West Seattle Project Report

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1 Introduction

West Seattle (WS) is a part of the city of Seattle, Washington, located on a peninsula west of the Duwamish River. On March 23, 2020, the city's most used bridge to travel to and from WS, the West Seattle High-Rise Bridge (hereafter referred to as the high bridge) was closed to all vehicle traffic because of deterioration of its structural integrity. The high bridge is currently being repaired, and its reopening is planned for 2022 [1]. After the closure, the number of travel lanes for vehicular traffic across the river decreased from 21 to 12[2]. The high bridge's average daily traffic volume of 84,000 vehicles [2] had to be distributed to alternative routes, including the 1st Avenue South Bridge (eight lanes) and the South Park Bridge (four lanes), located 2.1 and 3.4 miles south of the high bridge, respectively. Moreover, vehicular traffic over the Spokane Street Lower Bridge (hereafter referred to as the lower bridge), a two-lane bridge located below the high bridge and previously used for travel to and from Harbor Island and WS, was restricted to authorized vehicles only, including emergency vehicles, public transit, and freight vehicles (10,000+ pounds gross vehicle weight) between 5:00 am and 9:00 pm [3].

The unexpected closure of the high bridge disrupted passenger and freight mobility to/from WS, increasing travel times and generating bottlenecks on the remaining bridges, which has negatively impacted the livability of the peninsula as well as its economy and the environment. The situation might further deteriorate as traffic demand to/from WS increases during recovery from the COVID-19 pandemic.

The Seattle Department of Transportation (SDOT) established the "Reconnect West Seattle Implementation Plan" [2], which contains actions to monitor changes in travel behavior and identify and implement strategies to improve the level of access to the WS peninsula.

The purpose of this current study was to:

1. Understand the impacts of the high bridge closure on freight flow, businesses, and carriers
2. Understand current freight movements and quantify freight demand
3. Identify mitigation strategies for freight flow to/from WS.

In the next section we describe the project study area and highlight its main characteristics. Section 3 describes the method used to identify the main impacts of the high bridge closure and highlights the main results. Section 4 describes a freight trip generation study on the study area, and the main results are highlighted. Finally, section 5 concludes the report, summarizing the main results and listing potential mitigation strategies.

2 Study area

Figure 1 shows the study area, which comprised 13 neighborhoods located on the West Seattle peninsula and east of the Duwamish waterway and five port terminals. The study area was divided into three macro-areas: the west area, corresponding to the West Seattle peninsula, the east area, and the port terminals. Table 1 lists the neighborhoods and terminal names belonging to each macro area.

Table 2 summarizes the main characteristics of each macro area, while details at the neighborhood level are reported in Appendix 1. The total population in the study area comprised 101,231 people, of which 99,072 (98 percent) lived on the WS peninsula. Delridge and North Admiral were the largest (land wise) and the most populated neighborhoods in the study area. The neighborhoods with the highest population densities were Fairmount Park, Gatewood, Genesee, and Alki, all located in the center-north of the peninsula.

There were 30,331 buildings in the study area. The land-use type radically differed between the east and west areas, with the west peninsula being mostly residential (86.17 percent of building area) and the east area being mostly industrial (80.21 percent of building area).

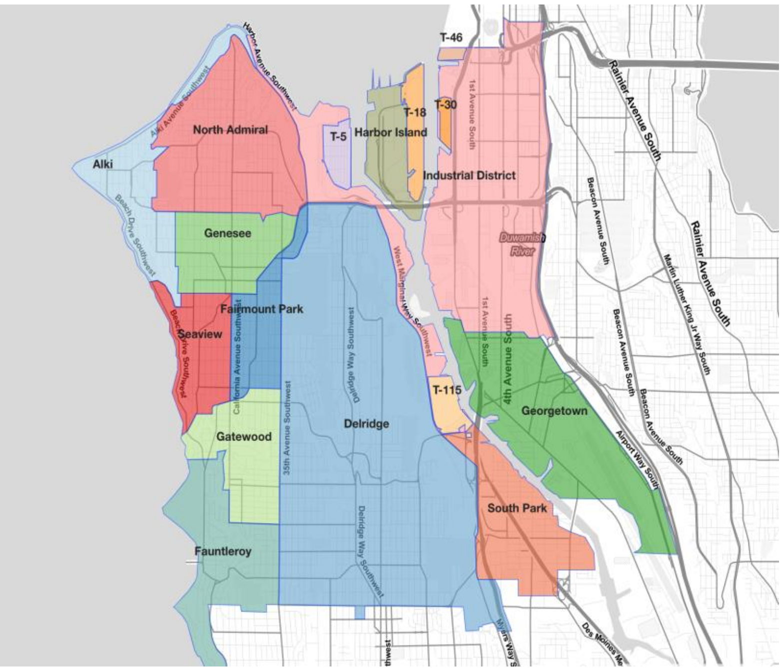

Figure 1. Map of study area and neighborhoods

Table 1. Neighborhoods and terminals in the study area

Areas	**Neighborhoods and Terminals**
West area	Alki, Delridge, Fairmount Park, Fauntleroy, Gatewood, Genesee, Industrial District West, North Admiral, Seaview, South Park
East area	Georgetown, Harbor Island, Industrial District East
Port terminals	T-5, -18, -30, -46, -115

Table 2. Study area population and land use

Statistic		**West area**	**East area**	**Total**
Land area		14.45	5.45	19.90
Population		99,072	2,159	101,231
Population density (people per square mile)		6,857	369	5,087
Number of buildings		28,759	1,462	30,221
Percentage of building area by land use type	Industrial	9.98%	80.21%	35.81%
	Public buildings	1.17%	10.92%	4.76%
	Residential	86.17%	4.94%	56.29%
	Commercial	2.67%	3.92%	3.13%

3 Bridge closure impacts

3.1 Methodology

The objective of this task was to understand the operations of different establishments receiving or delivering freight in the study area, as well as document the impacts of the WS bridge closure. To reach these objectives we deployed two survey tools:

- 30-minute. face-to-face interviews via Zoom
- An online survey.

