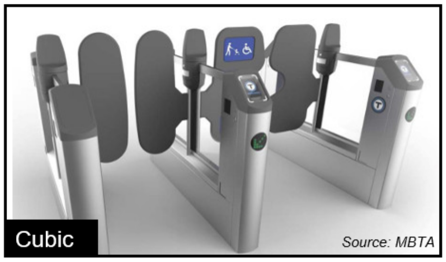
A few consistent themes arose throughout the interviews. Notably, all vendors were hesitant to commit to specifics about costs, installation, and maintenance requirements, as they felt that it was extremely context dependent.

3.1.1 Product Offerings are Similar Between Vendors

All vendors have a variety of ADA-accessible product offerings and can be integrated with any third-party fare payment system (Figure 16). Some vendors provide an option for turn-key installation, with fully integrated software and payment systems (Cubic, Scheidt & Bachmann); others simply make the gates and partner with third-party fare collection companies (Gunnebo, Hayward Turnstiles).

Choosing different product types best suited to different station typologies is a possibility and vendors did not emphasize scale factors of costing such as numbers of units purchased of a single product type.

Figure 16 Example Fare Gate Products


Cubic
Source: MBTA


Hayward Turnstiles


Scheidt & Bachmann


Gunnebo

3.1.2 Installation and Design is Fairly Straightforward but Project-specific

The vendors interviewed were hesitant to provide timelines and firm input on what is required during installation since specifics depend on the station location and existing conditions. The two vendors who typically oversee installation (Cubic, Scheidt & Bachmann) suggested that key things to consider during installation are utility wiring installation (and any ADA impacts from newly installed floor conduit), passenger impacts, and station typology. More information on this is found in Section 3.3.

3.1.3 Costs Vary Widely

All vendors were reluctant to quote specific prices for gates and installation but noted that costs vary by station typology. While they did not provide specific price quotes, fare gate units ranged in cost from $10,000 on the low end for older model turnstile gates without integrated fare media/fare validation to $50,000 on the higher end for modern paddle gates with integrated fare validation systems.

Fare gate useful life ranges from 10 to 15 years (mechanical components will typically need to be replaced) and maintenance costs also depend on the quality of the fare gate installed. For example, waterproof fare gates require less maintenance when exposed to all-weather conditions (but may not be needed at indoor stations). More information on this is found in Section 3.4.

3.1.4 Key Takeaways

The most relevant takeaways from these vendor interviews for Sound Transit's current project include:

- Installation costs are the primary driver of cost, rather than the back-end infrastructure or the fare gates themselves;

- Costs are highly dependent on the station context, and high-level estimates are difficult to do;
- While the vendors can install the fare gates, they may not necessarily install accompanying barriers elsewhere to make the fare gates effective; agencies may need to coordinate that separately; and
- All of the vendors indicated their gates were compatible with third party fare collection systems.

3.1.5 Areas for future research

Further research is needed to determine fencing needs and cost estimates for Sound Transit stations. Station typology and layout will result in a diversity of fencing or other barrier needs. Additionally, localized labor costs in the Seattle area may drive installation costs higher or lower than peer agencies that have undertaken similar projects. Sound Transit will need to do detailed analysis of individual stations representative for each typology (at-grade, elevated, underground) to develop context-specific requirements of fencing, number of gates, ADA- and elevator-related needs, and installation/retrofit costs of existing infrastructure.

3.2 Overview of Product Offerings

3.2.1 Physical Barrier Types and Product Offerings

The vendors interviewed provide a variety of physical barrier types. These range from waist-high turnstiles to full-height swing gates and generally fall into three categories: wing gates, swing (or paddle) gates, and turnstiles (Figure 17).

Figure 17 Example Fare Gates from Hayward Turnstiles

Source: Hayward Turnstiles

- **Wing gates** have two arms that protrude into the gate area and retract when a fare payment is made. The wings can be made of a variety of materials, some stronger than others.
- **Swing gates,** also called paddle gates, have two door-like barriers that swing open when fare payment is made. They can come in a variety of heights and materials.

- **Turnstiles** can range from very simple rotating posts to regulate traffic flow into a venue (for example at a sporting event) to full height rotating array of posts that prevent any entry without payment (see far right example in Figure 17)

Most of these vendors' offerings are limited to the fare gate unit itself, and do not include the surrounding fencing necessary to complete a closed system. Each had a range of fare gate products of various heights and dimensions, though most were moving away from traditional turnstiles and wing-style fare gates to higher paddle-style gates, whether they swing in or across (Table 9).

Table 9 Physical Barrier Product Offerings by Vendor

Vendor	Product Offering
Scheidt & Bachmann	Standard height for gates is 43 inches, but can be changed to specification. Turnstiles are no longer offered (fraud too easy). Pivoting swing gates and sliding wing gates. Sliding gates need cabinet depth half the width of the lane, so pivoting gates are more space efficient and preferred.
Hayward Turnstiles	Steel or powder coated turnstiles (full and waist heights), optical wing-style gates (full and waist heights, example in Figure 17) that automatically open and close and have clear acrylic or glass barrier.
Gunnebo	Swing gates and flap gates. Heights customizable. Sensors for evasions.
Cubic	Various heights, widths available. Swing-in flaps, heights adjustable. As few proprietary parts as possible to make them plug and play interchangeable. Various configurations of fencing (heights, lengths, materials).

3.2.2 Fare Media Integration and Data Management Offerings

Because Sound Transit recently began a contract with INIT as the fare collection vendor, all that is needed in the short-term regarding fare gate installation data interface is integration with the INIT system. In the future, it is possible that Sound Transit could transition to a single integrated fare gate-fare collection system. Many of the vendors have integrated fare collection/fare gate systems.

