Transportation Research Part A 211 (2026) 105122

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Commercial Vehicle Load Zone programs in US cities

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ARTICLE INFO

Keywords:
Curb management
Commercial vehicle load zones
Freight parking
City logistics
Parking policy

ABSTRACT

The rapid growth of commercial vehicle traffic in urban areas has increased competition for limited curb space, prompting cities to implement curb management strategies targeting freight transport demand. A Commercial Vehicle Load Zone (CVLZ) program is defined as a collection of infrastructure, policy, and regulatory strategies adopted by public agencies to manage commercial vehicle access and facilitate loading/unloading and provision of services in urban areas. This study identifies and reviews CVLZ programs from 13 US cities, performing a comparative analysis from a policy, regulatory, and infrastructure planning perspective.

The analysis reveals substantial heterogeneity in the allocation and regulation of curb access for freight vehicles. Differences arise in how cities classify load zones, define eligible users, determine allocation processes, and monetize them. Infrastructure data show that most cities allocate less than one percent of their curb space to freight, though denser and more clustered networks appear in cities like Seattle and San Francisco.

The study contributes a first formal definition and typology of CVLZ programs, providing a foundation for future research on freight curb management, including questions about optimal pricing, spatial allocation, and the adaptation of curb policies to emerging zero-emission and micromobility freight modes.

1. Introduction

The widespread use of personal and connected devices has accelerated online shopping, increasing commercial vehicle trips to residential and business areas. These vehicles depend on curb lanes for parking and completing the last 50 feet of delivery (Dalla Chiara et al., 2021). Yet, growing curb demand—also driven by ride-hailing, food delivery, and micromobility—has not been matched by greater curb availability. Although Complete Streets-inspired urban design standards have enhanced street livability, they often overlook freight needs, worsening curb shortages (Conway, 2018). This imbalance amplifies congestion, cruising for parking, and unsafe practices such as double parking and overstays, undermining safety and logistics sustainability. Limited curb access also makes the last mile the most expensive stage of supply chains, affecting both the urban economy and quality of life (Universal Postal Union (UPU), 2021).

To address these issues, public agencies have implemented various strategies for managing commercial vehicles. Historically,

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https://doi.org/10.1016/j.tra.2026.105122
Received 10 December 2025; Received in revised form 27 April 2026; Accepted 15 June 2026
Available online 25 June 2026
0965-8564/

urban transport policies focused on passenger mobility, giving little attention to freight. Earlier urban logistics policies aimed to control vehicle access to urban areas already suffering from passenger vehicle traffic. The most common approaches were vehicle and time window restrictions, which allowed heavy vehicles to operate only at certain times of the day or in restricted areas (Quak, 2009).

With the introduction of passenger paid parking zones, cities started developing curb management programs aimed at influencing travel behaviors, controlling curb demand, and reducing parking externalities such as cruising for parking. As cities increasingly recognized the role of the curb lane not as a place to store vehicles, but as a dynamic, service-oriented infrastructure necessary to support passenger pick-up, drop-off, deliveries, and building services, many of these programs expanded to include commercial vehicles. This shift has led to the emergence of what are hereafter referred to as *Commercial Vehicle Load Zone programs*, which recognize the importance of allocating curb space to commercial vehicles to support freight and service access and mobility needs.

1.1. Defining Commercial Vehicle Load Zone (CVLZ) programs

A Commercial Vehicle Load Zone (CVLZ) program consists of a collection of infrastructure, policy, and regulatory strategies adopted by public agencies to manage commercial vehicle access and facilitate loading/unloading and provision of services in urban areas. Fig. 1 summarizes the main initiatives adopted by cities within these programs.

Infrastructure strategies form the foundation of CVLZ programs and involve allocating *load zones* (LZs)—curb spaces designated for commercial vehicle parking and deliveries. These strategies determine how much curb space to dedicate, where to locate LZs, and the rationale behind their placement. They also include design considerations such as zone length, blockface positioning, and monitoring systems like curb sensors and video cameras.