The survey tools were used to survey the following:

- Carriers performing deliveries and pick-ups in the study area
- Business establishments located in the study area.

Interviews and surveys were structured into four parts:

- *Operations*: Current business operations, including freight trip generation and delivery methods
- *Impacts*: Impacts of the bridge closure on operations (comparing operations before/after the closure)
- *Actions*: Any actions taken by the business to mitigate impacts
- *Strategies*: Strategies SDOT could take to mitigate impacts of the bridge closure.

Table 3 reports the establishments that were interviewed/surveyed. In total 24 establishments were surveyed: 17 establishments were interviewed, and 7 establishments completed the online survey.

Four different business sectors were represented in the surveys:

- Carriers (food, beverage and parcel carriers)
- Food establishments (restaurants and supermarkets)
- Fetail and services
- Industry (port and manufacturers).

Additionally, interviews with neighborhood and business associations were also conducted. The latter were used as a way to establish contacts for different business establishments and to send out the online survey.

Table 3. Stakeholders interviewed/surveyed

Establishment type	Method

	Interview	Online survey
Carrier	UPS PepsiCo Merlino Foods Solid Ground	Amazon logistics BFI Transport Inc.
Restaurant and supermarket	Elliot Bay Brewing Peel and Press PCC Community Markets Safeway (Jefferson Square) WS Food Bank	Phorale FC Bloxom Company
Retailer and services	Fantagraphics Books	Equinox Studios Midnight Supply Company Seattle Public Schools
Industry	NW Seaport Alliance Nucor Steel	
Business Groups and Associations	WS Junction WS Chamber Delridge Neighborhood Association Morgan Neighborhood Association Admiral Neighborhood Association	

3.2 Interviews key insights

3.2.1 Impacts to restaurants and supermarkets

- Overall, demand was negatively affected by the pandemic. One restaurant reported a 40 percent reduction in customers, and one supermarket reported a decrease in its customer base. While restaurants reported that the local customer base of WS residents was not affected by COVID-19, they reported losing visiting customers (infrequent customers, e.g., visiting WS during weekends or for special events) and commuters. (Because of the increase in congestion, more commuters who resided in WS and worked outside the peninsula delayed their return trip, staying for dinner and shopping outside WS). As a consequence of lower demand, businesses that were still able to operate ordered lower volumes of goods. Moreover, a carrier serving food establishments reported that several restaurants were now open for only one shift per day, usually in the evening (i.e., not serving lunch).
- Deliveries to small food establishments were heavily affected:
    - Because of the pandemic, some supply chains experienced disruptions that resulted in shortened and incomplete deliveries (e.g., reductions in volumes delivered with respect to what was promised or missing items).
    - The decrease in demand caused a reduction in shipment volumes. However, food establishments still needed frequent deliveries (e.g., for bread, produce, pizza boxes etc.). Moreover, the bridge closure increased travel time to access WS, because of both an increase in congestion at access points and the need for commercial vehicles to re-route. Consequently, carriers increased consolidation and reduced delivery frequency.

Food establishments therefore experienced delivery delays (e.g., morning deliveries shifted to the afternoon or after closing times) and cancelled deliveries, disrupting business operations and potentially causing economic losses.

- While smaller food businesses experienced delivery delays and shortened deliveries, supermarkets did not generally report disruptions in delivery operations. One supermarket reported an increase in deliveries outside its receiving times (between 6:00 am and 2:00 pm), with no major disruptions in the supply of goods.
- As a consequence of delayed and cancelled deliveries, small businesses made the following types of changes:
  - Using their personal vehicles or company vehicles to pick up deliveries at the supplier site (mostly located outside WS). Furthermore, the travel time to pick up supplies was exacerbated by rerouting and the increase in congestion at access points, since most small establishments did not own larger vehicles that could use the lower bridge.
  - Driving and purchasing at local supermarkets located in West Seattle. One restaurant reported that if it was not going to receive bread in time, employees usually drove and purchased bread in bulk at a local Safeway.
  - Both restaurants interviewed reported changing delivery destinations for some of their supplies from their WS stores to other store locations outside WS and using their own personal vehicles to pick up those supplies.
- Restaurants reported that special temporary passes for smaller businesses' vehicles were beneficial. The WS Junction Association established a booking system for its six passes and noticed that 70 percent of the pass users were restaurants.
- Both smaller and larger food establishments reported difficulties in hiring new employees, especially because of the increase in commute time caused by increased congestion and the need for rerouting after the bridge closure. It was also reported that some smaller businesses lost employees who are not WS residents.
- Two interviewees reported that the service industry was heavily affected by the bridge closure in three ways. First, service vehicles coming from outside WS and serving WS establishments experienced detours and longer driving times, and sometimes they refused to serve WS establishments. Second, customers who resided outside WS and used to travel to WS for services (e.g., medical treatments) were also experiencing longer driving times. Third, establishments based in WS and serving businesses outside WS also experienced longer driving times.

3.2.2 Impacts to carriers

- Food and beverage carriers reported a decrease in demand from WS. One carrier reported restaurants closing, reducing volumes of deliveries, and limiting operations to only one shift per day, usually no longer serving lunch. As a consequence of the reduced demand, one carrier reported reducing its delivery frequency from five to four days a week.
- A parcel carrier reported an increase in demand from WS because of the pandemic. It reported an increase in the number of truck routes entering the peninsula on a typical day from 37 (September 2019) to 55 (September 2020), a 50 percent increase in the number of routes. The carrier reported the need to use personal vehicle drivers (drivers using their own personal vehicles) and rental vans during the peak holiday season. In September 2020 the carrier made approximately 5,864 stops. This implies 196 stops a day and, assuming eight customers served per stop, a total of 1,568 customers served per day in WS alone.
- While most of the extra 18 vehicle routes per day were due to the increase in goods delivery demand caused by the pandemic, the carrier reported that one vehicle route per day was added

because of the additional driving time necessitated by some of its vehicles having to reroute and others experiencing congestion, as well as DOT restrictions on hours/driver per day.