Those with integrated fare validation systems incorporate multiple forms of modern fare media, from tap cards to phone-based payment systems. Because Sound Transit would likely require a continued option for purchasing individual tickets from TVMs with cash, systems should be able to process tap cards, Near Field Communication (NFC) readers, and paper tickets. Some vendors had bar code reader systems that could process paper tickets, but others were less certain of how they could maintain cash-based single-ticket transaction functionality.

Table 10 Fare Media and Data Management Offerings by Vendor

Vendor	Fare Media and Data Management Offering
Scheidt & Bachmann	Integrated fare payment/fare gates. NFC in the gate itself collects data from cards or phones (better with Android Google Pay than Apple Pay currently). Bar code reader configurable. Tap on/off or entry only. Integrates with validators on buses for transfers. Bar

	code cannot be erased on validation, needs to be serialized. S&B does make TVMs (in USA) or can work with third party TVMs. Data sent from gates to device management. Either interface with data warehouse or handle it inhouse. Data is near real-time.
Hayward Turnstiles	No software. Turnstiles designed to work with other ticketing systems housed in separate physical units. Requires custom integration and special manufacturing for joint mounting.
Gunnebo	Can provide ticket reader, but otherwise no software. Partners with software providers on a case-by-case basis for each bid.
Cubic	Integrated fare gate/fare collection system. Prometheus line is very modular, configurable, updateable, can be integrated with any third-party card reader. Can use Cubic card readers or others. Integrated bar code scanning for paper tickets available, but moving away from this. Data management is integrated with the gating system. Can manage disparate back-office systems. Decoupling of hardware and software possible.

3.3 Installation and Design Considerations

Installation and design were significant drivers of complexity and cost. The vendors did provide general considerations that agencies should be aware of when pursuing fare gate implementation, as described below.

3.3.1 Installation Considerations

The overall size of entryway areas to fence off and/or gate varies by station typology and will impact installation costs. Two vendors (Scheidt & Bachmann and Cubic) typically oversee installation of the fare gates in tandem with local contractors and sub-contractors. From their experience, the following things are important to keep in mind during construction:

- **Wiring.** Installing wiring in the flooring can be a major cost impact.
- **Passenger impacts.** The cost to impede service or shut down stations - depending on the specific construction requirements at the station - and re-route service can be significant.
- **Retrofitting.** When stations are not designed from the start with gates in mind, retrofitting often leads to unexpected design challenges and construction costs (e.g., construction of new overhangs in outdoor stations).

Installation Timelines

The timeline of installing fare gate units, retrofitting the flooring on existing stations, and installing any necessary fencing has many variables, and vendors hesitated to provide timeline estimates (Table 11). In the simplest cases and with a complete shutdown of the station during construction, the installation work could potentially be completed over one week for a given station. More complex cases might entail 4 to 6 weeks for a single station. Usually, the specialized contractors with expertise in fare gate installation do not work in parallel on multiple stations, given their relatively small firm size and limited number of trained and skilled installers. This limits the ability to speed up the overall installation timeline for a network of stations, which is most commonly scheduled one station at a time until the network is completed.

Table 11 Installation Considerations by Vendor

Vendor	Installation Considerations
Scheidt & Bachmann	S&B supervises and trains local install contractors. The need to build wiring into flooring is major cost impact. Alternative is ramps over wiring, but problematic for ADA compliance. Easier in new stations. To minimize passenger impacts, keep closures as short as possible. Fire code/building code compliance. Fastest install 5 days if station is fully closed, longer if need to keep operational. Biggest time constraint/cost is retrofitting existing structures.
Hayward Turnstiles	Handled by third party installers. Hayward is typically the subcontractor to installers.
Gunnebo	Usually software company is prime, Gunnebo is sub, and other install contractors are also subs. Takes weeks to install. 4 to 6 lanes per day per crew. Assumes all wiring is installed, holes are drilled, just for final connections. One station per week is doable.
Cubic	Cubic is typically prime with contract installers. Ramp system for underfoot wiring makes install costs much cheaper and doesn't impede ADA compliance. Typically don't shut down stations and do one side at a time.

3.3.2 Design Considerations

Passenger throughput across devices is consistently around 30-40 passengers per minute in peak operation (all passengers swiping fare media consecutively without waiting for gates to close). All product useful life cycles are rated at 10 to 15 years. All vendors' products are designed to be bi-directional and able to be set for either direction exclusively or two-way operation.

ADA accessibility

All vendors offer special ADA gates that had wider entryways and remained open longer or could be kept open indefinitely. These double as emergency egress options, but also present fare evasion opportunities and fail points for fare collection enforcement.

Utility specifications

All utility requirements are limited to standard electric and internet connections. Generally, these are installed through the floor to reach the units from below.

A large installation and retrofit cost for existing stations includes tearing up existing flooring to embed wiring into or underneath the floor. Some systems transitioning to a closed-loop system simply place plastic/rubber ramps over wiring to protect the wiring without cutting into the existing floor. This is a much cheaper option, but can be a problematic barrier for ADA users (especially wheelchair and blind users) if not installed correctly. In most cases, the wire covering ramp is not a major obstacle for ADA users, but is a complicating factor that makes stations less welcoming. The wire covering ramps also present an aesthetic that may not be desired and another potential maintenance fail point over time.