Policy strategies define who can use LZs and under what conditions. Cities may designate different types of LZs for specific users and apply payment systems or pricing schemes, such as permits or pay-per-use models. Policies increasingly employ intelligent parking systems (IPS) leveraging monitoring infrastructure to provide parking information, guidance, and reservation capabilities (Dalla Chiara et al., 2022).

Regulatory strategies govern LZ use and depend on effective enforcement. Typical rules specify maximum parking durations and hours of restriction. Their success relies on enforcement methods—such as automated detection—and the severity of penalties like fines for violations.

1.2. Research objectives

While prior studies indicate that curb management strategies can mitigate negative externalities from commercial vehicle operations, existing CVLZ programs remain poorly documented, with limited evaluation or data collection. Public information on their design, features, and LZ network infrastructure is often incomplete or inconsistent across jurisdictions. Moreover, significant variation across cities has produced a range of approaches with little standardization or formal guidance.

This study addresses these gaps by defining, identifying, and characterizing CVLZ programs across US cities. It documents current practices in commercial curb management, highlights similarities and differences in approaches, and analyzes the infrastructure supporting these programs. Accordingly, the paper investigates the overarching research question:

How is curb parking for commercial vehicles managed in US cities?

This question is explored through three thematic sub-questions:

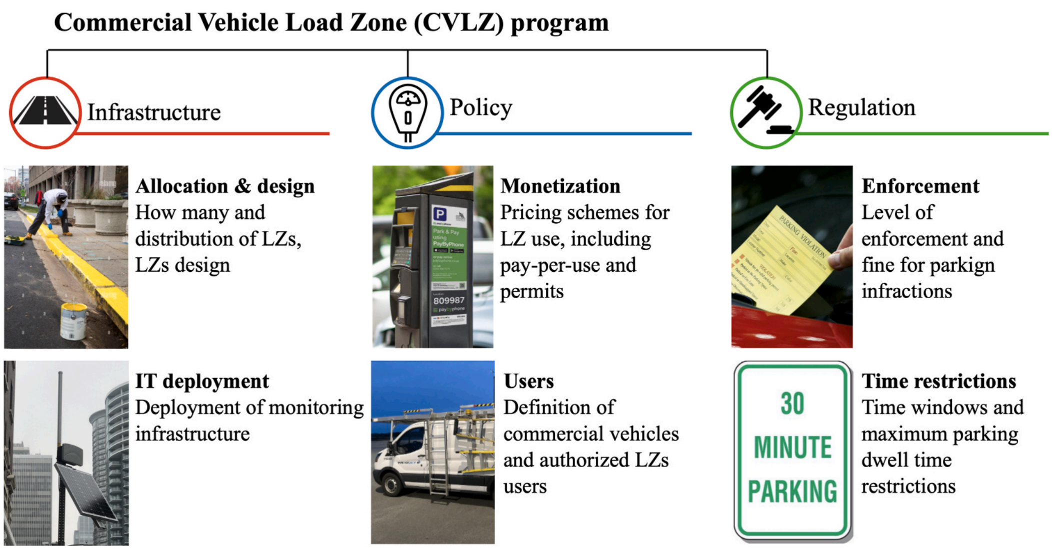

Fig. 1. Infrastructure, policy, and regulatory strategies often included in Commercial Vehicle Load Zone (CVLZ) programs.

- *Policy perspective*: What types of LZs exist, who is authorized to use them, and how are they priced and monetized?
- *Regulatory perspective*: How are LZs monitored and enforced?
- *Infrastructure perspective*: How much curb space is allocated to LZs, and what are the topological properties of LZ networks?

To answer these questions, CVLZ programs from 13 US cities were identified. For each city, data describing program policies, regulations, and infrastructure were collected from municipal codes, planning documents, city websites, and open data portals. A comparative analysis identified program characteristics, commonalities, and differences, as well as the influence of socio-economic and urban form factors on design and implementation. Geospatial data describing the location and characteristics of LZs were also processed to analyze network topology and allocation patterns.

