Supporting Comprehensive Urban Freight Planning By Mapping Private Load and Unload Facilities

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Abstract

Freight load and unload facilities located off the public right-of-way are typically not documented in publicly available databases. Without detailed knowledge of these facilities, i.e. private freight load and unload infrastructure, cities are limited in their ability to complete system-wide freight planning and to comprehensively evaluate the total supply of load and unload spaces in the city. To address this challenge, this research describes the development and application of a data collection methodology and a typology of private freight load/unload facilities for their inventory and documentation in dense urban centers.

The tools developed in this research are practice-ready and can be implemented in other cities to support research, policy and planning approaches that aim to improve the urban freight system. Assessment of the degree of harmonization between the current delivery vehicle dimensions and infrastructure they service is a crucial step of any policy that addresses private freight load/unload infrastructures. This includes providing: the adequate access dimensions, capacity to accommodate the volume and vehicle type, and an effective connecting design between the facilities and the public right-of-way.

A case study in Downtown Seattle found over 337 private freight facilities for loading/unloading of goods but that translates into only 5% of the buildings in the densest areas of the city had these facilities. Alleys were found to play a critical role since 36% of this freight infrastructure was accessed through alleys.

This research results in the first urban inventory of private freight load/unload infrastructure which has been shown to be a valuable resource for the City of Seattle that can be used to better understand and plan for the urban freight system.

Introduction

In many urban areas, vehicles of all types - freight, service, transit, emergency, passenger, ride-sharing, and taxis - compete for space to load and unload. As cities become denser and e-commerce continues to grow, there is an increasing concern for balancing the load/unload needs of all roadway users.

In the United States, facilities located off the public right of way (mainly off streets) are generally managed and owned by private stakeholders such as building owners (although a few are managed by public agencies). The result is that these facilities are not documented in public databases of transport infrastructure and thus cannot be effectively included in city and regional planning efforts. Private freight load/unload infrastructure, together with public on-street parking for commercial vehicles, increase infrastructure capacity. When the level and characteristics of the demand is matched with the infrastructure capacity, service quality to all roadway users can be improved. Therefore, not knowing the location of private freight load/unload facilities in cities hinders the success of curb management strategies that match delivery parking demands and existing infrastructure to avoid increase in traffic, causes a reduction in quality of service to customers, and increases in costs for carriers.

The City of Seattle was used as case study and city staff supported this research. Like most cities, Seattle lacks accurate, up-to-date and, detailed information on the locations and features of private freight load/unload facilities that serves their population. Seattle (2017 population of 725,000) is a relatively dense city (8,350 residents per square mile) and traffic is a concern with Seattle drivers spent 55 peak hours in congestion which in 2017 placed Seattle in the top 20 of the 1,064 gridlock-plagued cities worldwide (Cookson, 2018).

The primary goal of this research was to build a database of private load/unload infrastructure in the densest urban core of Seattle that can be transferred to and maintained by the City to support more effective freight planning. To this end, the research team developed a comprehensive and systematic data collection methodology that is standardized, has been validated for high data quality, and can be collected without accessing private facilities. This methodology included the design and programming of a computer app to efficiently support data collectors. This resulted in the first-of-its-kind inventory of private freight load/unload infrastructure.

Recognizing that in sources such as city reports, zoning or building codes, design standards and research papers, the terms used to refer, describe and classify private freight load/unload infrastructure vary (City of Toronto, 2017; General Services Administration, 2014; International Code Council, 2011; KELLEY, 2017; NOVA, 2013), this paper proposes a typology of urban private freight load/unload infrastructure. This allows researcher and planners a framework to better identify and understand the private freight load/unload infrastructures and their key attributes.

In this paper, Section 2 discusses the lack of data. Section 3 proposes a typology to classify this infrastructure. Section 4 offers a description of the developed data collection method. Section 5 shows the results of the application of the method in Seattle. Section 6 presents the conclusions and final remarks.

Literature Review

Many local governments provide open geographic information system (GIS) databases that inventory a city's physical assets. Some of these platforms also include datasets of freight parking infrastructure but the data in these online platforms only include load/unload infrastructure that is on the public right of way and is the city's responsibility to manage and maintain.

A few examples of these physical assets databases can be found in the cities of Seattle (SDOT, 2018), Sydney (TFNSW, 2016), Bologna (Dezi et al., 2010) and Lisbon (EMEL, 2021). They include key infrastructure attributes such as geolocation of the facility, number of spaces, length of a parking space, time restrictions, and permits required. Some of these databases have been used to study curbside freight load/unload spaces such as their level of service, calculated as the number of establishments per infrastructure within a walking range (Alho & de Abreu e Silva, 2014), and the optimal size, location and number of these facilities (Dezi et al., 2010).