3.4 Cost Considerations

All vendors were hesitant to provide specific price quotes, but did provide an overview of the things to consider when installing fare gates, including:

- **Fare Gates.** Fare gate units ranged in cost from $10,000 on the low end for older model turnstile gates without integrated fare media/fare validation to $50,000 on the higher end for modern paddle gates with integrated fare validation systems. Vendors emphasized that installation costs might be lower with a single product type chosen for all stations so as to streamline the install process through efficiency.

- **Retrofitting Station Flooring for Wiring**. All vendors acknowledged that civil contractor costs for installation and retrofitting of station flooring would be the majority of costs per station. Fencing needs would vary by individual station design and would add further to the balance of costs beyond just the fare gate units themselves. Some vendors worked closely with preferred installation contractors, while others just sold the fare gate units and were largely removed from the installation process.

- **Station Typology.** The size of entry way areas to fence off and gate varies by station typology and so overall ballpark cost estimates were not forthcoming through these interviews, given the many variables with high ranges of uncertainty.

Cost information gleaned from the vendor interviews are shown below (Table 12).

Table 12 Cost Information provided by Vendors

Vendor	Cost Information
Scheidt & Bachmann	Key factors include: 1) Wiring/flooring (retrofit flooring or ramp overlay). 2) Gate configurations and station layouts, fire codes. 3) How many stations and layouts. 4) Full station closures or maintaining operations during install. (No quotes given for gate costs, but indicated installation is majority of cost.)
Hayward Turnstiles	$10k for simple turnstiles, $30-$40k for ADA gates, $30-$40k for modern wing gates. (Not inclusive of fare card readers.)
Gunnebo	Each lane is about $15k (without software or install). Hardware is a fraction of cost, perhaps only 40 percent, while 60 percent is install costs (not inclusive of necessary fencing materials).
Cubic	No information on gate costs. Biggest variation is civil contractors. Consider room for conduits, distance from platform to communications room. Specific station schematics will affect cost.

3.4.1 Maintenance

Maintenance information focused on environmental considerations (Table 13) and useful life of the fare gate (Table 14) was provided. The main environmental consideration was weather exposure (for example, at an at-grade roadway median station entrance). This is a maintenance concern for all products, as none are designed to withstand direct heavy precipitation. However, most are designed to be resilient to some weather exposure and outdoor operation through the range of seasons if some overhang protection is provided. Indoor installations, such as in underground tunnels, will present fewer maintenance issues.

Table 13 Environmental Considerations by Vendor

Vendor	Environmental Maintenance Considerations
Scheidt & Bachmann	All products are same to streamline maintenance and operations. Not to be used outdoors, rain is a problem. Can withstand incidental spills. Outdoor under covering can be done, even with harsh seasonal variations of conditions, but design is primarily for indoor use. Modular design facilitates ease of replacing parts.
Hayward Turnstiles	Some products are weather rated, but require overhang shelter.
Gunnebo	Waterproof gates can handle any weather. Fully outdoor gates for example at Disney Europe and Sweden ferry terminals. Lifespan not impacted by weather. Upkeep costs of $300-$500/year per lane. Local contractors maintain standard, special cases handled by Gunnebo.
Cubic	Outdoor systems with weather hardening more expensive (new weatherized products in development pipeline). Rain curtains can be installed. No issues with corrosion of physical gates, have worked in field for over 10 years without issue. Electronics and card readers need to be replaced more frequently than the mechanical parts.

Useful life of each of the fare gates ranged from 10 to 15 years (Table 14) depending on use and environment. Another aspect is the ramps that can cover wiring in retrofitted stations, as these may be a potential maintenance fail point over time.

Table 14 Useful Life Benchmarks by Vendor

Vendor	Useful Life Benchmarks
Scheidt & Bachmann	Main chassis of gates last indefinitely. Interior motors good for up to 15 years.
Hayward Turnstiles	10-15 years with proper maintenance.
Gunnebo	10 years for normal use, some go much longer.
Cubic	10+ years. Electronics and readers need to be updated over time.

4.0 Fare Evasion Research

This section provides a review of academic literature on fare evasion, specifically in relation to fare gating and strategies for reducing non-payment activity.

4.1 Fare Evasion Research: Gates and Fencing vs. Fare Enforcement

The academic literature on fare evasion show that fare enforcement programs are not particularly effective compared to fare gates and fencing. However, transition to a closed system is a significant investment that may not recover the cost of installation through increased fare recovery for many years.

Academic research has identified a range of effectiveness for strategies for reducing fare evasion:

- **Infrastructure vs. Personnel:** Infrastructure-based strategies with gates and fencing are found to be more effective than personnel-based fare enforcement programs.[11]
- **Fare Enforcement Effectiveness:** Ramping up fare enforcement programs is found to have no or only modest impacts. Research shows that effectiveness of those programs is especially diminished if the fare enforcement program enhancements are not publicized. Other research shows some modest improvements in fare recovery through enforcement. Some of the findings on this topic include:
  - In New York City, staff presence did not have a significant impact on fare evasion.[12]
  - A scan of 31 transit operators found fare evasion rates to be inversely proportional to the number of fare inspectors.[13] In that broader study, the average fare evasion rate was found to be 4.2 percent. The most effective fare enforcement factors were ticket inspectors, police partnerships, contactless cards, and empowered inspectors.
  - In Flanders, Belgium, ticket price perception and enforcement did impact evasion rates on the margins.[14]
  - In Santiago, Chile, a ten percent increase in fares was found to increase fare evasion by two percent.[15] However, a 100 percent increase in fare enforcement only reduced fare evasion by 0.8 percent.
  - BART estimated that after installing upgraded fare gates, fare evasions fell by 55 - 60 percent.[16]