The study's aim is not to assess program effectiveness but to systematically describe how cities are responding to increasing commercial curb demand. By documenting current practices, it seeks to inform policymakers and researchers about emerging strategies, challenges, and opportunities in commercial curb management, as well as how CVLZ programs influence urban mobility infrastructure. Following the policy transfer theory (Marsden and Stead, 2011), the authors hope that by documenting CVLZ programs across cities, other public jurisdictions can find inspiration and replicate some of the approaches described below. Additionally, the work aims to encourage further research to better understand these methods of managing commercial vehicle parking. Although there is a growing body of literature on urban freight access to the curb, these studies often propose solutions without fully capturing what cities are currently testing and implementing. The authors aim to bridge academic research with practical application through this work, providing a foundation for discussions on which approaches and methods researchers should focus on to better support policy development.

The remainder of the paper is organized as follows. Section 2 reviews relevant literature and outlines this study's contribution. Section 3 describes the methodology, including terminology, data sources, city selection, and analytical approach. The results are then divided into two sections: policy and regulatory analysis (Section 4), infrastructure analysis (Section 5), and case study analysis (Section 6). The paper concludes with a summary of key findings and a discussion of policy and infrastructure implications.

2. Relevant literature

The scientific literature on city logistics highlights the importance of designating curb zones for commercial vehicle parking and loading/unloading. Amer and Chow (2017) proposed an analytical equilibrium model for on-street parking, considering both passenger and truck parking (Amer and Chow, 2017). It emphasized the importance of assigning curb zones to commercial vehicles along with appropriate parking fees for passenger vehicles: using Toronto as a case study, they found that reserving 4.1% of parking spaces for trucks and charging CAD $8 per hour for passenger parking maximizes social welfare. Comi et al. (2022) applied a discrete-event simulation model in Santander, Spain, to identify optimal curb space allocations for commercial vehicles and quantify deviations from current configurations (Comi et al., Dec. 2022). Alho et al. (2018) employed microsimulation to assess performance improvements from optimal LZ allocation, finding that double parking and delays could be reduced, though enforcement and compliance were critical (Alho et al., 2018). Similarly, Nourinejad et al. (2014) developed an integrated parking behavior-simulation model showing that prohibiting freight curb parking increases search time and walking distances, while permitting curb access reduces both (Nourinejad et al., 2014).

Beyond analytical and simulation approaches, more recent studies have empirically measured the benefits of LZ deployment through direct pilot testing, experiment design, and data collection. Dalla Chiara and Goodchild (2020) used GPS data from parcel delivery operations in Seattle to show that the presence of a LZ reduced cruising-for-parking time by up to 6.5% (Dalla Chiara and Goodchild, 2020). In Zapopan, Mexico, Mora-Quinones et al. (2024) estimated through a field experiment that introducing LZs led to a 3.6% reduction in air pollution and a 14% reduction in noise in treated areas compared to control sites (Mora-Quiñones et al., 2024).

Other research has explored broader curb management strategies beyond space allocation. Castrellon and Sanchez-Diaz (2024) emphasized that managing curb space for freight requires complementary policies such as information sharing, parking duration limits, and enforcement (Castrellon and Sanchez-Diaz, 2024). Enforcement itself has been identified as a key determinant of curb allocation effectiveness (Alho et al., 2014; Nourinejad and Roorda, Aug. 2017; Fransoo et al., Jun. 2022). Fransoo et al. (2022) conducted a field experiment in Queretaro, Mexico, showing that restricting unauthorized vehicles from LZs increased parking availability and reduced delivery time by 44% (Fransoo et al., Jun. 2022). Dalla Chiara et al. (2022) developed and tested an information system, OpenPark, which provided real-time curb availability data, resulting in a 30% reduction in cruising time and a 12% reduction in cruising distance (Dalla Chiara et al., 2022). Freight parking pricing remains understudied, though Dalla Chiara et al. (2020) and Alho et al. (2022) modeled how pricing can influence freight parking behavior in Singapore developing a parking choice model sensitive to parking pricing and tested it on a simulation framework using large freight traffic generators (Dalla Chiara et al., 2020; Alho et al., 2022). Quak and de Koster (2009) evaluated the effects of time-window and vehicle restrictions, finding that such policies can raise costs for retailers and increase local air pollution (Quak, 2009).