Regarding private space for parking in buildings, urban planners and parking policy formulators generally focus on setting of a rate (parking spaces per activity level) at which parking should be provided (Young & Miles, 2015). A surrogate measure of activity (e.g. floor area, types of commercial activity, number of employees, etc.), which is relatively easily measured, is typically used to calculate the number of required parking spaces. This also applies to zoning regulations that govern freight load/unload infrastructure in buildings. For instance, cities such as Seattle and New York consider building size, type of district, and land use to define the infrastructure requirements (Lubinsky & Kushan, 2017; SDCI, 2017).

There is some evidence that the current requirements and existing private freight load/unload infrastructures do not meet the operational needs of urban goods deliveries. Lubinsky and Dave (2017) conducted a study of zoning regulations in New York and found that regulations of freight load/unload infrastructure in buildings have not been updated since the mid-1950s. Also in New York, Morris (Morris, 2004) conducted focus groups and interviews in which carrier and shipper representatives repeatedly reported that inadequate private loading facilities in commercial office buildings were a major barrier to freight efficiency in New York's CBD.

Pivo et al. (Pivo et al., 2002) conducted focus groups of truckers in Seattle and identified private freight load/unload spaces as one of the principal ways by which freight is delivered in this city. Their study also documented several difficulties that delivery drivers experience while trying to use these facilities including tight access angles, small vehicle allowances and inconsistency of vertical clearance limitations, and the presence of obstructions such as garbage dumpsters and refuse containers.

Nourinejad et al. (Nourinejad et al., 2014) is one of the few examples found in the literature that considers this infrastructure as part of the freight load/unload network. They collected a sample of freight parking facilities both on- and off- street to evaluate truck parking policy impacts in a 5 by 4 city block area of the City of Toronto central business district. In addition to surface parking lots, parking garages and alleyways, private freight load/unload infrastructure were also considered as options suitable for off-street parking by trucks.

In summary, there are no previous examples of publicly available inventories of private freight load/unload infrastructure found that can be used to support a complete assessment of the capacity and performance of that infrastructure network in urban areas. Data about the physical design and location of this infrastructure can support assessments of freight and servicing sustainability through the provision of adequate space off-street. Curbside resource allocation decisions can then be better supported by integrating private and

public freight load/unload capacity of the urban freight system. This paper addressed this gap by providing a transferable methodology to inventory these facilities as well as case study demonstrating this methodology applied in the City of Seattle.

## Typology of Private Freight Load/Unload Infrastructure

This effort classifies loading and unloading infrastructure into three types of facilities:

- *Loading bay* (Figure 1). An enclosed space inside a building with an entrance/exit point (e.g. roll up doors, garage doors) that act as a barrier between the enclosed space and the exterior of the property or public right-of-way. This space is partially or completely dedicated to freight unloading and loading activities. Entrances and exits greater than 2.4 meters x 2.4 meters (8 feet x 8 feet) provide commercial vehicles with access to the site. Loading bays can include elevated platform (a loading dock) that supports delivery operations by allowing a truck to back up to load or unload.

Figure 1. Examples of loading bays (a) vehicle door to loading bay, (b) detail of loading dock inside loading bay.

(a)

(b)
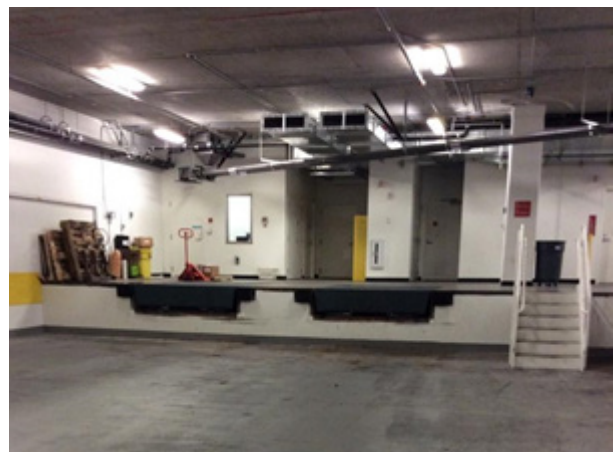
- *Exterior loading dock* (Figure 2). A loading dock that is located outside of the building's exterior walls. Exterior loading docks can be completely open to the sky or partially or completely covered by a canopy or by the upper part of the building. Exterior loading docks can include inside loading platforms, where trucks remain outside but truck's cargo compartment abuts the interior of the building and allows protected movement of the cargo into or out of the building. This typically occurs by a truck backing up to a freight door or in some cases a platform on the side of the building.