[11] Wolfgram, Pollan, et al, 2022. https://nap.nationalacademies.org/read/26514/chapter/1
[12] Reddy and Kuhls, 2010. https://journals.sagepub.com/doi/abs/10.3141/2216-10
[13] Bonfatti, Wagenknecht, 2010. https://trid.trb.org/view/915667
[14] Cools, Fabbro, et al, 2018. https://www.sciencedirect.com/science/article/abs/pii/S2213624X17302997
[15] Furst and Harold, 2018. https://repositorio.udd.cl/bitstream/handle/11447/1733/Fare%20evasion%20in%20public%20transport.pdf?sequence=1&isAllowed=y
[16] https://www.bart.gov/about/projects/fare-gate

- **The cost of converting** to an infrastructure-based system of gates and fencing is significant and may take many years to pay for itself. Using basic assumptions on cost per station, one study found the break-even period for retrofitting stations between 7 years for New York City and 63 years for Phoenix.[17]

Fare evasion rates are also found to be related to convenience of paying as well as the control of intermodal transfer stations travelers may be passing through. The lines at ticket vending machines and offering of multiple methods of payment can influence fare evasion rates.[18] Bus stops near gated railway stations are found to have lower fare evasion rates.

In 2022 the National Academy of Sciences released a technical paper on Measuring and Managing Fare Evasion. Chapter 3.12 focuses on capital infrastructure to reduce fare evasion. Relevant information from this chapter echoes the transit operator interviews and includes:

- Fare gates are expensive and cannot stop all fare evasion:
  - Hardening one station with secure fare gates will encourage fare evaders to get on at a less secure station.
  - Vital safety features like emergency exits allow people to evade fares.
- A potentially cost-effective way to minimize fare evasion is gating stations with the highest volume of passengers.
- Making it less complicated to pay fares can increase rider payment. People are more likely to pay fares when it is convenient and easy for them to do so.
- Fare payment equipment reliability is key to success. A broken fare gate is a service failure from a rider perspective.

[17] Freemark, 2009. https://www.thetransportpolitic.com/2009/08/17/are-turnstiles-worth-their-cost/
[18] Wolfgram, Pollan, et al. 2022.

5.0 Fare Gate Scenarios

This section outlines the three scenarios explored in this study and the results of the ROI analysis. The scenarios are compared against the no-build baseline to estimate the return on investment for each build scenario.

5.1 Methodology and Limitations

The findings from the existing conditions assessment, peer research, and vendor interviews were used to develop three distinct build options. A site visit of the different station typologies was conducted to anchor the cost estimates in on-the-ground conditions.

5.1.1 Site Visit and Station Typologies

The site visit revealed considerable variation not only between the three station typologies (elevated, at-grade, and underground), but also within each typology. For example, the Beacon Hill station has only one entrance/exit via elevators and is therefore relatively straightforward to cordon off with fare gates. On the other hand, Westlake has numerous entrances/exits, some of which provide direct access to retail buildings situated above, and would require extensive gating and fencing. In addition, it will be challenging to find acceptable locations in some of Sound Transit's stations given pedestrian safety and egress constraints.

Despite these variations, approximate locations of gates and fencing were identified and fencing perimeter distances were measured. The site visits were used to validate the assessments of fencing and gating needs (even at a high level) by station type, informing the cost estimates used in the ROI analysis.

5.1.2 Peer Research and Vendor Interviews

The peer agency research and vendor interviews informed the cost estimation process. Together, they provided the following key information which was used to estimate costs for each scenario:

- **Total Cost**: Peer agencies that had completed station retrofits were able to provide cost information, with some of the information broken down by specific element (e.g., utilities). This cost information was used to calibrate the assumptions contained within the cost estimation workbook used for this project.
- **Primary Cost Drivers**: Interviewees identified the primary drivers of cost that should be considered. Items such as fencing needs, station closures with replacement shuttle service, and utility hookups were noted as particularly costly.
- **Cost Variability**: All interviewees noted that costs would be heavily dependent on individual station contexts, making generalizations by typology or other attribute difficult. Contingency costs were used to account for the considerable unknown variables.

Assumptions and estimates subject to confirmation by a professional engineering study are denoted in the cost estimation workbook. Changes to these numbers could impact the relative cost and benefits of the individual scenarios, and are explored at the end of this section in the Sensitivity Analysis subsection.

5.1.3 Assumptions

Five assumptions included on the Summary Tab in the workbook were strong drivers in the cost effectiveness of fare gate installations:

- **Annual Discount Rate**: Economists use a discount rate in order to capture the time value of money. It is a generally accepted principle that money today is more valuable than the same amount of money in the future. This is not only because of inflation (which erodes money's value over time) but also because the future is uncertain. Federal guidelines require a 7 percent discount rate for benefit-cost analyses used in grant applications, though a lower discount rate (e.g., 3 percent) will allow up-front capital investments to break even sooner.

- **Fare Gate Payment Rate**: Based on the peer review of other gated systems, a fare evasion rate at gated systems was assumed to be on par with similar gated rail systems. For instance, BART estimates a 5 percent fare evasion rate and Translink estimates a 6.5 percent evasion rate. A fare payment compliance rate of 95 percent was assumed for this analysis.

- **Fare Payment Rates**: The Sound Transit system currently has low fare payment compliance on the main Link system, relatively higher fare payment compliance on the Sounder, and 100 percent fare compliance on the Tacoma Link Line (fare free, paid by the City of Tacoma as of the drafting of this report). A higher no-build fare compliance rate would decrease the value brought by the fare gates and make them harder to justify from a ROI perspective.