While many studies examine the impact of allocating and managing LZs, few investigate how public agencies implement such programs. Gregg and Maisel (2025) reviewed planning documents from 22 US and two Canadian cities, finding that freight delivery is the second-most-cited curb use after passenger parking, though only a subset of cities include freight-specific policies (Gregg and Maisel, 2025). McDonald and Yuan (2021) identified limited coordination and transparency in LZ allocation across 20 US cities, noting that many rely on ad hoc or request-based approaches and face enforcement challenges (McDonald and Yuan, Jun. 2021). Similarly, Maxner et al. (2024) found that while nearly half of 37 US cities mention freight curb management in sustainability plans, only 8% specify concrete implementation goals (Maxner et al., 2024) Diehl et al. (2021) interviewed curb managers from 14 US cities and technology providers, highlighting common challenges, trends, and solutions. Although not solely focused on freight, several cities expressed hesitation to replace parking meters with LZs due to potential revenue loss, identified LZ pricing as a policy option, and noted persistent difficulties in maintaining accurate curb inventories and understanding LZ demand (Diehl et al., 2021).

2.1. Contributions to the literature

Compared to previous research, this study is the first to formally define Commercial Vehicle Load Zone (CVLZ) programs as an integrated framework encompassing curb infrastructure, policy, and regulation for managing freight vehicles in urban areas. It contributes to the urban planning literature by systematically documenting and comparing CVLZ programs across multiple US cities, combining qualitative analysis of planning, policy, and regulatory approaches with a geospatial assessment of the LZ infrastructure implemented in each city.

The study also advances the analytical urban freight literature by reversing the traditional approach of proposing an analytical solution to the curb allocation and management problem and proving its effectiveness. Instead, it documents and synthesizes the real-world planning, policy, and regulatory actions undertaken by public jurisdictions, providing a grounded empirical basis for future research to evaluate, simulate, and test these strategies. In doing so, the paper directly supports policymaking by linking academic efforts with practical implementation.

3. Methodology

3.1. Overview

The methodology, summarized in Fig. 2, follows a two-stage approach. First, US cities with Commercial Vehicle Load Zone (CVLZ) programs were identified. Each program was then analyzed from two perspectives: (1) policy and regulation, and (2) infrastructure.

From the policy and regulatory perspective, official city websites, municipal codes, and other online resources were reviewed to document program rules, management practices, and enforcement mechanisms. These findings informed a comparative analysis and the selection of case studies.

The infrastructure analysis examined publicly available geospatial data from open data portals to describe the location and characteristics of LZs. This analysis provided a spatial overview of CVLZ networks, highlighting similarities and differences across cities.

3.2. Terminology

This section defines the key terminology used throughout the paper. Fig. 3 illustrates a typical *blockface*, defined as one side of a road segment between two intersections. A blockface includes building frontages, sidewalks, the curb lane, and travel lanes.

The *curb lane* is divided into *curb zones*—continuous segments governed by a consistent set of rules and designated for specific vehicle types, if applicable. Curb zones are typically marked by continuous colored lines, accompanied by regulatory signage and, in some cases, pay stations.

Each curb zone can be further divided into *curb spaces*, the smallest segments capable of accommodating a single vehicle. Curb zones have various attributes, including length, zone type (e.g., no-parking, load, or paid-parking zones), authorized users, and associated costs. When zones are monitored, occupancy may also be recorded, defined as the number of vehicles—or occupied spaces—within the zone.

3.3. Data sources

Multiple data sources, summarized in Table 1, were used to review and compare CVLZ programs and infrastructure across selected US cities.

The policy and regulation analysis relied on two primary sources: official websites and municipal codes. Public agency websites

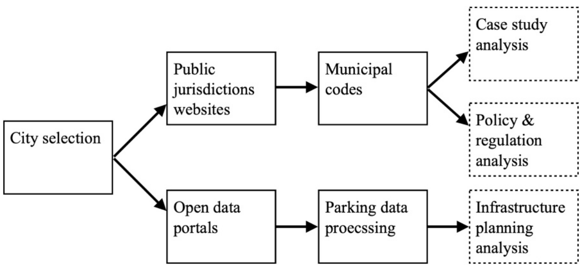

Fig. 2. Overview of methodology.