Figure 2. Examples of exterior loading docks (a) Exterior loading dock with platform inside building, (b) loading dock with a platform outside the building.

(a)
(b)

- *Exterior loading area* (Figure 3). Space for loading and unloading located outside of the building's exterior walls and without a loading dock. Exterior loading zones can be completely open to the sky, or partially or completely covered by a canopy or the upper part of the building.

Figure 3. Examples of exterior loading areas (a) Loading area accessed from a street, (b) loading area accessed from an alley.

(a)
(b)

A threshold of 2.4 meters (8 feet) for both the (i) vertical clearance and (ii) height of the vehicle door at the loading facilities was chosen. These measurements were established based on the typical height and width of the most common and smallest cargo van typically used for urban goods distribution.

Data Collection Method

To inventory the private freight facilities, the research team developed a systematic data collection methodology using direct observations of infrastructure while standing on public sidewalks and in alleys. The methodology consists of four components: (i) a survey form, (ii) a survey app, (iii) a geolocation capturing process and (iv) a data quality control process.

Survey form
Based on initial walk arounds in urban areas of Seattle, a survey form was designed and piloted tested (see 4 and 5). This survey provided information on what infrastructure attributes were feasible to capture from the public right of way as well as an estimate of the time needed the survey a typical city block. The finalized survey captured three attributes:

1. **Connectivity of the facility to the street network.** The connection of load/unload infrastructure to a street network is an important element of a functional urban freight system. Poor layout or design of roads or alleys that connect this infrastructure to the street network may significantly impact how effectively private freight infrastructure can be used. Addressing this category, the following attributes were collected:
   - Coordinates of the facility (latitude and longitude),
   - The type of road used to access the private infrastructure (e.g. alley, street),
   - The direction of traffic flow on the road used to access the private infrastructure,
   - Name of the street nearest to the surveyed infrastructure, and
   - Whether the infrastructure is inside or outside the building.

2. **Vehicle Access.** The infrastructure's functionality is directly impacted by how vehicles access that infrastructure. Understanding how the vehicles can use the infrastructure is necessary to assess if the facility's physical dimensions are adequate. The following facility attributes were documented:
   - For loading bays, dock doorway dimensions (width and height);
   - Cover over the facility,
   - Maximum height clearance restrictions as posted in visual warning signs;
   - Are vehicles required to back in to use the facility;
   - Is vehicle access entrance perpendicular or at an angle to the travel lane of access roadway
   - Apron space available to maneuver and position vehicles into place at the parking space,
   - Presence of security access measures, such as physical barriers (like a gate), access codes, or personal interaction needed to gain entry; and
   - Level of the infrastructure in respect to the street (above, same level or below street).

3. *Capacity.* This category indicates the maximum number of vehicles and freight delivery operations that the facility can accommodate. Attributes documented include:

- Presence of a dock platform,

- Total number of parking spaces (with and without access to dock platform),

- Number of parking spaces with access to a dock platform,

- Dock platform height, and

- Presence of dock-levelers (adjustable mechanized platform built into the loading dock platform edge that can move vertically or tilt to accommodate trucks).

Figure 4. Part 1 of survey form.

PART 1. Facility Access and Location

1. How is the infrastructure accessed? From a: ☐ Alleyway   ☐ One-way alleyway   ☐ Street

If the answer is "street":
1.1 What is the name of street? _____

If the answer is "alleyway" or "one-way alleyway":
1.2 What is the name of the street closest to where the facility access is located? _____
1.3 Take a photo of alleyway and street intersection.

If the answer is "one-way alleyway":
1.3 Traffic flow direction?

2. Is necessary to through a gate to access the infrastructure?   ☐ Yes   ☐ No

If the answer is "Yes":
2.1 Take picture of gate entrance.
2.2 Horizontal clearance at the gate: _____   2.3 Vertical clearance at the gate: _____
2.3 Capture GPS coordinate of gate by dropping location pin.