- **Contingency**: Given the number of unknown factors that impact total cost, a contingency rate of 35 percent was included. This level of contingency is typical for projects with a high degree of uncertainty, such as budgeting at the conceptual phase of a project. A lower contingency percentage would decrease the capital cost and enhance the business case for installing fare gates (though may understate actual construction costs).

The values used for these assumptions are based on the best current information and/or industry standards and are shown in Table 15. However, changes to these assumptions based on new information or different professional judgment will impact the break-even point of investing in fare gates, as discussed further in the Sensitivity Analysis at the end of this section.

Table 15 Model Assumptions

Assumption	Value
Annual Discount Rate (%)	7.0%
Fare Gate Payment Rate (%)	95%
Existing Link Fare Payment Rate (%)	55%
Existing Sounder Fare Payment Rate (%)	85%
Existing Tacoma Link Fare Payment Rate (%)	100%
Under-Construction Link Fare Payment Rate (%)	55%
Under-Construction Tacoma Link Fare Payment Rate (%)	100%
Construction Contingency %	35%

Additionally, the cost estimates included in this report:

- Use averages by station type to estimate costs rather than detailed engineering and construction estimates;
- Include existing operational stations and stations under construction;
- Reflect costs in nominal 2022 dollars;
- Assume reduced Fare Ambassador Program needs under each scenario proportional to the number of gated stations;
- Assume that gated stations increase fare compliance to 95 percent (or, conversely, reduce fare evasion to 5 percent of boardings), in line with gated peer systems;
- Assume some level of fare gate replacement after 10 years of useful life; and
- Do not consider locally specific pricing, which may increase or decrease the cost relative to peers.

5.2 Scenarios

Three scenarios were created for the ROI analysis:

- **Scenario 1: All Stations** – All Link and Sounder stations (including Link stations under construction) are retrofitted with fare gates. This is the most capital-intensive option, at an estimated cost of over $305 million.
- **Scenario 2: All Link Stations** – All Link stations are retrofitted with fare gates, while Sounder stations remain proof-of-payment. This would require building fare gates at 50 Link stations (including existing stations and those under construction) at a capital cost of approximately $214 million. This scenario assumes the current 85 percent fare compliance rate at Sounder stations.
- **Scenario 3: Top 5 Stations** – The top 5 ridership stations (Capitol Hill, Northgate, University Street, University of Washington, and Westlake) are retrofitted with fare gates. This requires the lowest capital investment at just over $34 million. In this scenario, non-gated Link stations retain their current 55 percent fare compliance rate, and Sounder stations are assumed to keep their current 85 percent fare compliance rate

All three scenarios show a positive return on investment over the 20-year time horizon. However, altering the assumptions or adding updated or refined values into the cost model could result in significantly different outcomes. Nonetheless, the findings described in this section provide order-of-magnitude findings for the three identified scenarios.

5.2.1 Scenarios Findings

The first scenario, "All Stations," has the lowest return on investment. The second scenario, "All Link Stations," has the largest dollar increase in net revenue, while the third scenario, "Top 5 Stations," has the highest return on investment, as shown in Table 16.

Using the assumed 55 percent fare payment rate and looking at just net revenue, adding fare gates across all Link stations (Scenario 2) generates the most new net revenue (over $750 million after 20 years). By year 20, it has netted nearly $400 million more than installing only at the top 5 stations.

However, from a Return on Investment perspective, installing fare gates only at the top 5 stations (Scenario 3) is the best performer with a 12-to-1 return. This is because it has a relatively low capital investment need while still capturing substantial new revenue.

Table 16 Scenarios Summary with 55 Link Percent Fare Payment Rate

	Scenario 1 – All Stations Gated	Scenario 2 - All Link Gated	Scenario 3 - Top 5 Link Gated
# of Current Stations Affected	62	50	5
Total # of Fare Gates Needed	500	341	58
Installation Costs	$305,800,000	$214,000,000	$34,200,000
Annual Operations Costs	$5,000,000	$3,991,000	$3,338,000
Results Under High Ridership			
ROI in 20 years (2043)	227%	381%	1209%
Years to Break Even	6	5	2
Net Revenue vs. No-Build (10 Years)	$183,100,000	$275,400,000	$149,200,000
Net Revenue vs. No-Build (20 Years)	$642,700,000	$754,600,000	$383,400,000
Results with Low Ridership			
ROI in 20 years (2043)	177%	308%	1037%
Years to Break Even	7	5	2
Net Revenue vs. No-Build (10 Years)	$116,100,000	$208,400,000	$128,200,000
Net Revenue vs. No-Build (20 Years)	$501,400,000	$610,700,000	$328,700,000

A significant variable is the fare compliance rate in the no-build scenario. The information provided by Sound Transit indicated that the fare non-payment rate was 31 – 60 percent on Link and 3 – 24 percent on Sounder, and so a fare payment rate of 55 percent and 85 percent were assumed, respectively. If the Link fare payment rate were the same as Sounder at 85 percent, then the incremental gain in revenue from installing fare gates would not support Scenario 1 (All Stations) and would take at least 18 years to pay off in Scenario 2 (All Link Stations). Scenario 3 (Top 5 Stations) has a positive ROI at 8 years after adjusting the fare payment rate upward (Table 17)

