Bringing alleys to light: An urban freight infrastructure viewpoint

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ABSTRACT

There is growing pressure in cities to unlock the potential of every public infrastructure element as density and demand for urban resources increase. Despite their historical role as providing access to land uses for freight and servicing, alleys have not been studied as a resource in modern freight access planning. The authors developed a replicable data collection method to build and maintain an alley inventory and operations study focused on commercial vehicles. A Seattle Case study showed that 40% of the urban center city blocks have an alley. 90% of those alleys are wide enough to accommodate only a single lane for commercial vehicles. 437 parking operations were recorded in seven alleys during business hours and found that all alleys were vacant 50% of the time. This confirms that, in its alleys, Seattle has a valuable resource as both space for freight load/unload; and direct access to parking facilities and business entrances for commercial, private, and emergency response vehicles. However, alley design features and the prevalence of parking facilities accessed through the alley may restrict the freight load/unload space in the alley. Future efforts should investigate how to better manage these infrastructures.

1. Introduction

The challenges faced by different transportation network users in dense and constrained urban areas are expected to increase as urbanized populations and concentrations of commercial activities increase (Dablanc, 2009; Nourinejad et al., 2014; Rodrigue et al., 2009; USDOT, 2015). Therefore, there is growing pressure in cities to unlock the potential of every public infrastructure element to address the increasing demand for public space.

Particularly, freight and servicing trips require the supply of adequate infrastructure to support vehicle access, load/unload activities, and final delivery/service to customers (Dablanc, 2007). However, existing infrastructure attributes (e.g., width, height clearance, road infrastructure barriers) and the accommodation of street furniture (e.g., street lights, bollards, benches, green infrastructure, power lines) may not meet the dimensional requirement to support the commercial and emergency operations. Additionally, potential conflicts with vulnerable transportation network users (e.g., passenger vehicles, pedestrians, and cyclists) may impact the efficiency and safety of these operations.

Despite their historical role as providing access to land uses for freight and servicing, to a large extent, alleys are overlooked as a resource in modern freight access planning. No major city in North America has a comprehensive geospatial database of its alley network. There is no literature about the current nature of commercial vehicle

operations in these spaces. Without that knowledge, it is impossible to understand the capabilities of these infrastructures as part of the transportation infrastructure network, nor is it possible to conduct comprehensive urban freight planning.

Alleys can provide access to land uses and parking infrastructure for freight, service vehicles, emergency and passenger vehicles, as well as cyclists and pedestrians. This is particularly true for cities with extensive alley networks. For instance, the city of Chicago, Illinois, has approximately 1900 miles of alleys. The City of Los Angeles, California, has an estimated alley network of more than 900 miles, and Baltimore's alley network encompasses over 600 miles (Newell et al., 2013). Moreover, the City of Vancouver has 404 miles of alleys (Ardis, 2014), City of Montreal 280 miles (Plourde-Archer, 2013), City of Toronto 194 miles, and Beijing, China, 1204 hutongs or alleys (Leinonen, 2012).

The City of Seattle, like many cities, lacks accurate, up-to-date and, detailed information on the location and features of its alleys, and the operations occurring on them. Meanwhile, the city faces both urgent- and longer-term pressures to better manage alleys as part of the larger urban freight infrastructure. With a population of 725,000 and a density of 8350 residents per square mile, in 2018, Seattle was the sixth most congested city in the USA (Cookson, 2018; Guy, 2018). Since 2010, Seattle has grown by 18.7%, becoming the fastest growing city in the decade among the 50 largest U.S. cities (Guy, 2018). At the same time, the city is expected to grow by 120,000 additional inhabitants and

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115,000 additional jobs by 2035 (OPCD, 2018). Seattle's unprecedented growth and geographic constraints set up a significant challenge for the municipality to efficiently meet the demands for the movement of people, services, and goods. In its alleys, Seattle is fortunate to have a resource that not all cities have, providing a "back door" to the city.

This research focuses on the alley's role as a network connector, its physical attributes and constraints, and its use by parked vehicles. To the knowledge of the research team, this effort has resulted in the nation's first comprehensive alley inventory with an accurate GIS map of the network's geospatial locations as well as measurements of physical attributes (e.g., alley length, alley width and, narrowest points). The attributes collected in this study directly impact alley operations and functionality, particularly for commercial and emergency vehicle access. Before this time, the city relied on a countywide street network database that only included alley centerlines.

To gain an evidence-based understanding of the existing parking behaviors in alleys in Seattle, data collectors recorded use patterns for every vehicle occupying the alley during observation periods. The data collected include vehicle type, parking duration, and, consequently, how long and at what times of day alleys were vacant.

The remainder of this paper is structured as follows; a literature review section discusses the role of alleys in cities worldwide based on academic journal articles, city guidelines, manuals and city planning documents. The data collection method section describes the alley inventory and occupancy methods developed. The Seattle case study section describes the empirical findings from the approach implementation in the City of Seattle. The paper concludes with a summary of findings and recommendations for policymakers.

2. Concept of the alley and predominant roles

Alleys are narrow pathways between or behind buildings functioning like a **narrow street or path** with walls on both sides (Cambridge Dictionary, n.d.). Alleys are referred to by many different names in the literature. The term laneway is usually used in Canada, UK, and Australia; mews, in UK; and hutongs in China. Alleys range from the pre-car era designs when cities needed to be walkable to post-automobile alleys in North America offering access to motorized vehicles (Wolch et al., 2010).

Alleys primary role is **connectivity** rather than mobility (Bain et al., 2012), providing access to land use either for motorized mode, non-motorize modes, or both. They have different spatial infrastructure characteristics than streets. Alleys' narrow width and location between buildings give them a volumetric attribute (i.e., length, width and vertical clearance attributes) that is often missing in a multilane street (Bain et al., 2012).

For alleys with vehicle presence, often, there is only enough space for one vehicle to drive through the alley. That means that few vehicles use them, and those vehicles are traveling low speeds. In these cases, as spaces with low traffic volumes and speeds, the alley may be the perfect candidate for shared use with non-motorized modes. However, alley's physical constraints may lead to conflicts between users as the demand for these spaces and the need for access alley's adjacent land use. For instance, during the periods where large vehicles are present, alleys can become inaccessible to other users, such as pedestrians (NACTO, n.d.).

For alleys operate as **shared streets**, the usage of bollards, signs, and design features help to make clear the intended alley users (NACTO, 2013). Hutongs are examples of non-motorized shared spaces. They consist of narrow streets, single-floor or low-rise courtyard buildings, and a highly connected street grid that facilitates walking and cycling and limits motorized traffic (Zhao, 2014). Similarly, woonerfs in the Netherlands act as shared streets and can be described as cul-de-sacs with highly restricted automobile access that privileges activities such as biking and walking (Wolch et al., 2010).