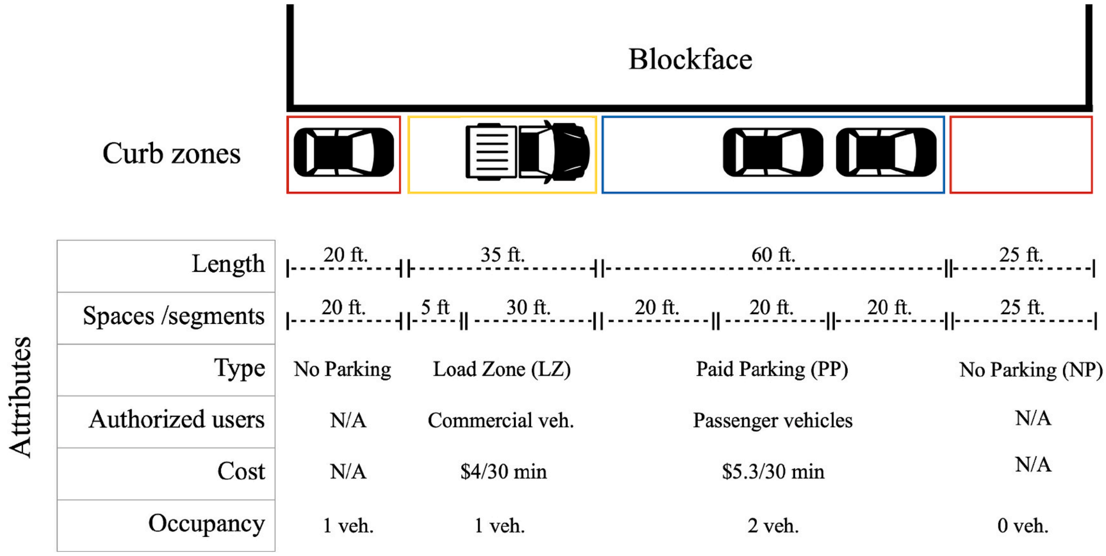

Fig. 3. Example of blockface with curb zones and their attributes.

were reviewed for information on CVLZ policies, including the types of load zones established and their monetization through pricing or permit schemes. Municipal codes were examined to identify laws and ordinances governing commercial vehicle operations in the public right-of-way, such as official definitions, enforcement rules, and time restrictions.

The infrastructure analysis provided a spatial overview of LZ networks using data from city open data portals. Two main datasets were collected: curb data (shapefiles describing the location, geometry, and type of curb zones) and sign data (inventories of street sign assets, including location and description). Both datasets were filtered to retain only curb LZs and associated signs. Raw curb layers for San Francisco, Minneapolis, Philadelphia, and Portland were obtained from INRIX Parking Solutions (INRIX, "INRIX Parking.", 2025).

Additionally, city boundaries, census tracts, and demographic data were sourced from the American Community Survey (ACS) (United States Census Bureau, 2022) and the Topologically Integrated Geographic Encoding and Referencing (TIGER) system (United States Census Bureau) of the US Census Bureau.

3.4. *Cities' selection and contexts*

A sample of 13 US cities was selected for analysis, listed in Table 2 and mapped in Fig. 4. The cities are Austin, TX, Boston, MA, Chicago, IL, Los Angeles, CA, Miami Beach, FL, Minneapolis, MN, New York, NY, Philadelphia, PA, Portland, OR, San Francisco, CA, San Jose, CA, Seattle, WA, and Washington, DC.

A non-probability sampling approach was used. The sample is not intended to represent all US cities but to illustrate diverse approaches to commercial curb management. Selection criteria included: *(i)* the existence of a documented Commercial Vehicle Load Zone (CVLZ) program, *(ii)* availability of infrastructure data, and *(iii)* evidence of one or more management strategies—such as

Table 1
Data sources description.