3. Are there any visible security measures that limited the usage of the infrastructure by a delivery vehicle?
   (Take picture if there are)

   ☐ Physical barrier   ☐ Access Code   ☐ Personal interaction   ☐ None   ☐ Other: _____

4. Is the infrastructure visible or partially visible?   ☐ Yes   ☐ No

If the answer is "No":
4.1 Is there indication of a space dedicated to loading/unloading? *(Take picture if there is)* ☐ Yes ☐ No
4.2 Proceed to "Part 2.A"

If the answer is "Yes":
4.3 Take a picture of the infrastructure.
4.4 Capture GPS coordinate of infrastructure by dropping location pin.
4.5 What is the level of infrastructure respective to street?

   ☐ Substructure (below street)   ☐ Superstructure (above   ☐ street)   Level with street

   4.5 Is there indication of a space dedicated to loading/unloading ?*(Take picture if there is)* ☐ Yes   ☐ No

   If the answer is "No":
   4.5.1 Proceed to "Form 1"

   If the answer is "Yes":
   4.5.1 Is the infrastructure inside the building?

   If the answer is "Yes":   *If the answer is "No":*
   4.51.1 Proceed to "Part 2.B"   4.51.2 Proceed to "Part 2.C"

PART 2.A - Undefined infrastruc-

5. Is there a door for truck access? ?*(Take picture if there is)* ☐ Yes   ☐ No

   If the answer is "Yes":
   5.1 Input door height _____   5.2 Input door width _____

6. *If there is a sign of maximum vertical clearance allowed to enter the infrastructure:*
   6.1 Take a picture of the clearance sign.   6.2 Input clearance measure.

7. Building address: _____   8. Additional Observations: _____

Figure 5. Part 2 of survey form.

PART 2.B - Loading Bay

10. Access type of the infrastructure vehicle door(s) ☐ Exit ☐ Entrance ☐ Entrance same as exit

If the answer is "Exit":
10.1 Survey ID of the entrance corresponding to this exit door: _____

If the answer is "Entrance":
10.2 Survey ID of the exit corresponding to this entrance door: _____

10.3 Vehicle entrance maneuverability: ☐ Drive-in ☐ Back-in

11. Door angle respective to traffic flow: ☐ Perpendicular ☐ Parallel ☐ Angled contrary to traffic flow

☐ Angled to traffic flow ☐ Angled (lane with bidirectional flow)

12. How many doors 8 x 8 ft. or larger act as the same vehicle door access type surveyed?
Note: *Questions from 13 to 15 repeat as many times as the total number of door.*

13. Door height : _____ 14. Door width: _____

15. *If there is a sign of maximum vertical clearance allowed to enter the infrastructure:*
15.1 Take a picture of the clearance sign. 15.2 Clearance measure _____

16. Total number of truck spaces: _____

17. *If there is a dock:*

17.1 Number of truck spaces with direct access to loading dock platform: _____
17.2 Dock height: _____ 17.3 Take a picture of the dock.

PART 2.C - Exterior Loading Area or Loading Dock

18. Is the infrastructure partially or completely covered? ☐ Yes ☐ No

If the answer is "Yes":
18.1 Minimum clearance between coverture & ground of parking space: _____

19. Is there a dock? (*Take a picture if there is*) ☐ Yes ☐ No

If the answer is "No":
19.1 Total number of truck spaces: _____

If the answer is "Yes":
19.2 Dock height: _____

19.3 Dock angle respective to traffic flow: ☐ Perpendicular ☐ Parallel ☐ Angled contrary to traffic flow

☐ Angled to traffic flow ☐ Angled (lane with bidirectional flow)

19.4 Is there a dock –leveler? (*Take a picture if there is*) ☐ Yes ☐ No

19.5 Is the dock platform behind building walls? ☐ Yes ☐ No

If the answer is "No":
19.5.1 Total number of truck parking spaces : _____
19.5.2 Number of truck spaces with direct access to loading dock platform: _____

If the answer is "Yes":
19.5.3 How many dock doors are there?
Note 1: *If there are more than one dock door take a picture of group of dock doors.*
Note 2: *Questions from 19.5.4 to 19.5.7 repeat as many times as the total number of dock door(s).*

19.5.4. Take picture of dock door. 19.5.5 Door height : _____ 19.5.Door width: _____

Survey app

The research team implemented the survey using a portable computer tablets loaded with ESRI GIS software Survey123, ArcView, and ArcGIS Online. This software offered a seamless data collection tool that not only allows for visualization of the collected data but editing of the data by the data collectors. This feature, in addition to the ability of for the collectors to call up an appropriate base map of the survey site to assist the manual input of the geolocation, made this software an ideal choice for data quality control implementation.