In some countries such as the U.S., U.K., and Canada, alleys have been predominantly designed to have a **utilitarian, freight and emergency access function** (Ardis, 2014); providing access to the rear of large lots and space for garbage cans, utilities, and other everyday aspects of living (Ford, 2001; HPO, 2014). In early Washington D.C., the back of the lots likely had kitchens, stables, carts, wagons, and animals in addition to other dependency buildings, equipment, and storage areas (HPO, 2014). Chicago's alleys saw servants and suppliers working in middle-class areas and small manufacturing, repair shops, rear houses, and children's play space in working-class areas (Conzen, 2005).

In some cities such as Montreal and London, where great fires consumed much of their buildings, planners turned to alleys not only as service streets but as firebreaks, and new standards were established for widths, construction and building heights on alleys (Ardis, 2014). Additionally, today's fire codes regulations establish the right-of-way minimum dimensions requirements. The International Fire Code indicates that lanes shall provide emergency vehicles an "unobstructed width of not less than 20 feet and an unobstructed vertical clearance of not less than 13 feet 6 inches" (International Code Council, 2015).

More recently, some cities are turning into alleys to reach the goal of reducing environmental impact. The City of Chicago, IL, pioneered their Green Alley Program in 2006 (Chicago Department of Transportation, 2007), after which other cities such as Washington DC followed (District Department of Transportation, n.d.). These programs strategies such as the management of stormwater and the mitigation of the urban heat island effect (the increased temperatures in urban or metropolitan areas due to human activities) and the implementation of permeable asphalt (Newell et al., 2013).

Alleys have also served as **inhabited spaces**. For instance, in the late 19th century and following the Civil War, a large influx of poor urban migrants resulted in an increase of substandard alley dwellings (Wolch et al., 2010) in the United States. Some contemporary cities have recently passed zoning regulations that encourage housing density in alleys. Mainly, alley houses are a growing trend in Canadian urban centers such as Toronto (Mathieu, 2019) and Vancouver (City of Vancouver, n.d.).

Alleys can serve as **functional social spaces** that foster community cohesion by offering a safe place for active recreation, pedestrian activity, community gatherings and events. For instance, the City of Sydney's, Australia, Laneways Temporary Art Program ran between 2008 and 2013 to "inject new energy into the urban life and stimulate creativity and innovation in the city" (City of Sydney, n.d.). In Seattle, more than 5000 people attended alley events as part of the Alley Network Project between 2008 and 2012. Seattle's alley events and projects have included art and poetry events, lighting installations, pet adoption events, holiday caroling, and film and sport event screenings (Majid et al., 2015; Stenning and Somers, 2012).

Some alleys, often located in commercial areas, can support **commercial development** by providing space for outdoor dining, additional entrances to neighboring businesses or could become tourist destinations, increasing adjacent property values. In some locations in China and Europe, old alleys have survived urban planning makeovers to become cherished elements of contemporary cities. Beijing's 1204 hutongs have great historical value and have recently received renewed commercial interest from the real estate and tourism industries (González Martínez, 2016). Similarly, mews in London hosts some of the most desirable addresses in the city and have become a tourist attraction in and of themselves (Ardis, 2014).

3. Empirical studies of alleys

The following summarizes studies that have used direct observations as part of their approach to document alley characteristics and vehicle activities in cities worldwide.

Several studies have investigated alley space with a focus on surrounding buildings in China and the U.S. Two of Beijing's alleys showed in their premises building types such as lodging, educational,

commercial and residential (Yao and Xin, 2018). In Washington D.C., alley dwellings have been studied at different times of the city's history. In 1896 and 1912, two investigations documented dwellings in 35 and 275 alleys, respectively. More recently, in 2011, the District of Columbia Office of Planning conducted the D.C. Historic Alley Building Survey. It was designed to identify extant alley buildings determined to be 50 years or older in over 15 historic districts (HPO, 2014). These studies share the limitation that infrastructure physical attributes and vehicle use characteristics of the alleys were not investigated.

Motivated by an evaluation of the appropriateness of alley housing in Toronto, an alley inventory was conducted that documented which alleys were public, private and are serviced by the city for snow removal or salting (City of Toronto, 2006). The study identified 2433 alleys and their lengths, but it acknowledges that outstanding work remains to validating alley classifications and completing field confirmation of alley characteristics. The report provides estimates of alley widths, typically between 16 and 19 ft, and allowing passage for a single vehicle in one direction. The connectivity role of alleys, providing vehicular access to the rear of lots, is considered as their main function. City services in Toronto alleys include regular services generally limited to litter pick-up/cleaning during the spring, summer and fall seasons, and salting in the winter months to provide safe passable conditions after snow events. However, city-wide snow plowing operation is not feasible in alleys due to constrained operating conditions and the absence of snow storage space (City of Toronto, 2006).

In the City of Los Angeles, Wolch et al. (2010) conducted physical audits of 300 alleys and behavioral observations of activities inside alleys. Alleys were selected for audits by dividing the total population of 12,309 alleys into the city's thirty-six Community Planning Areas and applying a random stratified sampling approach. Based on the distribution of LA's alleys, most of them are in residential zones (58%) followed by commercial districts (20%), industrial zones (6%) and zones with other land uses (9%) (Wolch et al., 2010).

Wolch et al.'s physical audit instrument was the Systematic Pedestrian and Cycling Environmental Scan for Alleys, which includes 14 questions divided into three sections concerning: i) surrounding land uses ii) substrate and iii) use, conditions, and safety. Wolch et al.'s behavioral observations were conducted in 30 alleys during weekdays and weekends and consisted of 12 observation periods per alley of 5–10 min each. Based on this study, access by vehicles was a prominent use of LA's alleys.

Also, in Los Angeles, Seymour and Trindle (2015) quantified the different uses in one renovated and one control alley. The alleys were located one block away from each other and primarily surrounded by commercial land uses and one residential building with offices.

Focused on commercial vehicle curbside loading, Transportation for London (2017) published guidelines for facility size required for freight vehicle parking and navigation and specified strategies for reducing multimodal conflicts at the curb. Although still under development, the guide considers a street audit and provides examples of adequate baseline data that would be gathered in the audit, including the number of vehicle lanes, waiting and loading restrictions, multimodal facilities, and primary vehicle accesses for premises.

There is a growing pressure in cities to expand upon the current purpose of their alleys and better use underutilized alleys to encourage housing density, create lively spaces, pedestrian and bicycle connectors, and spaces for delivery vehicles to load and unload. As cities aim to incorporate in their plans the increase in connectivity for non-motorized modes and other functions provided by alleys, research on alleys as elements of urban structure and dynamics is warranted (Wolch et al., 2010).

By deprioritizing vehicle access, some of these initiatives can have unintended consequences for freight and emergency vehicles access if the current and future use of alleys by these vehicles is not explicitly considered. Meanwhile, there is limited coverage of freight and emergency vehicles in guidelines for multimodal streets (NYSERDA, 2019).