- Some carriers reported an increase in congestion, both on the lower bridge (one carrier reported that container trucks caused long queues around Harbor Island and all the way up to I-5) and at the 1st Avenue Bridge.
- One carrier reported that because of the increase in congestion, drivers who were not able to use the lower bridge, or who had to deliver south, were instructed not to use the 1st Avenue Bridge but to reroute to southern access points, such as the South Park Bridge. The carrier reported that the company also considered performing deliveries earlier in the morning, but this strategy was not possible because of restaurants not open for the lunch shift.
- Food and beverage carriers used a mix of larger trucks that were able to use the lower bridge and vans. Parcel carriers used a mix of parcel delivery vans, rental single-axle box-trucks, and some personal vehicle drivers. They expressed a preference to be able to request permits or passes that would allow their personal vehicle drivers to use the lower bridge.
- A parcel carrier reported that if volumes and/or travel times continued increasing, it would consider adding vehicle routes (e.g., pulling vehicles out of downtown) or having some of the routes depart from the southern depot (which would require considerable infrastructure cost to provide extra capacity at that facility). The parcel carrier said that it was not considering cargo bikes because of high volumes and the geography of the area, nor was it considering opening a satellite distribution center in the area because of infrastructure costs.

3.2.3 Impacts to industry

- Manufacturers and port operations seemed not to be affected by the bridge closure, as the heavy goods vehicle freight traffic that had previously used the high bridge was now using the low bridge and West Marginal Way. Drivers from manufacturing and ports were not able to re-route to southern access points.
- With the reopening of the T-5 terminal, the port expects an additional 1,800 vehicle trips per day through the lower bridge. The T-115a and T-18 terminals are also using the lower bridge and West Marginal Way.

4 Freight trip generation estimation

4.1 Introduction

Different establishments have different needs for goods supply, generating different amounts of freight. Freight is transported to an establishment via commercial vehicles, performing one or more vehicle trips, and for each trip, performing a delivery/pick-up. The number of freight vehicle trips generated by an establishment is referred to as the Freight Trip Generation (FTG). We will estimate FTGs using the number of deliveries and pick-ups to establishments.

FTG models are mathematical models that characterize the relationship between FTG of an establishment and some characteristics of that establishment. Characteristics used as model inputs are the type of establishment (e.g. residential, industrial or commercial), and the size of the buildings hosting the establishment (measured in acres, for commercial and industrial buildings, or in number of residential units, for residential buildings). The number of deliveries per establishment is used to quantify its FTG.

The goal of this task is to develop and implement an FTG model for the case study area by using public data sources. The output of the FTG model can be interpreted as the number of deliveries and pick-ups to a given building on a typical day. The FTG estimated for each building in the study area are then aggregated to obtain the total FTG for the whole study area, which can be interpreted as the total number of deliveries and pick-ups performed by commercial vehicles in the study area on a typical day.

While the results of the FTG modeling provide an indication of the amount of traffic generated in a given area by different types of buildings, the model has several limitations that should be taken into consideration when interpreting the results:

- The current model does not account for any changes due to the COVID-19 pandemic.
- The model does not distinguish between different vehicle types.
- The model does not take into account the tendency for vehicles delivering smaller shipment sizes (e.g., parcel delivery vehicles) to aggregate multiple deliveries into a single stop (i.e. a driver might stop the vehicles and perform multiple deliveries of foot) and aggregate multiple stops into tours (i.e. parcel delivery vehicles often perform "milk runs"); as a consequence, the reader should be careful in using FTG results to directly estimate traffic volumes as more modelling is needed to derive volumes from the FTG.
- Service vehicles (i.e. plumbing and HVAC, etc) are not taken into account.

All metrics developed here are reported on an interactive map accessible at the following link:

https://sgunes.shinyapps.io/WestSeattle/

4.2 Methodology

We assumed that different land uses attract different amounts of freight trips, but freight trip generation is homogeneous within the same land-use type. We considered the following land uses:

- Industrial/manufacturing
- Public buildings
- Residential
- Retail/commercial.

Table 5 and Table 6 report the trip rates used to compute the total commercial vehicle trips by land use and the data sources used. The following subsections contain more details on how we implemented the FTG framework here proposed.

Table 5. Trip rates per land use type and examples of present uses

Land-use type	Examples of present use[1]	Trip rate
Residential	Apartment, Single Family, Condominium, Duplex, Triplex	Single-unit: 0.48 daily trips/unit[3]
		Multi-unit: 0.38 daily trips/unit[3]

Industrial/ manufacturing	Warehouse, Terminal (Rail)	3.61 daily trips/acre[2]
Retail/ commercial	Grocery Store, Retail Store, Shopping Center, Convenience Store, Restaurant	14.25 daily trips/acre[2]
Public building	Governmental Service, Office Building, Auditorium / Assembly Building	0.4 daily trips/acre[2]

[1] King County categorization [6]
[2] Holguin-Veras et al. [4]
[3] PSRC dataset [8]

Table 6. Model inputs and data sources

Model inputs	**Source**
Trip rate per land-use type	NCHRP 739 database [4]
Building area	King County Department of Assessments [5]
Present use	Parcels for King County with Address, Property and Ownership Information (King County GIS Center) [5]
Parcel/lot area	Parcels for King County with Address, Property and Ownership Information (King County GIS Center) [5]
Daily truck trips generated at Port terminals	2015 Container Terminal Access Study (CTAS) [7]
Number of home deliveries on travel day	Puget Sound Regional Council Household Travel Survey [8]

4.2.1 Estimation of residential freight trips

To estimate the number of freight trip ends for residential parcels, the research team used the data gathered from the Puget Sound Regional Council (PSRC) Household Travel Survey [7]. In the PSRC survey participants were asked about delivery frequency, i.e., the number of times they received a home delivery (food, package, service, or grocery) on a given day. The total number of deliveries received on a given day was calculated as the sum of food, package, service, and grocery delivery frequencies. The *Residence Type* attribute was re-coded into multi-unit residence or single-unit residence categories. Then, grouping by the residence type, the average number of daily deliveries (number of freight trip ends) was computed. By using the *Number of Units* attribute from the King County Department of Assessments (KCA) data set, the residential parcels were categorized as multi- or single-unit and were matched with the computed trip rate. For these parcels, the number of trip ends was assumed to be the average number of daily deliveries for that residence type multiplied by the number of units.