The mobile device data collection survey app (developed from the survey form shown in figures 4 and 5) was implemented using Survey123 app. This app allowed data collectors to collect geopoints in field, enter relevant attributes of the infrastructure, and take pictures of the infrastructure.

Geolocation capturing process

Initially, automatic GPS recordings of a facility's location was considered but urban canyons due to high buildings in the survey area resulted in inaccurate GPS reads. The research team thus collected GPS coordinates (geopoints) manually by dropping a pin within the data collection app on the base map (using World Street from ArcGis.com viewer (17)) at the infrastructure location. This manual input of the infrastructure location was conducted in-field and supported by base maps loaded beforehand and offline. This was an important feature that helped researchers increase the precision and accuracy of the survey.

Quality control process

Data quality control measures were implemented throughout the process. The research team identified the following possible errors:

- **Positional errors** can be caused by either to inaccuracies of GPS coordinate readings due to device issues (e.g. low satellite signal in urban canyons) or mistakes by humans manually collecting this data with tablets.

- **Attribute errors** are associated with non-spatial infrastructure description data collected during the survey such as data entry mistakes buy the data collectors due to wrong measurements or mistyped data. Lack of easy access to a facility information (for example to measure a door) due to obstructions or safety issues could also result in inaccurate data.

- **Conceptual errors** are due to identification and classification of relevant infrastructure or related information using the wrong concepts to describe a real-world phenomenon. For instance, to describe private freight load/unload infrastructure, the authors developed vocabulary and meta data that included concepts such as a "potential freight vehicle loading door" and "door angle respective to traffic flow". These and other concepts, if wrongly used, could lead to errors.

The researchers implemented data quality control measures to address each of these errors during the three stages of the data collection process: before data collection, during data entry, and after data entry. Four types of resources were used to implement data quality control: data collectors, data collection supervisors, survey app, and local parcel carrier knowledge. For instance, the data collection supervisors (the research team) created standard terms and concepts and trained the data collectors. Each data collector received three different training sessions:

1. The first session instructed data collectors in concepts and attributes regarding the private load/unload infrastructure.

2. The second session was an in-field session with focus on practical aspects of data collection, such as how to use the questionnaire in the tablet app and the measurement tools.

3. The third session centered on how to implement data quality-control measures.

Other measures included in the quality control plan were:

1. Data collectors used ArcGIS Online to conduct same-day checks of data collected in field to flag possible mistakes in geolocation and attributes entries. This process compared the coordinates in the database with the data collectors notes on hard-copy paper maps they filled out in field.

2. Data entry constraints and visual aids were coded in the data collection app to limit positional and attribute errors. For instance, only relevant questions of the survey were activated based on responses to previous questions with if-then rules (e.g. if the facility does not have a loading dock platform, then no dock platform height is requested by the app).

3. The research team collaborated with a large national package delivery and supply chain management company, to improve the accuracy of the data. Drivers from this company, with knowledge about the survey area in Seattle, reviewed locations with missing information and suggested data additions and corrections.

Application to Greater Downtown Seattle

The research team inventoried and mapped private load/unload infrastructure in a 3.97 sq. mile area in downtown Seattle, plus three adjacent and rapidly growing neighborhoods: Uptown, South Lake Union and First Hill/Capitol Hill (see Figure 6). The downtown area is home to 70,000 residents and 250,000 jobs and is the region's the largest job center and transportation hub (WSDOT, 2017)

The data collection for the Seattle study area took 440-person hours using hourly university student over 2 months (November 2016 and July 2017). The data collectors worked in teams of two both for security reasons and to perform an efficient operation.   Based on field tests it was found to be more efficient to have one collector using measuring devices, while the other oversaw filling out the survey form.

Results and discussion

Data collection in Seattle's Greater Downtown found in a regular street grid of 944 blocks (each block approximately was 240 ft. x 240 ft) that there was a total of 337 off-street facilities including 174 loading bays, 137 exterior loading docks, and 26 exterior loading areas. Two hundred and seven additional cases were reported as undefined by data collectors because there was not enough information available in the field to confirm if they were load/unload infrastructure. This occurred in these cases such as when a closed door blocked the view of the facility's interior. As noted previously, a parcel carrier company had their local drivers review the closed-door locations that the data collectors could not evaluate. Information from these drivers reduced the 207 undefined facilities (33% of the total inventory) to only 21 locations (less than 1% of the inventory).