The literature review of empirical studies in alleys showed that some alley features had been researched including adjacent building types, number of access points, pavement type, and slope. Related to activities in alleys, previous studies documented uses by vehicles and non-motorized modes. Despite these efforts, alleys have not been the subject of any comprehensive study focused on commercial and emergency response vehicle activities, including those of freight, waste management, servicing, firefighting, and police vehicles. Thus, little is known about the physical characteristics that could preclude vehicle movements in these spaces. Additionally, the existing studies do not capture sufficient data about vehicle operations in alleys including type of vehicle and stop durations.

In the Seattle case, the City's Right-of-Way Improvement Manual considers that the primary purpose of commercial alleys is to provide access for freight loading, waste collection for commercial uses, and parking (City of Seattle, n.d.-b). However, Seattle's alley advocates are working to change the idea that alleys should be solely utilitarian (Miguel, 2015). A study about Seattle's alleys in 2010 estimated that reinvigorating alleyways could increase the amount of total public space in the city by 50% (Fialko and Hampton, 2011).

As Seattle and other cities investigate repurposing and better using underutilized alleys, an adequate assessment of physical characteristics and vehicle activities in these spaces is key to determine what is feasible in terms of street design and freight and emergency vehicle adaptation.

4. Data collection method

4.1. Alley inventory

The research team developed a data collection process to collect the locations and features of all alleys in Seattle's Greater Downtown area, which produces a replicable ground-truthed data collection method based on direct observations.

4.1.1. Survey form

The developed survey captures three types of features:

1. *Connectivity to Street Network*. Constrained and congested alleys can push onto the street the queue of vehicles trying to access the alleys or force the driver to cruise for adequate space to park. Additionally, sometimes, alleys are the only access route to particular land use. The study included these characteristics:
   - Name of streets that the alley connects to,
   - Whether the alley is connected to a one-way or two-way street,
   - Whether the alley is one-way or two-way traffic, and
   - The direction of one-way alleys.
   The connectivity to the street network of an alley will depend on its end-points. An **end-point** of an alley is defined as the point where an alley begins or ends. By definition, every alley has two end-points; each of them falls in one of the following categories (see Fig. 1):
   A. **Access Point**: End-point located at the block face of a city block, connecting the alley directly to the street network. This is the most common example of an end-point. Often, there will be buildings on either side of the alley's access point, but in some cases, there may be vacant lots or surface parking lots.
   B. **Dead End**: End-point where an alley ends at a dead-end, such as a building or a staircase. There are three subtypes of alley dead-ends:
      1. Dead end ending at a physical barrier,
      2. Dead-end at a driveway, which could lead to private or public infrastructure, and
      3. Dead end at an open area (private or public property), such as a public square.
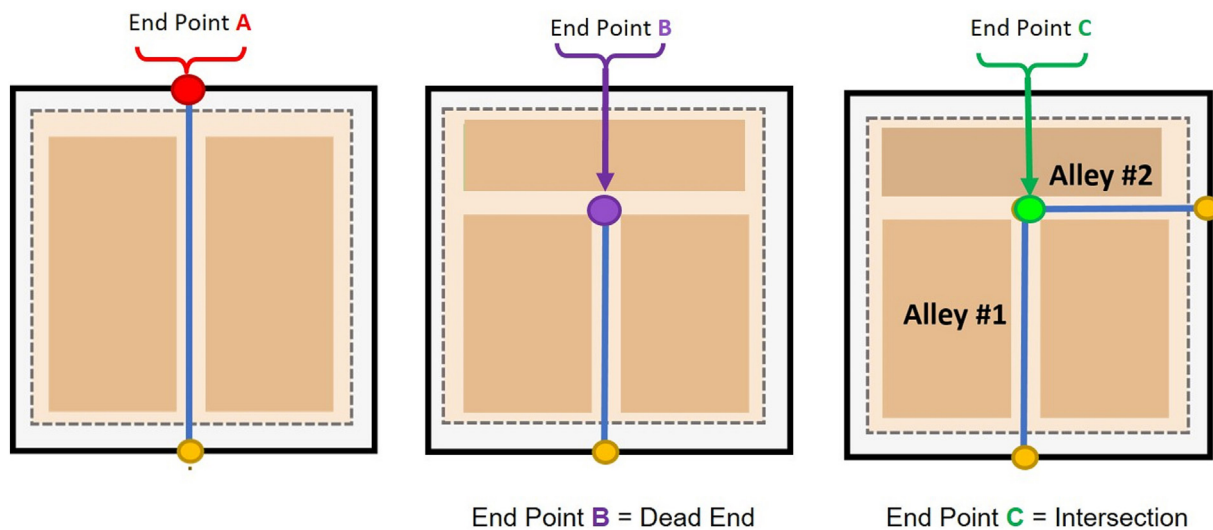   C. **Intersection**: End-point where two alleys intersect inside a city block.

Fig. 1. Alley end-point classification.

2. *Design*. The way an alley is designed has a direct impact on its functionality. The inventory examined design features at the alley end-points, alley aprons, and alley interiors.

Alley **end-point** features include width and height with measures recorded as the smallest width (i.e., effective width) and height within 30′ from the alley entrance. Researchers used the 30′ threshold because it captures the bumper-to-bumper length of most cargo vans and trucks conducting deliveries.

The alley **apron** is a driveway (an entranceway) that starts at the curb and continues until the start of the alley pavement. The apron edge uses a curb cut to provide vehicle access from the street. Apron width, length, and cross slope were recorded; slope can determine whether fully loaded handcarts can maneuver.

Alley's **interior** features measured included alley length (end-point to end-point), pavement surface type (e.g., concrete or asphalt), narrowest point, and fixed overhead obstructions. As most emergency vehicles are 16 ft tall or under, the researchers documented any fixed overhead obstructions under that threshold (such as trees, fire escapes, wires). The research team also recorded any fixed on-the-ground obstructions that protrude 1′ or more into the alley, as this impacts an alley effective width.

3. *Access*. The features below were included to capture the infrastructure to which the alleys provide access to, and that may impact its use:

- Driveways connected to the alleys, including each driveway that grants access to a parking lot; driveways that link the alley with a nearby street; and driveways that connect the alley to private property.
- Location of buildings' main entrances.
- Private freight load/unload infrastructure.
- Passenger parking, if visible or signed.
- Restrictions on alley usage, as shown on posted signs.

It is important to note that all alley features measured in this study were chosen in consultation with the Seattle Department of Transportation (SDOT) and other City agencies, including police, fire, ambulance, and public utilities. These groups depend on alleys to provide access for commercial and emergency response vehicles to buildings.

4.1.2. Data collection mobile app and instruments

This research included the development of a mobile data collection app that we have made publicly available online (SCTL, 2018). The team implemented the survey form and data-collection process on tablets using Esri GIS software Survey123, ArcView, and ArcGIS Online. These Esri products offer a data-collection tool with features that facilitate data quality control, such as visualization and editing of the collected data. Additionally, Survey123 allows the selection of the most appropriate basemap to assist the geolocation input, which was manually collected as a GPS coordinate reading by dropping a pin in the basemap. For this project, the research team selected the World Street basemap from ArcGis.com viewer that was last updated in July of 2017 (ESRI, 2017) to assist the manual input of the infrastructures' location.