4.2.2 Estimation of commercial and industrial freight trips

The number of freight trips for the case study area was calculated by using a Commercial Trip Generation model previously developed by Holguin-Veras et al. [4]. This model uses as inputs a building footprint area and its land-use category, and it outputs the total number of commercial vehicle trips that end in a given building during a typical day. To compute the daily number of freight trips generated by a building i the following formulation is used:

$$TG_i = A_i \sum_j \beta_j 1_{[use_i = j]}$$

where:

- TG_i = number of commercial vehicle trips that end in building i during a typical day
- A_i= area of building i footprint (in acres)
- β_j= daily trips per acre of a building of land-use category j (see Table 5)
- $1_{[use_i=j]}$= binary variable equal to 1 if the land use of building i corresponds to land-use type j, 0 otherwise

Table 6 describes the main data sets used to implement the above-described methodology. The Parcels for King County with Address, Property and Ownership Information data set provided the geometry and location for individual parcels, as well as address, present use (*Present Use*), and lot area (*Lot Square Footage*) information. The KCA data were used to get information about the buildings located on each parcel, including the establishment size in square footage. These data sets were matched by using the Major and Minor attributes as key, defined by King County to identify each parcel.

Figure 2 summarizes the data processing method used. To find the building area located on each parcel, the parcel data set (in shape file format) was merged with the processed KCA data set containing information about apartment buildings, residential buildings, commercial buildings, condo units, and complexes. For parcels that did not have a match with the KCA data set and were not listed as vacant in the Present Use cell, missing data were imputed by extrapolation. For every Present Use, the average ratio of the building size over the parcel lot size was calculated. Building areas for missing cells were calculated by multiplying the parcel area by the average ratio by Present Use.

Once the parcels data set had been processed to include the building area, either matched from the KCA data or estimated via extrapolation, the Present Use attribute was used to classify the parcels in terms of the land-use categories proposed in the FTG model selected [4]. For the parcel level FTG estimation, the area of each establishment was multiplied by the trip rates for each land-use type.

The results were visualized on a map by using the geometric locations of the parcels and the calculated number of trip ends. This visualization was used to identify any discrepancies or inconsistencies, such as a very high number of trip ends at a parcel that was not commercial. As a result of this process, some modifications to the land-use category corresponding to the *Present Use* were made.

Following the estimation of the freight trips for each establishment, the results were aggregated by neighborhood to identify neighborhoods with higher freight activity.

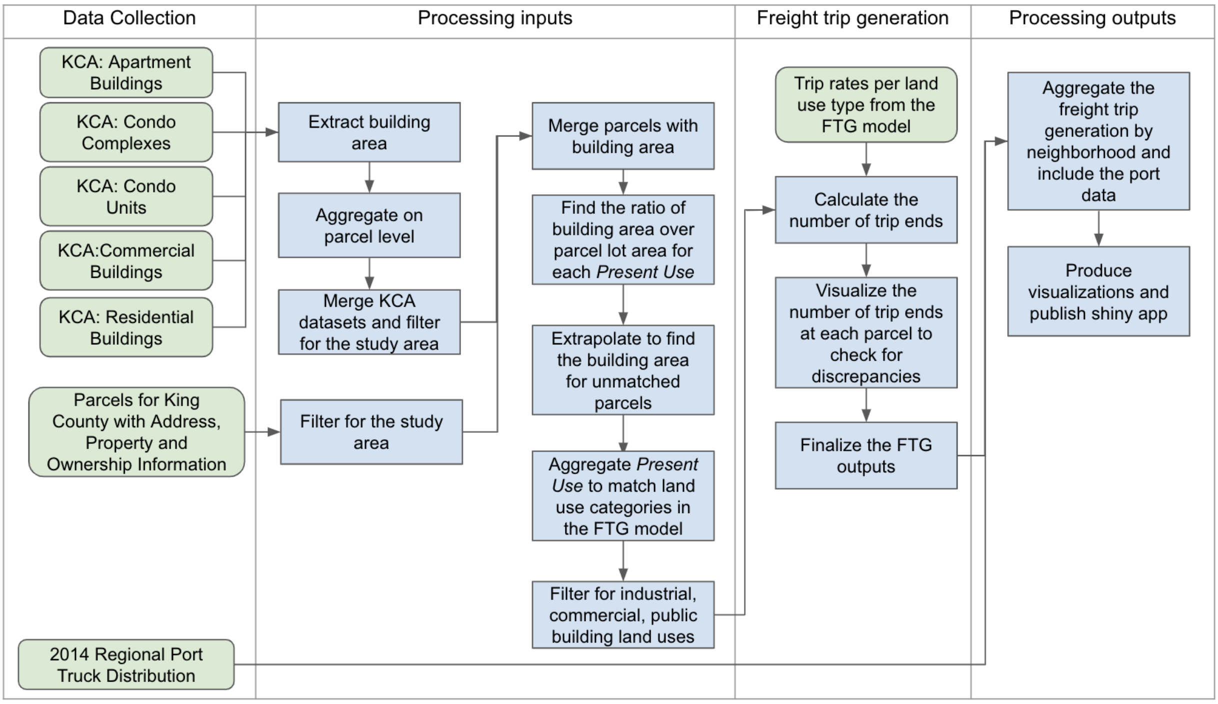

Figure 2. Freight trip generation methodology for commercial and industrial (not including residential) land use

4.2.3 Estimation of freight trips to port terminals

Real traffic counts from the 2014 Container Terminal Access Study [7] were used to compute the daily truck trips generated by each terminal.