Table 17 Analysis with 85 Percent Link Fare Payment Rate

	Scenario 1 – All Stations Gated	Scenario 2 - All Link Gated	Scenario 3 - Top 5 Link Gated
# of Current Stations Affected	62	50	5
Total # of Fare Gates Needed	500	341	58
Installation Costs	$305,800,000	$214,000,000	$34,200,000
Annual Operations Costs	$5,000,000	$3,991,000	$3,338,000
Results Under High Ridership			
ROI in 20 years (2043)	-27%	18%	275%
Years to break even	> 20	18	8
Net Revenue vs. No-Build (10 Years)	-$186,300,000	-$93,900,000	$11,500,000
Net Revenue vs. No-Build (20 Years)	-$76,900,000	$35,000,000	$87,200,000
Results Under Low Ridership			
ROI in 20 years (2043)	-39%	-1%	224%
Years to break even	> 20	> 20	8
Net Revenue vs. No-Build (10 Years)	-$202,800,000	-$110,400,000	$6,300,000
Net Revenue vs. No-Build (20 Years)	-$111,900,000	-$2,500,000	$71,000,000

Using the current assumed fare payment rate of 55 percent on Link, installing fare gates at all stations, including Sounder (Scenario 1), is the worst performing scenario. This is primarily because of the large capital expense of installing gates at stations with relatively low passenger throughput (50 percent more expensive than the cost of installing at all Link stations and ten times as expensive as installing at just the top 5 stations).

Another way to think about the scenarios is through net revenue. While Scenario 3 has the lowest net revenue generation (Figure 18), it still has the highest return on investment of all the scenarios (Figure 19).

Figure 18 Net Revenue – High Ridership

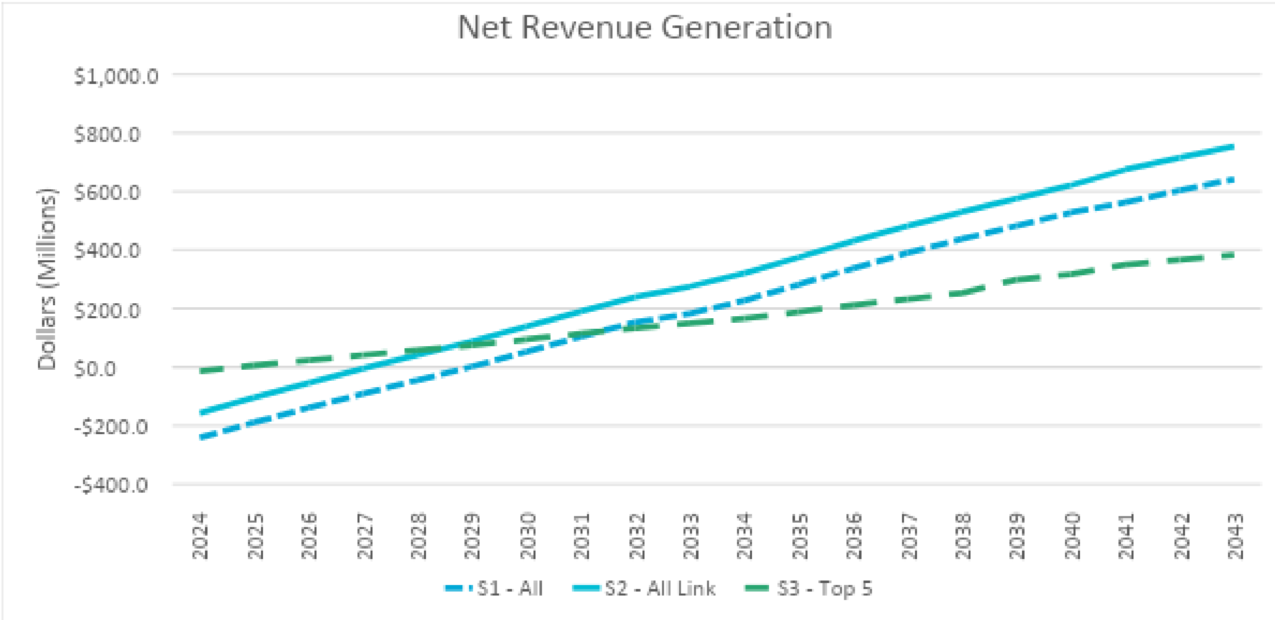


Figure 19 Return on Investment – High Ridership

The main driver for a positive return on investment of installing fare gates is Link's current very low fare payment rate (Figure 20 and Figure 21).