For accurate measurements, data collection teams were equipped with a measuring wheel and a laser device. The first one was used to collected alley length (typically the longest measure). Every other Design feature was collected with a Laser measuring device.

4.1.3. Data quality control

The research team set up a quality control process to reduce errors from entering and propagating within the database. This helped to ensure the quality of the data before it was collected, entered, or analyzed; it also helped to monitor and maintain the data through the collection effort. The team identified the types and possible sources of error specific to this type of project including:

1. **Positional error** refers to the inaccuracies of the GPS coordinate readings due to device issues (e.g., low satellite signals in urban canyons) and mistakes by humans manually collecting this data with tablets.
2. **Attribute error** is associated with the remaining non-spatial alley data collected with the survey. Some examples are incorrect data entry due to wrong measurements or data mistyped. Lack of access to the information due to obstructions or safety issues may also result in inaccurate data.
3. **Conceptual error**. The description of a real-world phenomenon or object such as an alley requires its conceptualization through identification and classification of relevant information. Concepts wrongly used can result in information misclassified and not captured information.

Table 1 below shows the developed project data quality-control design to address the three types of errors above. Table 1 illustrates the measures implemented in three stages: before data collection, during data entry, and after data entry. Three types of resources carried out quality-control procedures throughout the three stages:

1. **Supervisors**: responsible for defining and enforcing data-collection

Table 1
Data quality control measures.

	Stage 1. Before collection		Stage 2. During data entry		Stage 3. After data entry	
	In office	In field	In field	Survey app	In office	Supervisor(s)
	Supervisor(s)	Supervisor(s)	Collector(s)		Collector(s)	
Positional	- Establish physical reference of geopoints	- Deliver training session to collectors about GPS location collection with survey app	- Instructed to be always aware of their location - Keep track of surveyed alley locations with hard copies of maps	- Includes manual collection of GPS reading by dropping location pin - Includes updated base map with city blocks, building outlines, King County TNET alleys and loading bays in alleys.	- Conduct same-day check of surveyed alley locations by reviewing alley endpoints in ArcGIS Online - Check street names of alley endpoints - Check alley TNET id the alley exists in King County's TNET database	- Check alleys in TNET database to identify alleys not visited (i.e. missed)
Attributes (infrastructure features)	- Build questionaries' data entry constrains in survey app - Deliver theoretical training session to data collector	- Deliver training session on data collection with survey app and measurement devices regarding infrastructure features	- Take clear photos to aid data entries	- Includes visual and written aid for data fields	- Conduct same-day check of data collected in field using ArcGIS Online platform	- Check numeric fields for outliers - Conduct revisits to missing alley locations
Conceptual (infrastructure concepts)	- Establish metadata and vocabulary related to the surveyed infrastructure - Deliver theoretical training to collector	- Train collectors in field on how to identify infrastructure relevant to the survey	- Write open-ended comments, take additional pictures and use "Other" categories for "undefined" cases	NA = not applicable	NA = not applicable	- Resolve collectors' observations - Check classification of alley endpoint types with pictures collected and basemap in ArcGIS Online

NA = not applicable

Table 2
Types of vehicles for alley occupancy study.

I. Commercial vehicles (CV)
a. Delivery vehicles
  a.1 Trailer truck (T)

  a.2 Single unit truck – Box truck (B)

  a.3 Cargo van (CV)

  a.4 Cargo-bike (C)

b. Waste management trucks (G)

c. Service vehicles (SV)[a]

d. General van (V)[b]

e. Construction vehicles (C)

II. Passenger vehicles
a. Passenger vehicle making a package or food delivery (D)[c]

b. Vehicle making a passenger drop-off (e.g. Uber/Lyft) (U)

c. Passenger vehicle (P)

III. Other categories

Table 2 (*continued*)

a. Taxi (X)

b. Motorcycle (M)

c. Buses (B)

d. Emergency vehicles (E)

[a] Service vehicles include single-unit, vans, sedans and pick-ups vehicles used for service operations.
[b] Cargo or service vans usually display a company logo. If there was not enough information visible, vehicle was marked as a general van.
[c] A personal vehicle being used to deliver packages (such as Amazon Prime Now) or food (such as Amazon Fresh).

standards and methodology; training the data collectors; and monitoring and maintaining the database. They handled the data-control measures implemented before data collection and after data entry.

2. **Collectors**: responsible for data entry in-field and carrying out same-day data quality-control checks after data entry.
3. **Survey app**: the digital and online tool that helped create entry constraints, eases the digitization of the data as it is collected and ends the need for manual information digitalization. The survey app played a critical quality-control role because it was programmed to limit inaccuracies in the data-entry stage by considering the data structure rules, attributes, and relationships.

4.1.4. Data collector training

The research team recruited and trained 32 data collectors, who worked in teams of two to improve security conditions and enable efficient operation of the multiple data-collection instruments (e.g., laser measurement device, measuring wheel, tables). As data quality control measure, data collectors received approximately 5 h of training in three different sessions covering the following topics:

1. *Concepts regarding the infrastructure surveyed*: This session instructed data collectors in alley concepts and the features. This session was given in a classroom-type setting, with a slide presentation that covered every feature collected in the survey.
2. *Practical aspects of data collection*: This session was done in-field, leading the collectors through the process of collecting data, such as how to use the questionnaire in the tablet and the measuring tools. Special attention was paid to teach how to take accurate measurements with the laser and wheel devices and how to divide the collection work between the data collectors effectively.
3. *Data quality control tasks*: The final session centered on how to implement the data-cleaning process. After every shift in-field, one of the data collectors in each pair cleaned the data he/she just collected.

4.2. Alley occupancy

Occupancy data included use patterns such as how long vehicles were parked in alleys, how long and what times of day alleys were vacant, and what types of vehicles were parking in alleys. Observations

were made during business days hours (i.e., Monday through Friday from 8 am to 5 pm). Using human data collectors to track alley usage allowed for the reliable capture of important details, such as windshield permit stickers and company names on vehicles.

4.2.1. Survey form and instruments

Each data collector was stationed at one of two positions in the alley. Each alley was divided in half, with each data collector covering three or four zones that met roughly in the middle of the alley. To aid with the identification of zones, detailed maps of the alleys subject of study were created. These zones allowed data collectors to quickly determine and record wherein the alley, a vehicle was parked.

Any vehicle parked in the alley for 1 min or more was recorded manually in field using hard copies of data-collection sheets and maps specifically tailored to each alley and data collector's position. The data-collection sheet was divided by zone, with space for the data collector to record:

- The start/end time a vehicle spent parked in the alley (recorded to the minute);
- The type of vehicle parked in the alley;
- If visible, the company name for commercial vehicles parked in the alley; and
- If visible, the presence of a commercial permit on a passenger vehicle parked in the alley.
- If visible, the Uber/Lyft logo on a passenger vehicle parked in the alley.