5 Conclusion

5.1 What were the main impacts of the bridge closure to businesses and carriers?

To document the impacts of the WS high bridge closure to freight flow in and out West Seattle, the research team performed several interviews with local business owners and carriers' managers performing deliveries and pick-up in the study area. In total 24 establishments were surveyed including parcel delivery carriers, food and beverage carriers, supermarkets and restaurants, retailers, manufacturers, the Port of Seattle and several business associations.

Table 6 summarizes the main impacts that were reported by the surveyed establishments.

Table 6. Summary of main impacts

Establishment type	Main impacts
Food establishments	• While supermarkets did not report major changes, smaller food establishments (restaurants, cafes) reported important delivery disruptions (cancelled, delayed, and incomplete deliveries). • As a consequence of these disruptions, small food establishments reported often relying on the use of smaller vehicles (personal cars or business vans) to pick up goods at supplier locations, change the delivery destinations of their supplies to other locations outside WS, and source their supplies from local supermarkets located in WS. • Businesses reported difficulties in keeping their employees and hiring new ones because of increased commuting times.
Service establishments	• Services (e.g., repair, maintenance, medical offices) reported a loss of customers and increased difficulties due to longer travel times, increased traffic congestion, and the inability (of their customers and themselves) to use the lower bridge (most vehicles used were smaller and cars).
Carriers	• Because of the reduction in delivery volumes to food and beverage establishments (because of the COVID-19 pandemic and the reduction in demand for small food establishments) food and beverage carriers reduced their delivery frequency and increased consolidation of deliveries, hence delivering to more customers per route. • Parcel carriers increased the number of routes serving the peninsula because of the increase in demand (due to the COVID-19 pandemic) and the increase in travel times (due to increased traffic delays at access points and an inability for most fleet vehicles to use the lower bridge).
Industry	• Port and industry operations did not experience major disruptions, especially because they were still able to use the lower bridge. • Traffic congestion was reported on the lower bridge caused by container trucks lining up at the port gates waiting to enter the terminal.

5.2 How many freight trips were generated in the study area?

A Freight Trip Generation (FTG) model was developed and applied to the study area. The output of the FTG model can be interpreted as the total number of deliveries and pick-ups performed by commercial vehicles in the study area on a typical day, which we will generally refer to as freight trips.

While the results of the FTG modeling provide an indication of the amount of traffic generated in a given area and by different types of buildings (including residential, commercial, industrial buildings and Port Terminals), the model has several limitations that should be taken into consideration when interpreting the results: (*i*) the model does not account for any changes due to the COVID-19 pandemic, (*ii*) the model does not distinguish between different vehicle types, (*iii*) service vehicles are not taken into account (*iv*) The model does not take into account the tendency for vehicles delivering smaller shipment sizes (e.g., parcel delivery vehicles) to aggregate multiple deliveries into a single stop (i.e. a driver might stop the vehicles and perform multiple deliveries of foot) and aggregate multiple stops into tours (i.e. parcel delivery vehicles often perform "milk runs"); as a consequence, the reader should be careful in using FTG results to directly estimate traffic volumes, and more modelling is needed to derive vehicle volumes from the FTG.

Table 7 summarizes the total estimated freight trips generated by the whole study area, the West Seattle peninsula (West) and the east part of the study area that includes the neighborhoods of Georgetown and SoDo (East). Approximately, we estimated that the buildings in the study area generate 27,700 freight deliveries and pick-up trips per day, across all types of activities, including deliveries and pick-ups to residential buildings (e.g. parcel deliveries), commercial activities (e.g. retail stores and restaurants), Port terminals and industrial buildings (e.g. manufacturers). Of these, the 74 percent of deliveries and pick-ups are generated by the West Seattle peninsula (20,505 trips per day), 14 percent by Port Terminals (3,815 trips per day) and 12 percent by Georgetown and SoDo (3,376 trips per day).

The west and east parts of the study areas are characterized by a different distribution of freight deliveries and pick-ups. Deliveries and pick-ups in the West Seattle peninsula (ignoring Port Terminals) are predominantly generated by residential buildings (93.6 percent), followed by industrial (3.4 percent) and commercial (3 percent). Conversely, deliveries and pick-ups in the east part of the study area (ignoring Port Terminals) are predominantly generated by industrial buildings (73.8 percent) followed by commercial (15.5 percent) and residential (9.4 percent).

The model provides a baseline quantification of the freight demand in the study area. We expect, during the COVID-19 pandemic, an increase in demand for residential deliveries (e.g. one interviewed parcel carrier reported an increase in 50 percent of their daily vehicle routes serving the West Seattle peninsula), and a decrease in demand for commercial deliveries.

Table 7. FTG estimates

	West	**East**	**Port**	**Total**
Total industrial	700.07 (3.41%)	2,492.82 (73.84%)	3,815.00 (100%)	7,007.89 (25.30%)
Total public buildings	8.59 (0.04%)	40.57 (1.20%)	0	49.17 (0.18%)
Total residential	19,188.82 (93.58%)	318.83 (9.44%)	0	19,507.65 (70.43%)
Total commercial	607.71 (2.96%)	523.75 (15.51%)	0	1,131.46 (4.09%)
Total	20,505.20	3,375.97	3,815.00	27,696.17

Figure 3 (a) show the geographical distribution of freight trips across the neighborhoods and Port Terminals (see Appendix 2 for details). The neighborhoods that generated the largest number of trips are Delridge, followed by North Admiral and Genesee. Figure 3 (b) shows the trip density, computes as the total number of trips divided by acres of area covered by buildings in each neighborhood (excluding Port Terminals). The neighborhoods with the largest trip density are Genesee, Fairmount Park and Gatewood. Figure 3 (c) shows the total number of trips to residential buildings. The neighborhoods with the largest number of trips to residential buildings are Delridge, North Admiral and Genesee. Figure 3 (d) shows the total number of trips to commercial buildings. The neighborhoods with the largest number of trips to commercial buildings are SoDo, Delridge and Genesee.