Figure 20 Years to Break Even by Non-Gated Fare Payment Rate - High Ridership

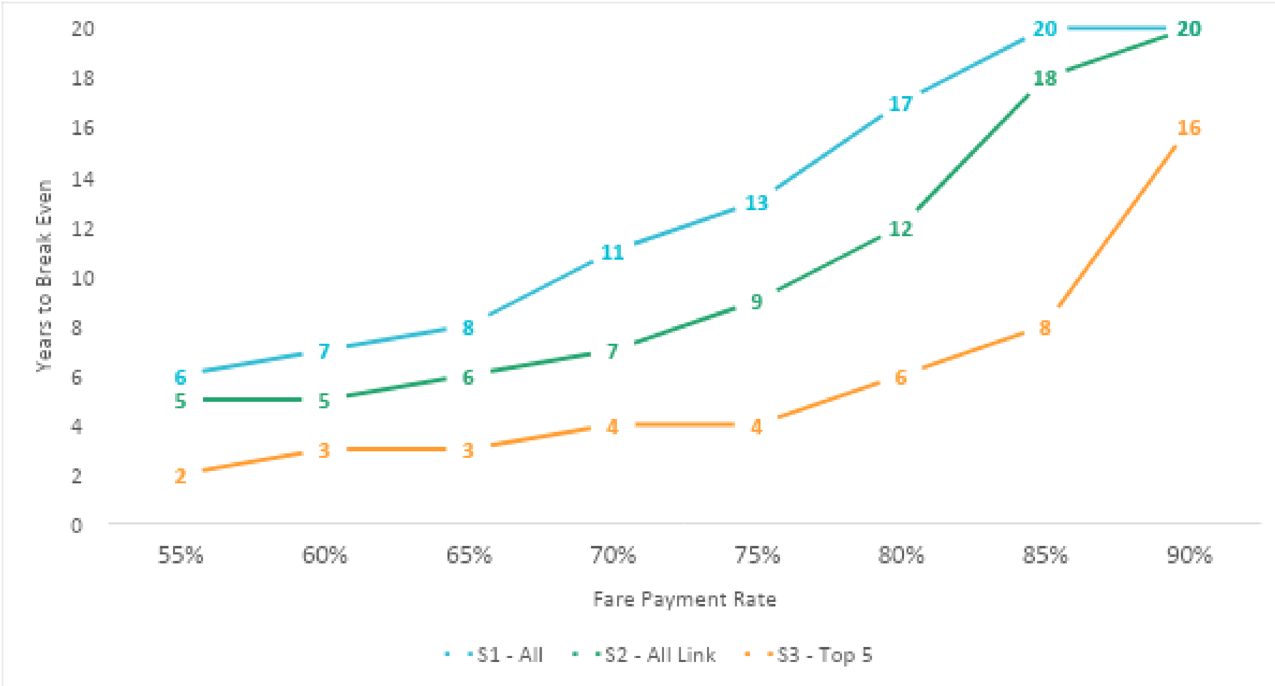
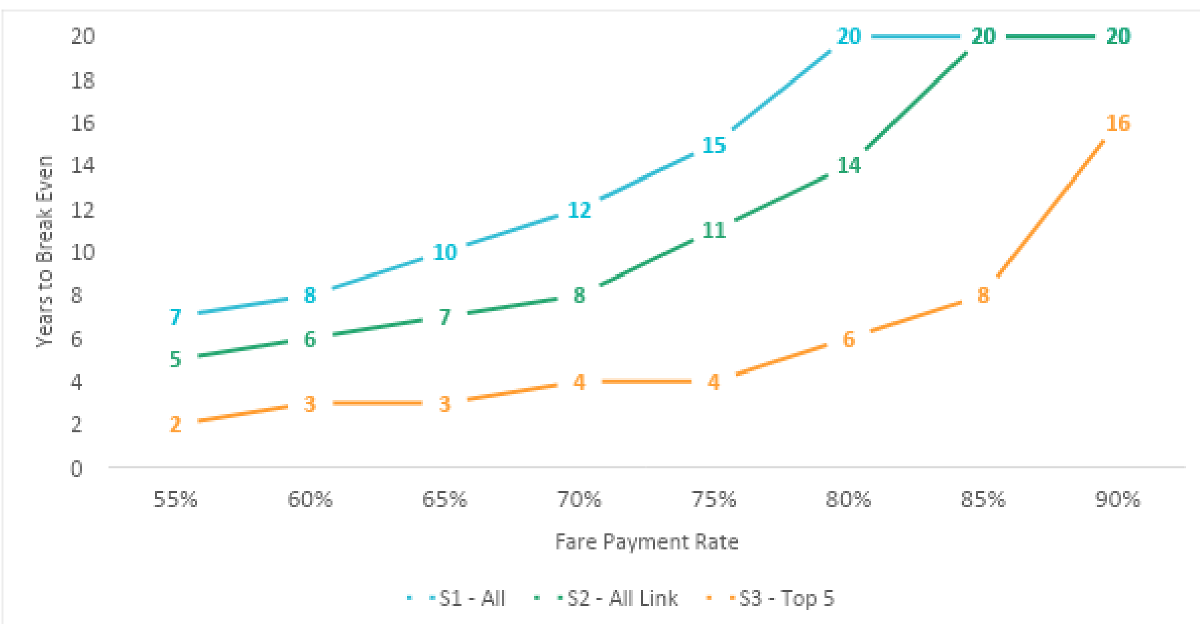


Figure 21 Years to Break Even by Non-Gated Fare Payment Rate - Low Ridership



While beyond the scope of this study, Sound Transit could pursue non-infrastructure approaches to improving fare compliance that are not already being employed, such as innovative public education campaigns, alternative fare ambassador approaches, and other low- or no-capital alternatives. This could be an interim step while fare gates continue being studied.

5.2.2 Scenarios Development

The three scenarios were designed so that they were distinct enough to model meaningfully different investment strategies. Using an iterative approach, the three scenarios described in the previous section were developed:

- **Scenario 1: All Stations** – This approach represents the most capital-intensive option for installing fare gates in the Sound Transit System. It assumes all Link and Sounder stations have fare gates and fencing installed regardless of the ridership levels.
- **Scenario 2: All Link Stations** – The second scenario examines installing fare gates just at Link Stations (existing and under construction) and leaves Sounder Stations as proof of payment. Taking this approach, 50 out of 62 stations have fare gates installed capturing 98 percent of ridership, as shown in Figure 22. The proportion of riders who would pass through gates in this scenario is potentially higher because it does not reflect riders who transfer between Link and Sounder.
- **Scenario 3: Top 5 Stations** – This scenario takes the opposite approach as Scenario 1 and represents the lowest capital investment alternative considered. The top 5 stations by ridership were selected and it was assumed that the fare compliance improvement would only occur at these stations. As seen in Figure 23, the top five stations by ridership comprise nearly half of estimated ridership in 2024.