The research team designed a highly detailed commercial vehicle typology to track specific vehicle categories (see Table 2). The typology covers 16 separate vehicle categories, from various types of commercial vehicles to passenger vehicles. For this research, the term commercial vehicle includes trailers, box trucks, cargo vans, cargo vans, service vehicles, waste management trucks, and construction vehicles. In the case of passenger vehicles, data collectors tracked, whenever possible, if the drivers were conducting the specific activities of goods delivery/pick-up or passenger pick-up/drop off. If relevant, collectors also tracked the presence of an Uber/Lyft logo and the company name.
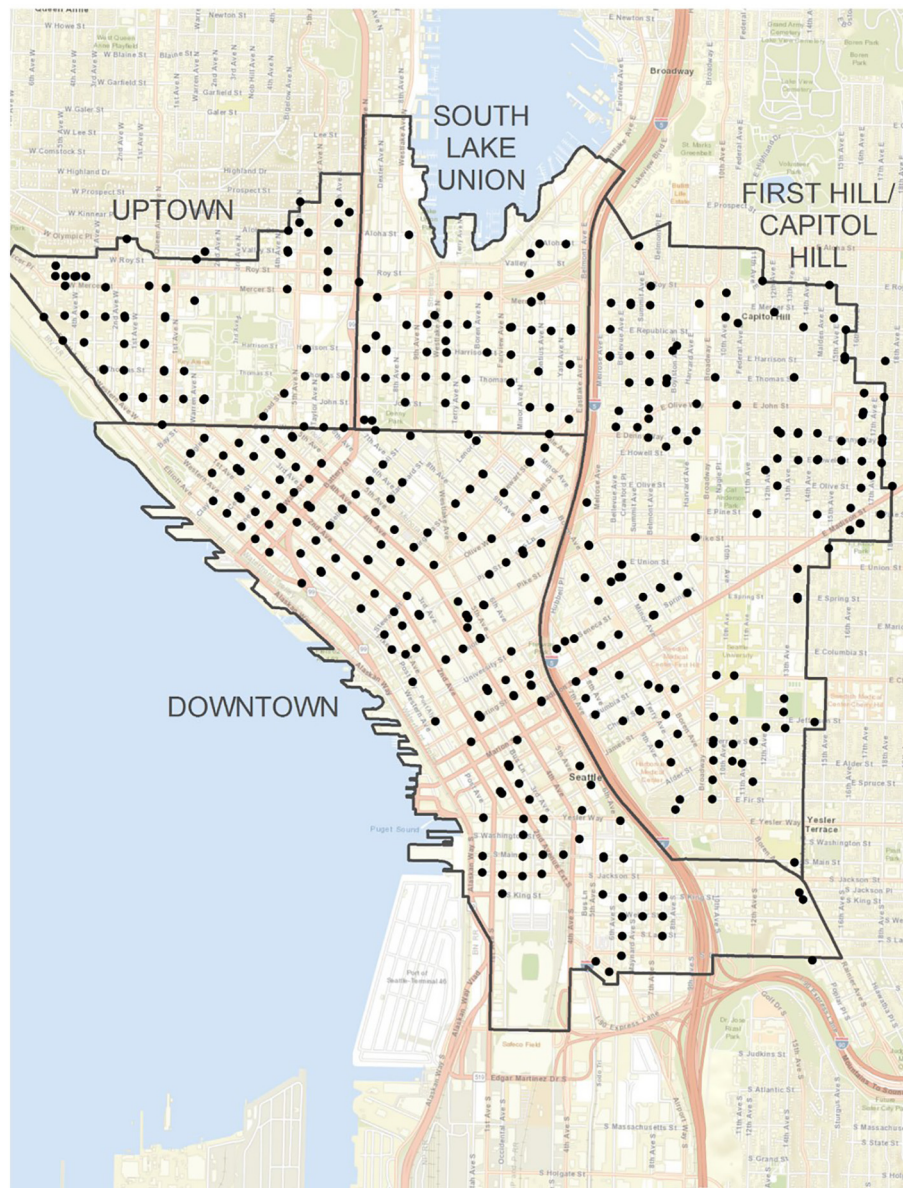
Fig. 2. Map of the Greater Downtown Area alleys surveyed. Dots represent the alley end-point. Note: Map scale forces dots to overlap, so not all 417 alley end-points are discernible.

4.2.2. Data collector training

As a data quality control measure, data collectors received approximately 3 h of training in two different sessions:

1. *Theoretical training session.* This session was given in a classroom-type setting, with a slide presentation. It instructed data collectors on the data collection on the following aspects of the data collection effort:
   - The study parameters,
   - The typology of vehicles,
   - The data collection method,
   - Review of data collection forms and collector's position in-field.
2. *In-field training session.* This session was done in-field, leading the data collectors through the actual process of collecting data and applying the vehicle typology. Finally, data collectors did a 20-min data collection exercise and classified vehicles that parked in the alley while being supervised.

5. Case study of Seattle

5.1. Application of the alley inventory and observation methodologies

The research team applied the alley inventory and alley observation methods in the Greater Downtown area of Seattle. For the alley inventory, the researchers completed the data collection over three weeks in January 2018. Data collectors walked 941 city blocks to examine and collect data on the 417 Greater Downtown area alleys (see Fig. 2). Data collectors were unable to obtain full information inside 6% of all Greater Downtown area alleys, most commonly because construction activity in or near the alley resulted in the alley being closed or fenced off. Less frequently, a truck operating in the alley did not give the data collectors enough room to record measurements safely and accurately.

Seven alleys were selected for the alley occupancy study. Some alleys provide access to off-street passenger car garages, some connect to drive-through hotel entrances, and some are used mostly for commercial purposes. Each alley as shown in Table 3 was chosen to represent various features (such as the number of access points for freight or

Table 3
Alley locations for occupancy study.

Alley #	Location	Surrounding land use	# of days surveyed	Time frame surveyed	Total hours surveyed
1	From Virginia to Lenora Streets, between 4th and 5th Avenues	Two hotels; surface parking lot; one residential building; and one office building.	4	8:00 am to 5:00 pm	36
2	From Stewart to Virginia Streets, between 4th and 5th Avenues	Residential tower, commercial businesses; and surface parking lot.	3	8:00 am to 5:00 pm	27
3	From Columbia to Marion Streets, between 2nd and 3rd Avenues	Restaurants, offices and a public parking garage.	3	8:00 am to 5:00 pm	27
4	From Harrison to Thomas Streets, between Terry and Westlake Avenues	Offices and restaurants.	4	8:00 am to 5:00 pm	27
5	From Union to Pike Streets, between 1st and 2nd Avenues	A hostel, retailers, and restaurants.	1	8:00 am to 5:00 pm	9
6	From Pine to Stewart Streets, between 2nd and 3rd Avenues	Temporary construction, restaurants and retailers.	3	8:00 am to 5:00 pm	27
7	From Union to Pike Streets, between 4th and 5th Avenues	Hotel and retailers.	3	8:00 am to 5:00 pm	36

passenger parking); characteristics (pavement type, alley width, overall condition); and location (some are near—and therefore serve—office buildings, retail centers, residential buildings, or some mix of these).