Data type	Data Sources	Description	Main variables obtained
Policy and regulation	Official Websites	Public jurisdictions' website describing active commercial vehicle parking policies	• Definition of commercial vehicles
	Municipal Codes	Legal codes containing local laws, ordinances and regulations enacted by local government authorities.	• Monetization and pricing schemes • Types of LZs • Enforcement • Time restrictions
Infrastructure	Curb Data	Geospatial data storing location and geometry of individual loading zones	• Location of LZs • Length of LZs
	Sign Data	Geospatial dataset describing physical street sign assets of cities	• Location of parking signs • Type of sign • Sign rules
Context	TIGER	The Topologically Integrated Geographic Encoding and Referencing (TIGER) system contains shapefiles of incorporated places in the US	• City boundary • Land area
	ACS	The American Community Survey (ACS) is a yearly survey conducted by the US Census Bureau collecting demographic and other information	• City population • Census tracts

Table 2
Sociodemographic of selected cities and data availability.

City, State	Counties	Population	Population density (people/km^2)	Land area (km^2)	Data Availability Curb	Data Availability Sign
Austin, TX	Travis	1,093,314	1,391.41	785.76		✓
Boston, MA	Suffolk	700,063	5,232.16	133.80		✓
Chicago, IL	Cook	3,047,075	5,151.61	591.48		
Los Angeles, CA	Los Angeles	4,648,125	3,776.38	1,239.84		
Miami Beach, FL	Miami-Dade	109,417	5,614.01	19.49	✓	✓
Minneapolis, MN	Hennepin	492,173	3,311.84	148.61	✓	✓
New York City, NY	New York, Kings, Queens, Bronx, Richmond	8,622,467	9,822.93	877.79		✓
Philadelphia, PA	Philadelphia	1,593,208	4,320.68	368.74	✓	
Portland, OR	Multnomah	686,450	1,841.48	372.77	✓	✓
San Francisco, CA	San Francisco	847,900	7,147.43	118.63	✓	
San Jose, CA	Santa Clara	1,245,247	2,660.95	467.97	✓	
Seattle, WA	King	811,520	3,145.30	258.01	✓	✓
Washington DC	District of Columbia	670,587	3,805.18	176.18	✓	