Figure 22 Ridership Split Between Link and Sounder

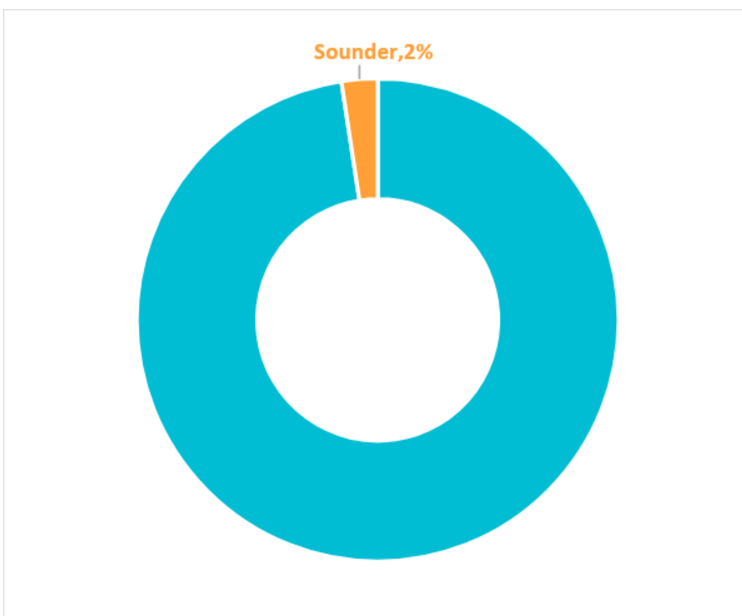
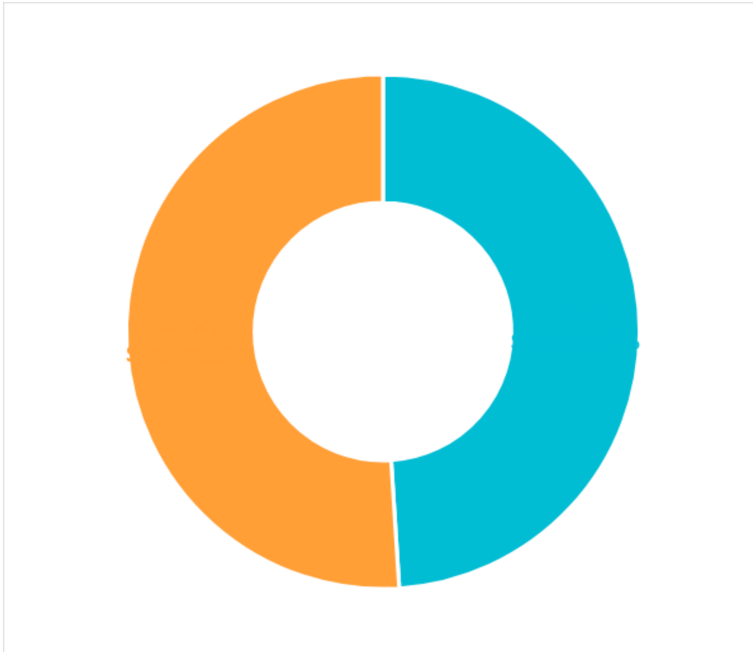


Figure 23 Top 5 Ridership Stations Percentage



5.2.3 Sensitivity Analysis

The three scenarios present three distinct options for implementing fare gates, all of which are anticipated to result in a positive return on investment after 20 years. An important consideration is which variables or assumptions could substantively impact that breakeven point should they change.

An important variable is the discount rate. At 7 percent, the discount rate used by federal grant guidance places a strong emphasis on realizing benefits closer to the present. If the discount rate were instead three percent (a number commonly used to reflect inflation expectations), then the fiscal rationale for installing fare gates is stronger. Under the high-ridership projections, the ROI for Scenario 3 (Top 5 Stations) increases to over 18-fold and the return on investment for installation in Scenario 1 (All Stations) stations increases from 227 percent to 376 percent. Scenario 2 (All Link Stations) has a ROI of over 600 percent (Table 18).

Table 18 Analysis with 3 Percent Discount Rate

	Scenario 1 - All	Scenario 2 - All Link	Scenario 3 - Top 5
# of Current Stations Affected	62	50	5
Total # of Fare Gates Needed	500	341	58
Installation Costs	$305,800,000	$214,000,000	$34,200,000
Annual Operations Costs	$5,000,000	$3,991,000	$3,338,000
Results Under High Ridership			
ROI in 20 Years (2043)	376%	604%	1874%
Years to Break Even	6	4	2
Net Revenue vs. No-Build (10 Years)	$292,300,000	$394,800,000	$198,900,000
Net Revenue vs. No-Build (20 Years)	$1,149,500,000	$1,291,900,000	$641,100,000
Results Under Low Ridership			

ROI in 20 Years (2043)	302%	496%	1607%
Years to Break Even	7	5	2
Net Revenue vs. No-Build (10 Years)	$205,300,000	$307,800,000	$171,500,000
Net Revenue vs. No-Build (20 Years)	$923,500,000	$1,060,700,000	$550,000,000

Finally, the only benefit this analysis considered was increased revenue. There was no consideration of potential decreases in crime, changes in ridership, or other monetized impacts of installing fare gates using these different scenarios. Other agencies which have installed fare gates have done so with the explicit rationale of increasing safety. A broader analysis of these monetized costs and benefits may produce different results, though would also introduce further assumptions into the model. sound transit