Additionally, substantial development is projected adjacent to two of the observed alleys (#1 and #2). Four new residential towers will add over 2000 apartment units and approximately 1000 off-street parking stalls that will be accessed through alleys (SDCI, n.d.). Currently, these alleys serve several land uses including hotels, surface parking lots, residential buildings and businesses (see Table 3).

The research team deployed data collectors to observe the seven alleys and apply the granular vehicle typology introduced in Table 2. Six out of the seven alleys were observed for three or four days for two weeks in February and March 2018. The remaining alley was observed for one day due to security issues. The data collected provided a sample of 437 parking operations between the seven alleys.

6. Results and discussion

6.1. Alley infrastructure feature findings based on alley inventory

6.1.1. Alley effective width: 90% of the alleys in the Greater Downtown area are just one-lane wide

Fig. 3 shows the distribution of alley widths measured as the narrowest alley end-point width. In practice, most of Greater Downtown area alleys are restricted to one lane for trucks, cargo and service vans. As box trucks are roughly 9.5 ft wide (including mirrors) and delivery vans are typically 8.8 ft wide, alleys up to 19-ft-wide provide only one lane for commercial vehicle use.

This fact is critically important to measure the load/unload capacity of the city's alleys. When a truck, car, or van parks in a one-lane alley, it blocks all other vehicles there unless they back into the alley to park, or back out of the alley to exit. Backing into street traffic and backing up into alleys are both prohibited by the Seattle Municipal code for safety reasons (City of Seattle, n.d.-a).

Additionally, horizontal restrictions inside the alley can reduce the alley's overall capacity. 10% of the alleys showed within-alley restrictions that reduced alley travel width by more than 1 ft due to overhead or on-the-ground fixed obstructions.

Based on alley width estimates in other cities, Seattle's alleys resemble those in Toronto, which are typically between 16 and 19 ft (City of Toronto, 2006). On the other hand, Seattle's alleys are slightly wider than Beijing inner city's hutongs (10–16 ft) (Zacharias et al., 2015).

6.1.2. Points of access to land use: 73% of Greater Downtown area alleys contain entrances to passenger parking facilities

Data collectors recorded all parking facility access points in each alley. Of the 417 Greater Downtown area alleys, 311 alleys (or almost 75%) contain entrances to passenger parking facilities. This within-alley passenger parking access suggests an increased frequency of vehicle entry/exit and added demands on alley use. This is important to note because these alleys cannot, therefore, be allocated solely to commercial and emergency vehicles.

The typical parking facility types found were underground garages, covered surface-level garages, and open-air surface parking lots. The covered facilities often had more than one access point in an alley, such as a separate entrance and exit. A total of 767 parking facility access points across 311 alleys were recorded.

About 33% of the alleys served at least one private freight load/unload infrastructure inside the alley. Of those, 75% also contained at least one parking facility access point. In other words, about 25% of the 417 surveyed alleys contain both freight and passenger parking facility access points. This suggests a confluence of potentially competing users in these alleys.

In some cases, albeit rarer, data collectors identified a private building entrance (for people, not vehicles) located inside an alley. Of the 417 alleys surveyed, 29 contained one private building entrance.
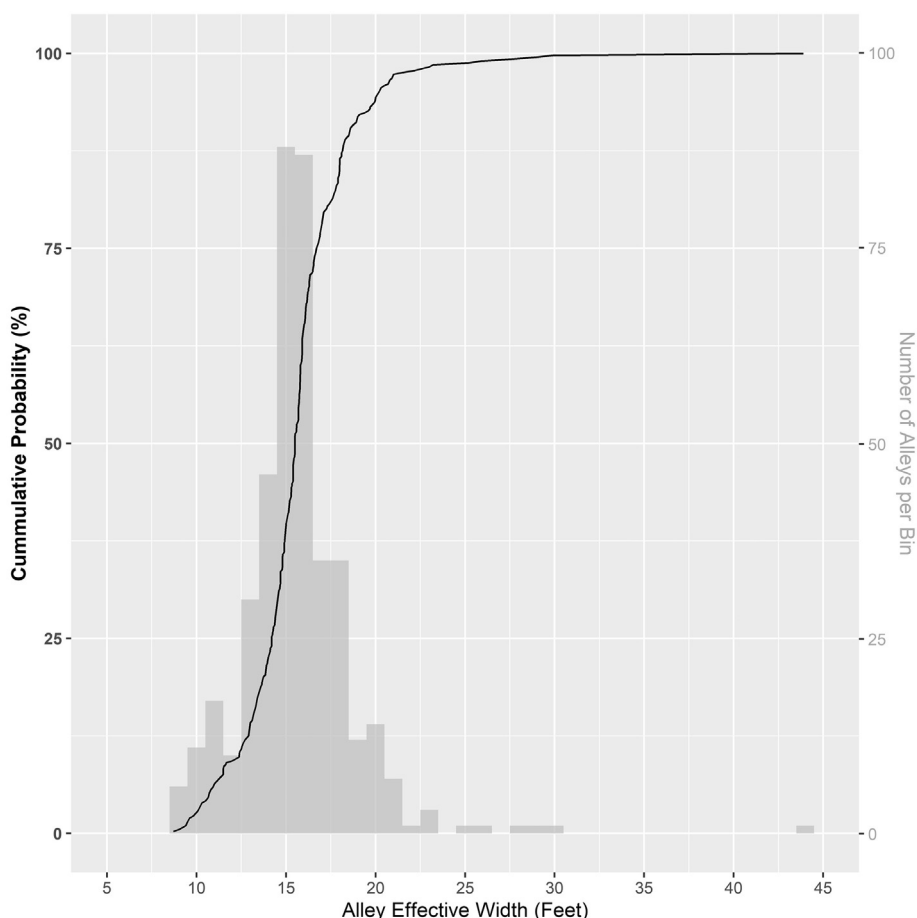
Fig. 3. Cumulative probability and histogram of alley effective widths in Seattle Greater Downtown Area. Note: The figure represents 408 of 417 total alleys because nine alleys were missing alley width values.

Local policies in Seattle consider alleys as primary means for access to the rear of homes, apartment buildings and businesses. Alleys are prioritized for delivery and servicing-vehicle access and allow expedited load/unloads up to 30 min. At the same time, Washington State Legislation considers that "no person shall stop, stand, or park a vehicle within an alley in such position as to block the driveway entrance to any abutting property" (Washington State Legislature, n.d.).