Figure 6. Private freight load/unload infrastructure locations in Greater Downtown Seattle.
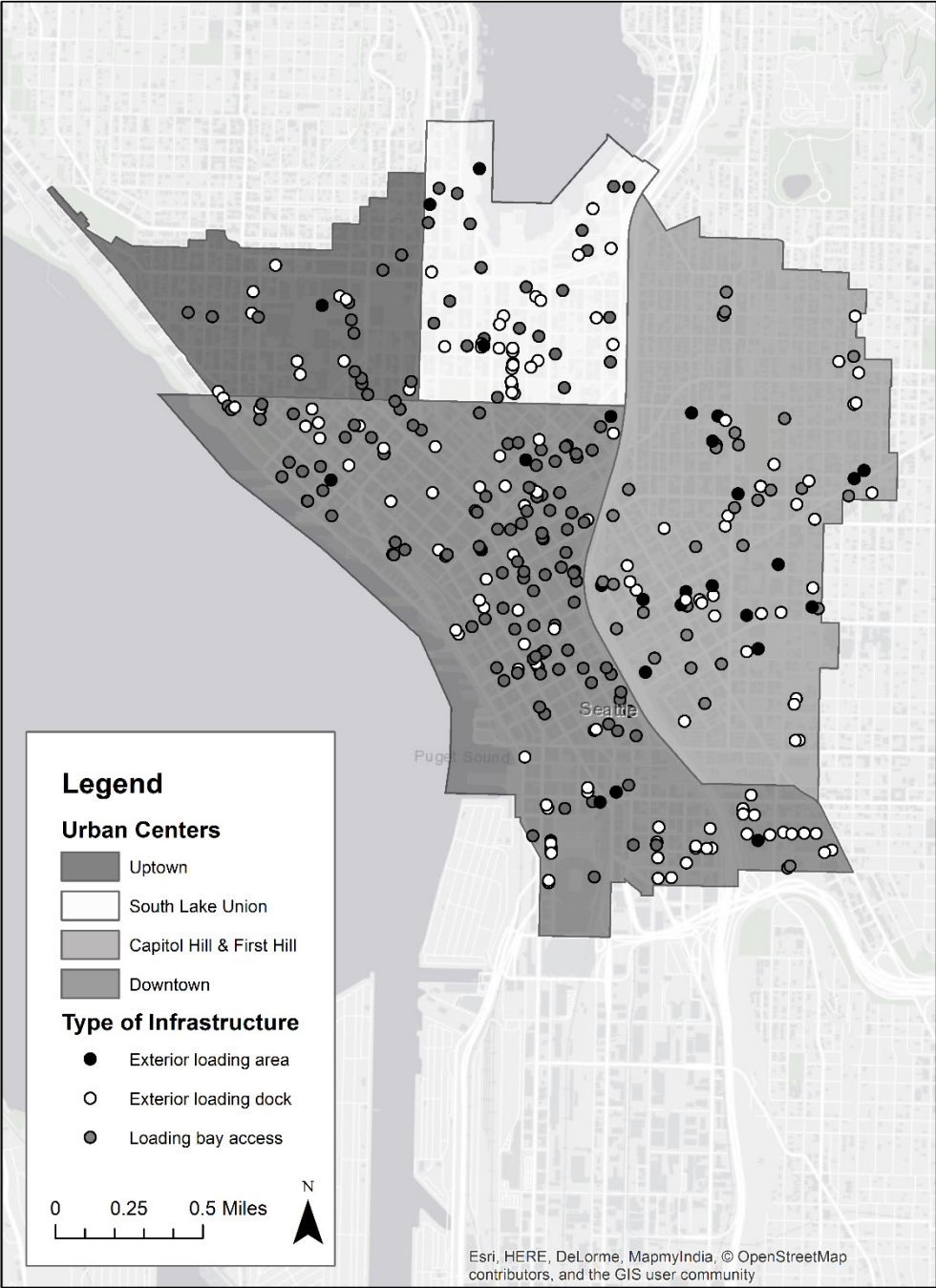
The Seattle case study resulted in findings which are illustrative of the types of detailed and useful information that can be collected using this research's methodology.

Finding #1 - 95% of the buildings in the Greater Downtown do not have private freight faculties and depend on the public load/unload infrastructure. The research team compared the total private infrastructure against the number of buildings located in each study area neighborhood using building level GIS data obtained from the Seattle' open data portal (City of Seattle, 2018). The research team found that only 5% of the buildings have private infrastructure so that suggests that 95% of the buildings in Greater Downtown Seattle need to rely only on on-street commercial vehicle loading zones and alleys for pick-ups and drop-offs of goods.