Additional visualizations can be generated interactively by using the following app:

https://sgunes.shinyapps.io/WestSeattle/

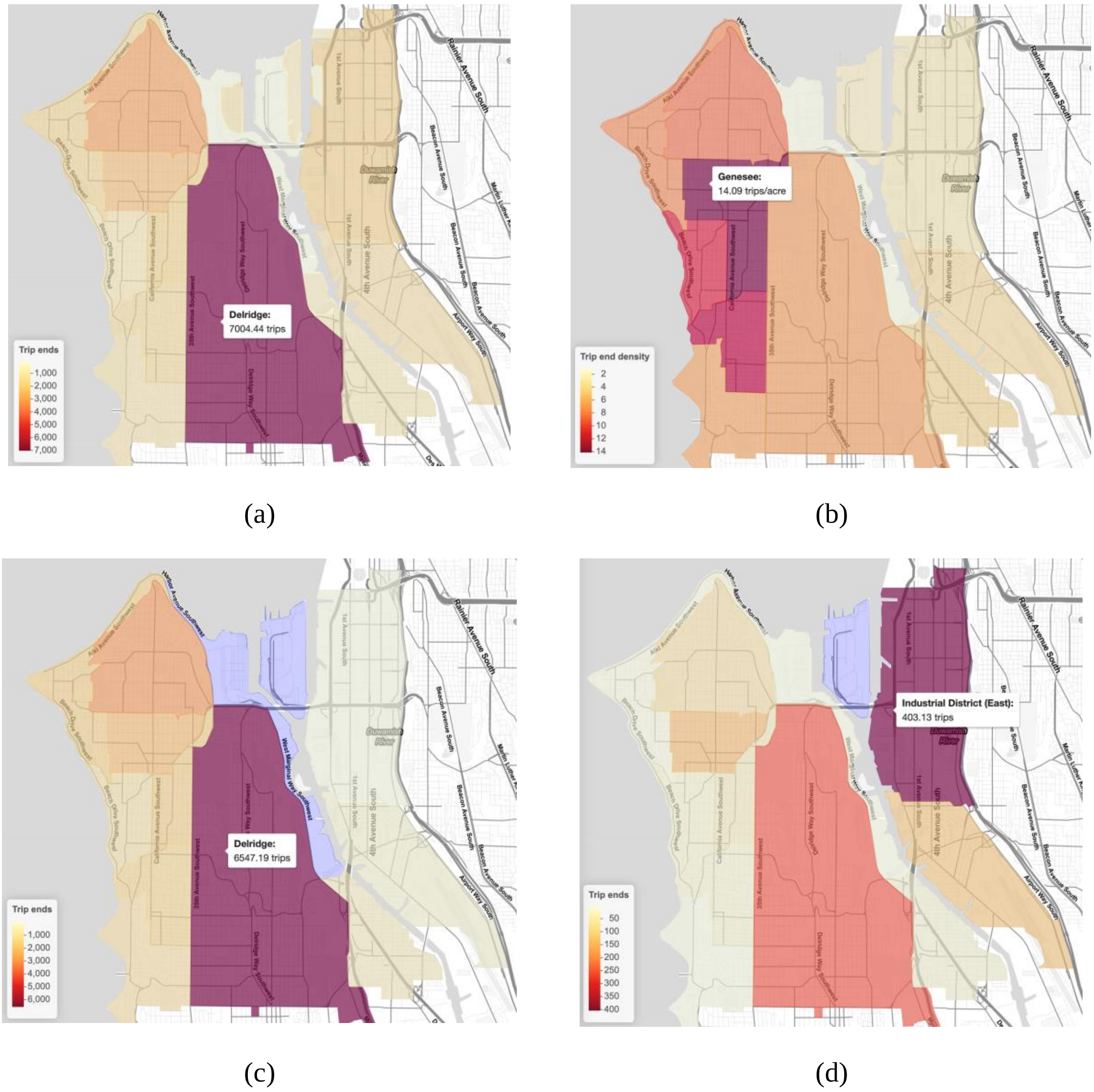

Figure 3. Distributions of total freight trips generated, by neighborhood. (a) Total number of trips. (b) trip density measured in trips per acre of buildings area. (c) Total residential trips. (d) Total commercial trips.

5.3 What were the most affected neighborhoods?

To identify the neighborhoods that were the most affected by the bridge closure, we considered the following variables:

- Neighbourhood percentage residential/commercial FTG. Percentage of deliveries/pick-ups that were generated by residential and commercial buildings in a given neighbourhood. According to the interviews performed, compared to deliveries/pick-ups to industrial buildings, commercial and residential deliveries/pick-ups were more likely to be performed by smaller commercial vehicles and personal vehicles, which weight is less than 10,000 pounds.
- Neighbourhood total number of FTG. Total number of deliveries and pick-ups in a given neighbourhood.

- Neighbourhood re-route time. Maximum re-route times from Eastbound to Westbound, defined as the difference between the travel time from a fixed point on the east side of the Duwamish river (Spokane St Viaduct, Seattle, Washington, 98134) to the center of each neighborhood before the bridge closure (assuming the use of the high and lower bridge, no peak hour) and after the bridge closure (assuming no possible usage of high and lower bridge and peak hour). Travel times were obtained using the Google Maps Distance Matrix API, and include peak hour traffic congestion (around 4 PM).

Figure 4 displays all three variables for different neighborhoods. We can identify five different clusters, summarized in Table 8.