These policies could lead to incongruencies in commercial vehicle operations in alleys such as that parking is not allowed at all. This results from the combination of two of the findings of the alley inventory, alleys are narrow and frequently show vehicle access points to land uses. Therefore, alley blockages impact vehicles parked in the alley but can also limit access to private parking facilities for passenger and freight.

6.1.3. Infrastructure conditions: building managers' proactive role in alley maintenance

Our studied exposed anecdotal evidence that some building managers demonstrated a proactive role in the maintenance and managing of the alleys adjacent to their property by either:

- Enforcing rules to ensure intended use,
- Providing security cameras and/or staff,
- Placing speed bumps to slow traffic,
- Getting pavement improvements completed, and
- Placing signage to identify different usage areas and vehicle circulation rules clearly.

One example of this is shown in Fig. 4. The recently constructed

buildings on both sides of the alley are owned and managed by the same company. During the design phase of these mixed office/retail buildings, deliberate steps were taken to ensure the alley (although publicly owned) was designed to accommodate both truck deliveries to the alley's two loading bays as well as regular passenger vehicle traffic for the two parking garages accessed via the alley. Notably, the alley is signed one-way for passenger vehicles while still allowing trucks to travel in both directions. Also, the alley has a pedestrian crosswalk connecting two building entrances, a wide width, speed bumps, clear sight-lines, surveillance cameras, and frequent building security patrols.

6.1.4. Alley signage: wide variety of restrictions signage found in Seattle's alleys

22% of alleys had signage indicating some type of use restriction of the space. The types of restrictions found are listed below and it is worth noting that 5% of alleys showed one-way sings.

- One-way traffic direction
- customer and resident parking rules,
- no parking restrictions,
- load/unload parking,
- construction signs,
- garbage bin location rules,
- alley closures,
- access restrictions to non-local traffic,
- pedestrian access restrictions,
- no trespassing and littering,
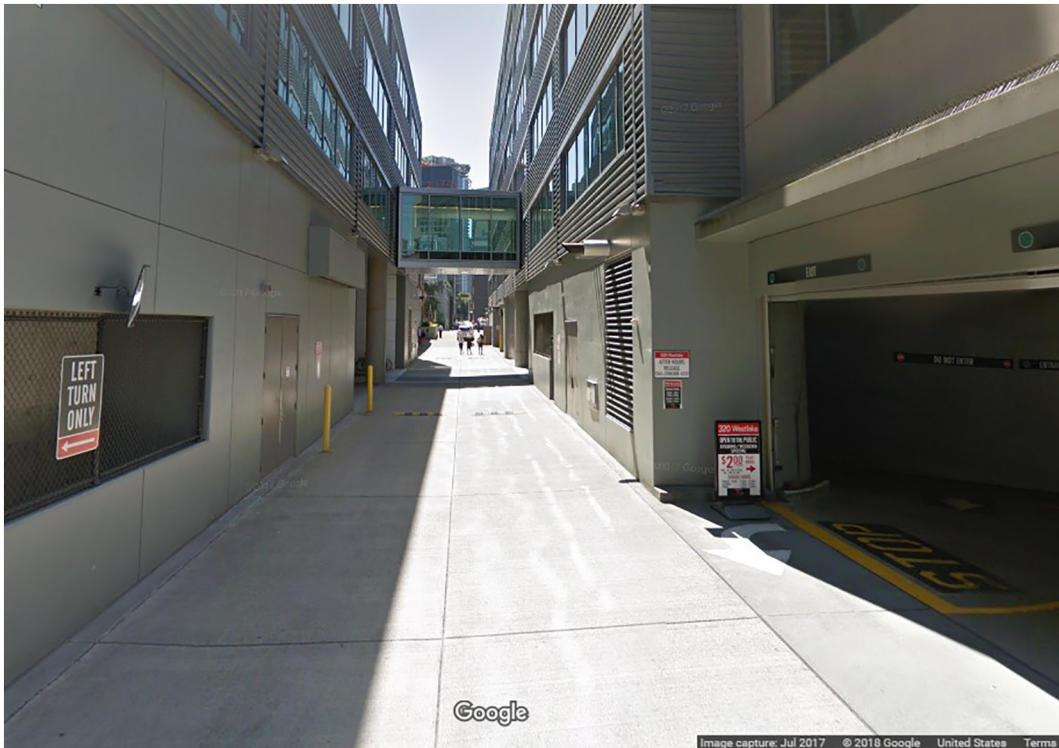- fire lane - do not block area,
- maximum vertical clearance.

Fig. 4. Alley in South Lake Union, Seattle, with a high level of ownership from the developer.
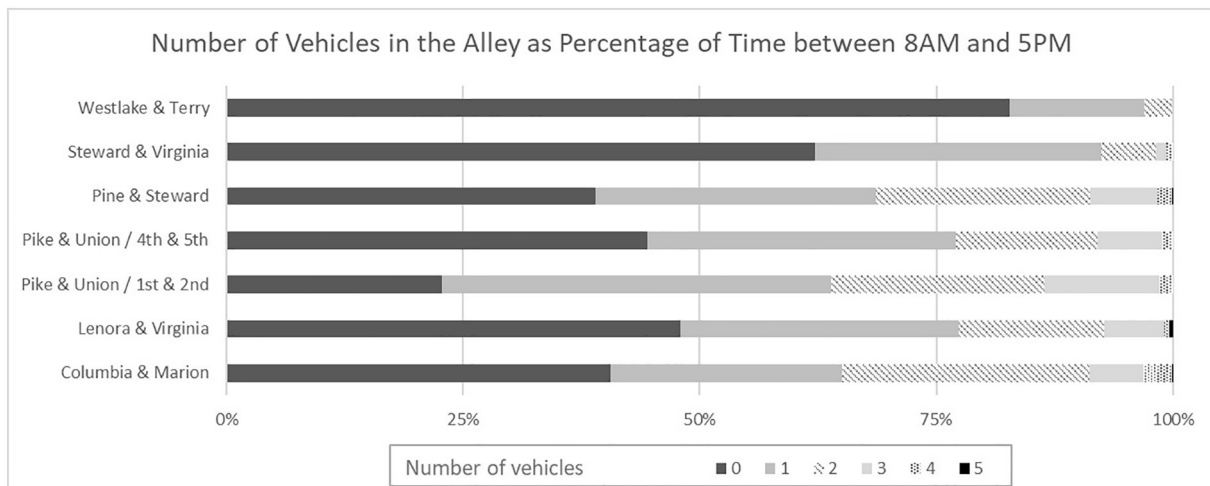Source: Imagery ©2018 Google.

Fig. 5. Average occupancy level of alleys over the observation study period. Note: Pike & Union/1st & 2nd alley shows occupancy level of the alley between 8 AM and 5 PM based on one day of data collection. The remaining six alleys show average occupancy level based on 3–4 days of data collection.