Finding #2 – The densest part of the study areas show a higher proportion of building that had private freight load/unload infrastructure. Table 1 shows the total of private freight load/unload infrastructure and the proportion of buildings with these facilities in Greater Seattle Downtown aggregated by neighborhood. The neighborhoods with land use that encourage the densest developments and higher employment density (Downtown and South Lake Union) showed the highest percentage of buildings with these facilities (11% and 9%, respectively). Conversely, the more residential / less dense neighborhoods (Capitol Hill/First Hill and Uptown) showed a significantly lower proportion of buildings with private freight loading/unloading infrastructure (around 2%). This suggest that areas with different density and building types have a linkage to the number of private freight faculties.

Table 1. Distribution of private freight load/unload infrastructures and buildings per neighborhood

| Neighborhood	Number of private freight load/unload infrastructure facilities	Number of buildings in 2015	Percentage of buildings with freight facilities (%)	Predominant Land Use	Employment density in 2016 (jobs/ 1,000 square-feet)
Downtown	186	1,685	11%	Mixed-use and, Offices	3.9
South Lake Union	51	557	9%	Mixed-use	2.7
Uptown	23	938	2%	Mixed-Use and Low-rise	1.1
Capitol Hill & First Hill	77	4,181	2%	Low-rise and Midrise	1.1
Total	**337**	**4,039**	**5%**	-	-

Finding #4 - 36% of the private freight load/unload infrastructure is accessed through alleys. Most of the private freight load/unload infrastructure are accessed directly from the street (64%) with the remained being accessed from alleys (36%). This finding highlights the critical role of alleys as a connecting infrastructure that provides access to these private facilities and supports the urban freight network.

Finding #5 - 38% of infrastructures with maximum height clearance restrictions showed enough vertical clearance to allow use by the highest typical single unit truck. The researchers evaluated the distribution of vertical clearance at the infrastructures (Figure 7). For loading bays, vertical clearance refers to the minimum value between maximum height clearance restrictions and vehicle door height. For the rest of the infrastructure types (i.e. exterior loading dock and exterior loading area), vertical clearance was the maximum height clearance restriction. A total of 201 infrastructures showed vertical clearance restrictions. (There were eighteen cases of infrastructures where the vertical clearance could not be measured.) The remaining 118 infrastructures did not have canopies or any other elements that limited vertical clearance.

The infrastructures' vertical clearance restrictions ranged between 2.4 m (8ft.) and 7.3 m (24 ft.) with average height of 4 m (13 ft.). To put these numbers into context, the maximum height of design vehicles considered in the 2001 AASHTO Green Book is 4.1 meters (13.5 feet) (i.e., the maximum design height for single unit trucks in the market) (Harwood et al., 2003). The dimensions of AASHTO's design vehicles represent a composite of the vehicles currently in operation.

This finding showed that in the Seattle study area, 38% of the facilities with maximum height clearance restrictions showed enough vertical clearance for vehicles with the maximum height as considered in the 2001 AASHTO Green Book. This indicates vertical clearance is not a major limitation for truck access to most private freight infrastructure in Seattle.