Table 8. Clusters of neighborhoods and their re-route time and share of commercial and residential FTG

Cluster	**Neighborhoods**	**Re-route time**	**Percentage of commercial and residential neighbourhood FTG**
Cluster 1	North Admiral	21 minutes	97 %
Cluster 2	Genesee, Alki, Seaview, Gatewood and Fairmount Park	15 minutes	98 %
Cluster 3	Fauntleroy and Delridge	5 minutes	96 %
Cluster 4	SouthPark, Industrial District East (SoDo), and Georgetown	0 minutes	35 %
Cluster 5	Industrial District West	11 minutes	4 %

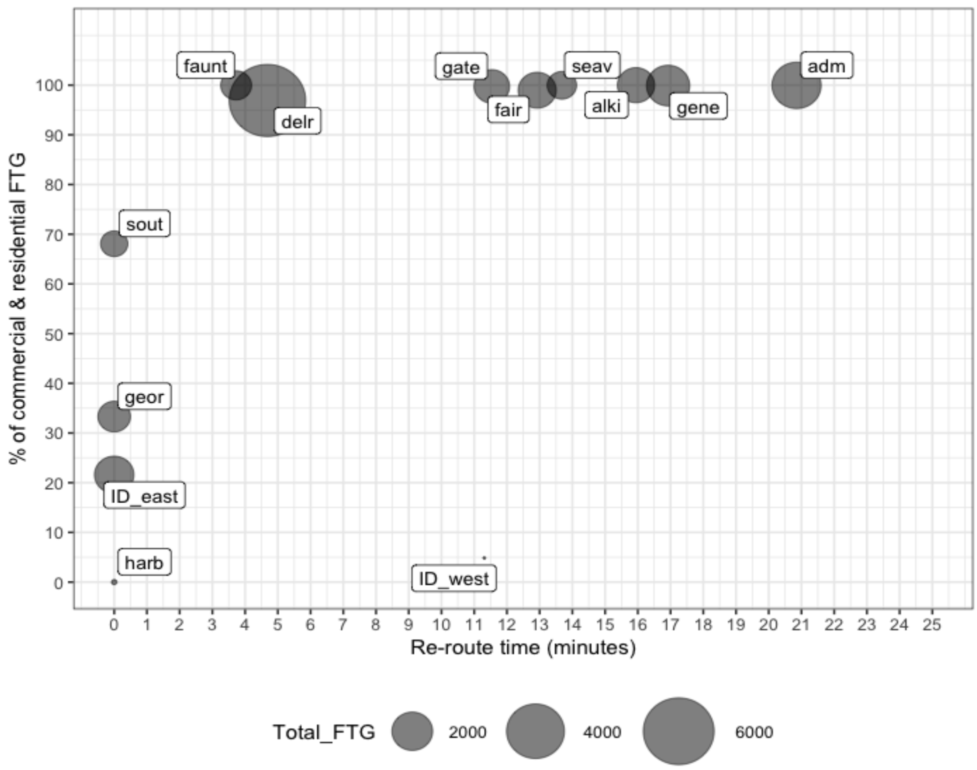

Figure 4. Comparison of neighborhoods by re-route times, percentages of residential and commercial FTG, and total FTG

5.4 Which freight strategies could mitigate the impacts of the bridge closure?

5.4.1 Short-term impact strategies: Allow lower bridge use

- *Provide lower bridge access to small businesses*
  The businesses most affected by the bridge closure were found to be smaller food establishments and service establishments. These businesses often made use of smaller freight and personal vehicles to perform pick-ups and deliveries to overcome any delivery disruptions. Providing lower bridge access to these smaller establishments, would support their operations and reduce the negative effects of delivery disruptions.
- *Provide lower bridge access to parcel carriers*
  The FTG effort showed that the majority of freight trips generated daily were home deliveries, including food and parcel deliveries. These deliveries were also often performed with vans and personal vehicles. To reduce vehicle miles traveled and the use of alternative vehicle routes, parcel delivery vehicles should also be allowed to use the lower bridge.
- *Guarantee lower bridge free-flow traffic*
  The increase in permits for lower bridge use might come at the cost of an increase in traffic congestion. To avoid this, several policies could be applied:
  - Permits could be time-based (e.g., morning/afternoon only) to avoid peak traffic congestion and stagger the lower bridge use throughout the day
  - It was reported that container trucks accessing terminals T-5 and T-18 often created queues on the lower bridge. To guarantee free flow on the bridge, queues of container trucks could be staged along Marginal Way, with a system of traffic lights, and allowed access to the lower bridge only when previous trucks have already been checked in at the terminal gates.
- *Promote zero-emission vehicles*
  In addition, to promote the use of zero-emission vehicles, lower bridge permits could be given to establishments that make use of electric vehicles to perform deliveries and pick-ups.

5.4.2 Long-term impact strategies: Support local businesses

- *Centralized receiving station*
  Several smaller businesses, and especially smaller food establishments, reported experiencing delivery disruptions, including delayed, cancelled, and incomplete deliveries. One possible strategy to overcome these disruptions would be to provide a centralized receiving station in a location closer to the businesses on the peninsula. There, larger vehicles carrying deliveries for multiple smaller establishments could deconsolidate their deliveries in a central location, and goods could be staged until businesses or third parties (e.g., cargo bike delivery companies) could pick them up and cover the last mile. Such a strategy could increase delivery density for carriers, thereby reducing delivery delays, and could guarantee businesses access to their deliveries in a timely fashion, avoiding the need for use of smaller vehicles and vans to pick up goods outside the peninsula and for use of the lower bridge.
- *Shared freight vehicle fleet*
  Several establishments reported the use of personal vehicles to perform deliveries and pick-ups, especially to overcome disruptions caused by delivery delays. Moreover, these establishments had been sharing a small number of lower bridge passes that were given to business associations. To increase vehicle utilization and reduce the total number of vehicles used, a fleet of smaller commercial vehicles could be purchased or organized among business owners to be shared across multiple businesses. These vehicles could be given a pass to use the lower bridge and could also be electric, to reduce travel emissions.
- *Increase customer base*

The combination of the COVID-19 pandemic and the bridge closure heavily affected consumer demand. Businesses reported losing customers especially from outside the peninsula, such as tourists, weekend visitors, and special events customers visiting WS for events such as birthdays and weddings, while the local customer base grew stronger. To support smaller businesses several strategies could be undertaken to increase the customer base:

- Promote access to WS by bicycle and other micro-mobility modes, in partnership with local businesses, to attract new customers and support demand.
- Encourage "Stay Local" and "Shop Local" campaigns, with access encouraged by the various travel options featured in the Reconnect West Seattle Implementation Plan, to support local businesses and keep trips contained within the peninsula.
- Deploy a system of parcel lockers, able to receive deliveries from multiple carriers, at local businesses to increase foot traffic at local commercial areas on the peninsula, as well as increase delivery density and reduce the numbers of home deliveries

6 References

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- Appendix 1: Study area statistics

Neighborhoods	Land area (square miles)	Residential population	Population density (people per square mile)	Number of buildings	% of building area by land use type			
					Industrial / Manufacturing	Public buildings	Residential	Retail / Commercial
Alki	0.88	8,146	9,277.94	2,194	0.02%	0.11%	99.17%	0.69%
Delridge	5.82	34,131	5,860.51	10,106	11.13%	1.79%	83.89%	3.19%
Fairmount Park	0.58	8,465	14,558.8	1,814	4.18%	1.87%	91.02%	2.92%
Fauntleroy	1.22	6,449	5,307.7	2,208	0.10%	0.22%	99.14%	0.54%
Gatewood	0.82	8,159	9,939.05	2,550	0.89%	0.18%	97.31%	1.63%
Genesee	0.76	7,218	9,517.04	2,352	0.31%	0.87%	92.61%	6.21%
Industrial District W.	0.90	1,499	1,665.43	29	83.33%	11.90%	0.00%	4.76%
North Admiral	1.75	14,421	8,246.09	4,412	0.11%	0.68%	96.38%	2.84%
Seaview	0.66	5,588	8,438.48	1,873	0.08%	0.41%	97.37%	2.14%
South Park	1.06	4,996	4,717.54	1,221	69.71%	2.63%	26.39%	1.27%
Total West	**14.45**	**99,072**	**6,857.23**	**28,759**	**9.98%**	**1.17%**	**86.17%**	**2.67%**
Georgetown	1.85	1,306	706.21	852	82.54%	7.84%	6.70%	2.91%
Harbor Island	0.65	0	0	17	100.00%	0.00%	0.00%	0.00%
Industrial District E.	2.95	853	289.23	593	80.29%	8.33%	2.08%	9.29%
Total East	**5.45**	**2,159**	**396.25**	**1,462**	**80.21%**	**10.92%**	**4.94%**	**3.92%**
Total	**19.90**	**101,231**	**5,087.92**	**30,221**	**35.81%**	**4.76%**	**56.29%**	**3.13%**

- Appendix 2: Freight Trip Generation estimation results

Neighborhoods	Total daily trip ends	Trip density (trip ends per acre)	Total trip ends			
			Industrial/ Manufacturing	Public Buildings	Residential	Retail/ Commercial
Alki	1,681.88 (8.20%)	7.45	0.10 (0.01%)	0.06 (0.004%)	1,669.33 (99.25%)	12.39 (0.74%)
Delridge	7,004.43 (34.16%)	6.62	212.59 (3.04%)	3.78 (0.05%)	6,547.19 (93.47%)	240.87 (3.44%)
Fairmount Park	1,753.22 (8.55%)	14.08	17.04 (0.97%)	0.84 (0.05%)	1,688.31 (96.30%)	47.02 (2.68%)
Fauntleroy	1,184.83 (5.78%)	6.37	0.44 (0.04%)	0.10 (0.01%)	1,175.33 (99.20%)	8.96 (0.76%)
Gatewood	1,540.67 (7.51%)	12.06	3.87 (0.25%)	0.08 (0.01%)	1,508.77 (97.93%)	27.95 (1.81%)
Genesee	2,244.68 (10.95%)	14.09	1.72 (0.08%)	0.53 (0.02%)	2,106.71 (93.85%)	135.72 (6.05%)
Industrial District W.	172.02 (0.84%)	1.28	162.68 (94.57%)	1.00 (0.58%)	0.00	8.35 (4.85%)
North Admiral	2,895.92 (14.12%)	8.21	0.93 (0.03%)	0.58 (0.02%)	2,819.76 (97.37%)	74.65 (2.58%)
Seaview	1,081.70 (5.28%)	10.6	0.26 (0.02%)	0.14 (0.01%)	1,054.78 (97.51%)	26.52 (2.45%)
South Park	945.84 (4.61%)	4.18	300.44 (31.76%)	1.47 (0.16%)	618.64 (65.41%)	25.29 (2.67%)
Total West	**20,505.20 (74.04 %)**	**7.60**	**700.07 (3.41%)**	**8.59 (0.04%)**	**19,188.82 (93.58%)**	**607.71 (2.96%)**
Georgetown	1,307.74 (38.74%)	3.89	863.04 (65.99%)	9.10 (0.70%)	314.98 (24.09%)	120.62 (9.22%)
Harbor Island	184.00 (5.45%)	2.62	184.00 (100.00%)	0 (0%)	0	0 (0%)
Industrial District E.	1,884.23 (55.81%)	2.8	1,445.78 (76.73%)	31.47 (1.67%)	3.85 (0.20%)	403.13 (21.39%)
Total East	**3,375.97 (12.19 %)**	**3.13**	**2,492.82 (73.84%)**	**40.57 (1.20%)**	**318.83 (9.44%)**	**523.75 (15.51%)**
T-5	1,250 (32.77 %)	217.83	1,250			
T-18	970 (25.43 %)	360.49	970			
T-30	380 (9.96 %)	182.91	380			
T-46	730 (19.13 %)	179.03	730			
T-115	485 (12.71 %)	23.85	485			
Total Port	**3,815.00 (13.77 %)**	**109.26**	**3,815.00 (100.00%)**			
Total	**27,696.00 (100%)**	**7.27**	**7,007.89 (25.30 %)**	**49.17 (0.18 %)**	**19,507.65 (70.43 %)**	**1,131.46 (4.09 %)**