Most of alleys are less than 19-ft wide but only 5% of them showed one-way signs, this could lead to unsafe situations caused by vehicles backing out of alleys. Defining entering and exiting routes for vehicles and clear signage are measures to avoid these situations.

The proportion of alleys with signage was lower in Seattle than in LA, when compared to Wolch et al.'s (2010) study, which showed that 65% of LA's alleys had signage concerning parking, dumping, dog waste, and trespassing, It is worth noting that some of the categories of restrictions were similar in both cities, and Seattle showed additional types related to deliveries, fire lane, circulation restrictions, vertical clearance and temporary restrictions such as alley closures and construction zones.

6.2. Alley usage findings based on alley occupancy study

6.2.1. Observed demand: parking per alley is typically limited to less than three commercial vehicles

The authors investigated the occupancy of the seven alleys by parked vehicles. Six levels of occupancy were considered ranging between 0 vehicles (vacant) and five vehicles parked at the alley at the same time. For each alley and day of data collection, the proportion of time that the alley had the different levels of occupancy was calculated. Fig. 5 shows proportion of time that each alley showed different number of vehicles averaged between the days of data collection.

The occupancy study finds that all seven study alleys predominately had just one to two vehicles parked at a time. Higher occupancy levels of three or more vehicles were observed only during a small fraction of

Table 4
Dwell time distribution by vehicle types for all seven alleys studied.

Vehicles type	No. of vehicles observed	15 min or less	15–30 min	30 min–1 h	More than 1 h	Total share of parked vehicles
Trucks and cargo vans	229	30.0%	12.6%	6.2%	3.6%	**52.4%**
Service vehicles	31	6.0%	0.9%	–	0.2%	**7.1%**
General van	42	5.7%	2.5%	0.9%	0.5%	**9.6%**
Passenger	86	16.9%	1.8%	0.5%	0.5%	**19.7%**
Passenger making a delivery (only when logo was visible, or activity was observed)	15	2.8%	0.2%	0.2%	0.2%	**3.4%**
Garbage truck	17	3.4%	0.5%	–	–	**3.9%**
Uber/Lyft (only when logo was visible)	1	0.2%	–	–	–	**0.2%**
Others	15	1.6%	0.5%	0.7%	0.7%	**3.4%**
Unknown	1	0.2%	–	–	–	**0.2%**
Total	**437**	**66.8%**	**19.0%**	**8.5%**	**5.7%**	**100%**

time in each of the seven alleys. The proportion of time with three or more vehicles averaged 8% between the seven alleys, and the maximum observed was 14% at the alley located at Pike & Union /1st & 2nd.

6.2.2. Level of vehicle activity: alleys are vacant about half of the time during the business day

As shown in Fig. 5, the seven alleys were unoccupied between 23% and 83% of the studied hours. The percentage of time that the seven alleys were empty averaged 50%.

6.2.3. Vehicle dwell time: 68% of all vehicles parked in alleys were there for 15 min or less

Even more, 87% of vehicles were parked in alleys for 30 min or less (see Table 4), which is the time limit considered by the Seattle Municipal Code. In general, the most frequent alley users were truck and cargo vans, at 54% of all recorded vehicles. The second-most-frequent alley users were passenger vehicles, at nearly 20%.

Since six out of the seven alleys were 17 ft wide or less, some of these parking operations could be considered as not allowed in the sense that one vehicle could block access to land uses from the alley for several minutes. Preserving alley access function may become crucial as some city blocks in downtown Seattle will accommodate new and dense growth. Policies should be in place to ensure best practices are followed for alley operations and design of access points in alleys for parking garages and loading bays in buildings.

7. Conclusion and policy recommendations

There is growing pressure in cities worldwide to find innovative ways to better manage and use scarce space. Cities increasingly recognize the potential to incorporate the increase in resources provided by functional alleys for environmental, economic and social benefits. As the literature review of this research shows that cities have try to unlock the potential of this urban infrastructure element using different approaches. Netherlands' woonerfs or alleys illustrate the implementation of shared-street schemes to improve alleys as connectors for pedestrians and bicycles. Beijing's hutongs exemplify the potential of historic alleys to become touristic attractions and enhance commercial development. Also, some Canadian cities have recently passed zoning regulations to encourage housing density in center city alleys.

As we promote connectivity for non-motorized modes in these spaces is essential to acknowledge their function of providing access for utilitarian, freight and emergency responses vehicles. Despite this important function that many alleys play, our literature review shows that alleys have not been the subject of a comprehensive study focused on physical characteristics that can preclude the movement of vehicles particularly vehicles providing these services (e.g., freight, waste management, service and fire truck). Additionally, studies related to activities in alleys do not capture sufficient data about vehicle operations including type of vehicle and stop durations. To address this gap

in the understanding of alleys and help communities assess and plan alley utilization and management, our research provides with:

1. A data collection methodology to support an adequate assessment of physical attributes that directly impact alley operations and functionality, particularly for freight, waste management, and emergency vehicle access.
2. The demonstration of our alley inventory methodology in Seattle that results in the first comprehensive alley inventory in North America with an accurate GIS map of the network's geospatial locations as well as measurements of physical characteristics.
3. Evidence-based understanding of existing vehicle parking behaviors in alleys based on occupancy studies in seven alleys in the Seattle's densest area.

This research also elaborates recommendations that cites can use to better manage alley space and unlock of these infrastructures. As illustrated by Seattle's alleys, their narrow width and location between buildings with multiple access points to parking facilities and pedestrian entrances can limit vehicle operations in these spaces. Usage of these spaces by delivery vehicles such as box trucks (typically 9.5-ft wide) can lead to blockages of the entire alley for vehicles trying to access buildings in the premises or parking in the alley. To avoid unsafe situations caused by vehicles backing out of alleys, entering and exiting routes in all one-lane alleys should be defined with clearly posted operating rules.

Cities can use the information provided by a comprehensive scan of physical characteristics of urban alleys to make data driven decisions about the most cost-effective freight distribution systems for the last mile. Geospatial information of alley restricting dimensions such as effective height and width can help to decide between delivery vehicle designs that balance maneuverability, size and load capacity.

As illustrated by the occupancy study in seven alleys in Seattle's densest area, these spaces can be vacant (without parked vehicles) a significant fraction of the time be typically used by up to two parked vehicles simultaneously. There is a potential for alleys to be used as a flexible and dynamic space that adapts to different uses and users throughout the day, including vehicle accessing land uses, space for load/unload, and nonmotorized modes such as pedestrians and bicycles.

The data quality control plans considered in this research did not include the application of validity and reliability scores, future applications of the alley inventory and observation tools could consider these scores to add to the robustness of the methodology.

This research adds evidence that alley networks are a valuable resource as both space for freight load/unload; and direct access to parking facilities and business entrances for commercial, private, and emergency response vehicles. We encourage future research to investigate how to effectively allocate alley space for load/unload, access to buildings and parking facilities and other uses.

Author statement

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Declaration of competing interest

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