Fig. 7. Histogram of vertical clearance.
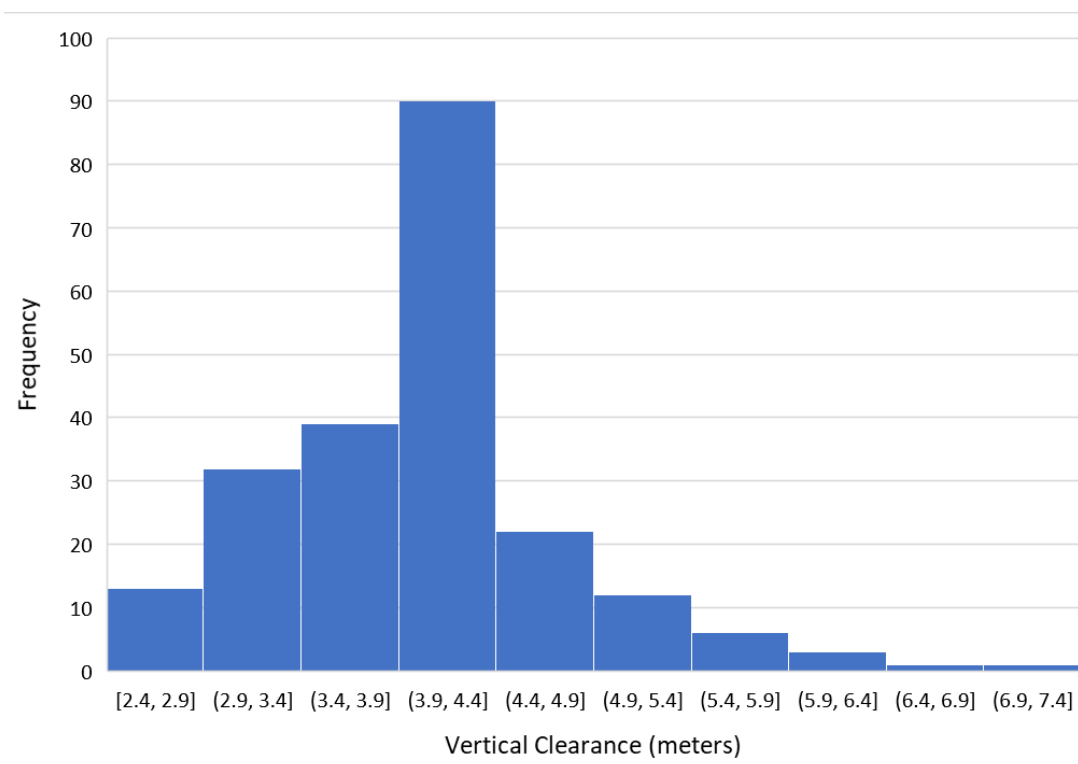
Finding #6 – 42% of private freight load/unload infrastructure required vehicles to back into them. Backing can be a challenge for trucks but this survey found much of the infrastructure requires backing. But in Seattle, for safety reasons, backing into street traffic and into alleys are prohibited by the municipal regulation. This finding calls attention to a disconnect between infrastructure design and regulations which may be relevant for freight policy improvements.

Conclusions and Recommendations

Information about the location and physical characteristics of private freight load/unload infrastructure are not available for use by policymakers and stakeholders. These elements increase capacity, and, when the characteristics of the demand is matched with the infrastructure, service quality to all roadway users can be improved. As a result, an essential piece of the urban freight network, has been missing from the approaches taken by many cities to improve the urban freight transportation system. Without this information, current solutions to allocate the curbside resource are potentially suboptimal leading to increase traffic, reduce quality of service to customers, and increase costs for carriers. This research helps address this concern and supports efforts to make urban freight delivery more efficient in the increasingly dense and constrained urban areas.

As cities aim to mitigate conflicts between freight and servicing trips with other users of the road by encouraging that these operations happen off-street, data on existing facilities helps to understand the magnitude of the efforts that lay head. Data collection in Seattle's Greater Downtown 944 block area found that there was a total of 337 private freight load/unload facilities. With this information, it can be determined that 92% of buildings rely on public, on-street infrastructure for freight deliveries. As Seattle's current building stock has limited private spaces available on site and the construction of new facilities will not happen overnight, planning efforts should focus on making the most out of the existing facilities. Examples of initiatives include creating incentives to share these freight facilities between buildings, consider the feasibility of these spaces to serve as micro hubs for sustainable urban logistics or reuse unprofitable surface parking as alternative delivery locations.

Adequate access to freight load/unload infrastructures relies on the physical characteristics of these infrastructures and the nearby streets, alleys, sidewalks, and buildings. The constraints and competition for space in such dense urban environments should carefully considering entrance maneuvers of vehicles and the appropriately use of advanced infrastructure designs such as rotary platforms that allow trucks to turn around in small spaces.

Assessment of the degree of harmonization between the current delivery vehicle dimensions and infrastructure they service is a crucial step of any policy that addresses private freight load/unload infrastructures. This includes providing:

1. the adequate access dimensions (e.g., loading bay doors dimension), space to maneuver (e.g., apron),

2. capacity to accommodate the volume and vehicle type (e.g., parking space dimensions, dock's height), and

3. an effective connecting design between the facilities and the public right-of-way (i.e., streets, sidewalks and alleys).

This research provides a practice-ready data collection tools that can be readily implemented in other cities to support the development of research, planning and policy strategies to improve the urban freight transportation. Furthermore, this research results in the first urban inventory of private freight load/unload infrastructure which has been shown to be a valuable resource for the City of Seattle that can be used to better understand and plan for the urban freight system.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available in a repository or online in accordance with funder data retention policies.

Seattle Department of Transportation. 2017. Freight Loading Bay and Dock, GIS Datasets. URL: https://gisdata.seattle.gov/server/rest/services/SDOT/SDOT_Freight/MapServer

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