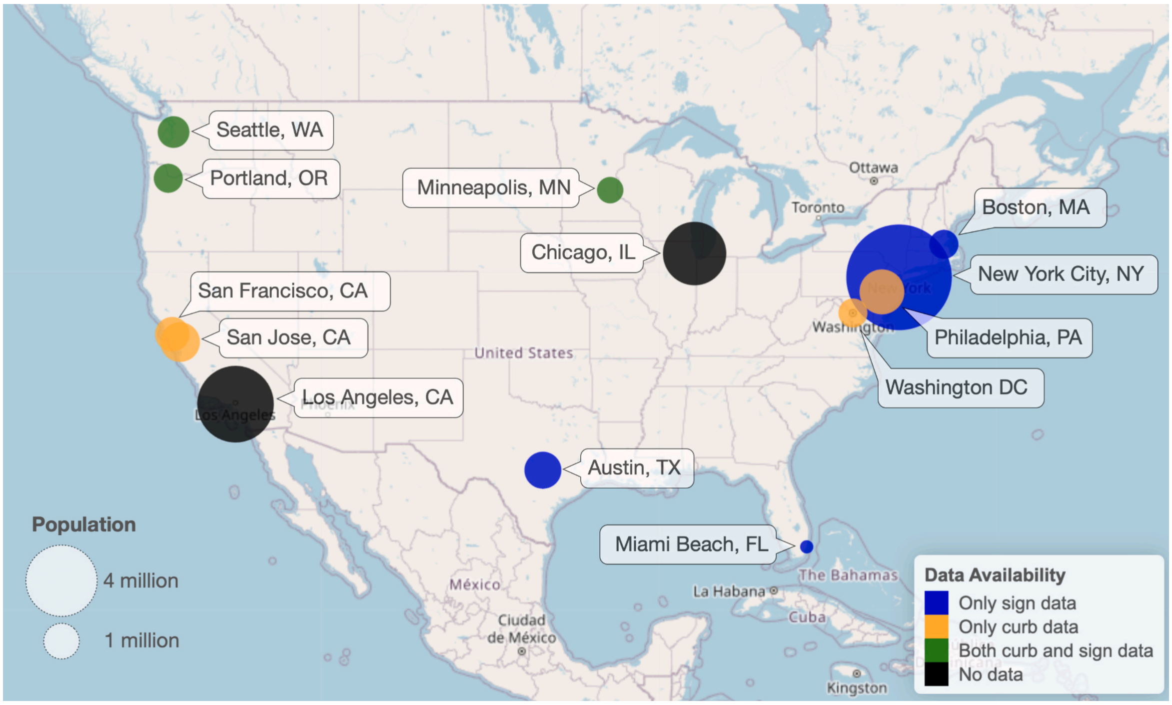

Fig. 4. Map of selected cities, data availability, and population size.

monetization, enforcement, regulation, or infrastructure allocation—described in Section 1.1 .

Two research networks helped identify relevant programs. The first comprises cities awarded a Strengthening Mobility and Revolutionizing Transportation (SMART) grant from the US Department of Transportation, focused on curb management (US Department of Transportation, 2025). Ten grant recipients formed the SMART Curb Collaborative, coordinated by the Open Mobility Foundation (OMF), a nonprofit supporting open-source data standards and public-private collaboration (Open Mobility Foundation, 2024). Additional cities with well-documented CVLZ programs and open-source infrastructure data were also included.

Table 2 summarizes the main features of the selected cities. The sample spans 10 US states, reflecting a range of urban forms, from dense, land-constrained areas like New York to more sprawling cities like Austin. Data for most cities were obtained through open data portals, through city contacts, and INRIX, except for Chicago and Los Angeles, which were analyzed only in the policy and regulation review.

3.5. Data processing and analysis

Sign and curb data were collected, processed, and analyzed to examine the topological properties of load zone infrastructure across the selected cities. The methodology followed three main steps: (1) contextual analysis, (2) integration of curb and sign data within the urban context, and (3) geospatial analysis of LZ networks and derivation of key spatial properties.

City boundaries were obtained from the Topologically Integrated Geographic Encoding and Referencing (TIGER) system, which provides shapefiles of incorporated places in the US, accessed via the Tigris R package (Walker and "tigris, 2024). Census tracts and their key attributes, such as land area and population, were retrieved from the American Community Survey (ACS) through Tidycensus (Walker and Herman, 2024). Tracts were plotted and inspected to remove peripheral areas (e.g., islands), after which total population and land area were computed for each city.

Curb and sign datasets were processed and aligned with the contextual data. Because these datasets were not standardized, each was inspected and mapped to the regulations identified in the policy and regulation analysis. LZs were identified by examining the regulatory attributes associated with each geometric line (curb) or point (sign). Sign data were further processed to *(i)* remove obsolete or duplicate records, *(ii)* retain only LZ-related signs, and *(iii)* aggregate adjacent signs representing individual curb spaces into continuous curb zones using spatial clustering. When only curb data were available, sign data were approximated using line centroids. Conversely, when only sign data existed, curb segments were estimated by clustering signs representing fixed-length spaces.

Curb and sign datasets were analyzed to derive topological properties of LZ networks. Three types of analysis were conducted. First, individual LZ characteristics were examined using the empirical distribution of LZs by city and type. Second, network-level statistics were calculated, including the total number of LZs, total population, and LZ density (both overall and by LZ type). Where curb data were available, the total curb length allocated to commercial vehicles and the share of total parking curb space reserved for LZs were computed. The denominator included all curb zones used for parking (e.g., paid parking and taxi stands) and excluded non-parking areas such as no-parking zones or parklets.

Finally, the spatial dispersion of LZs was quantified using the Observed Mean Nearest Distance (D_0) and the Nearest Neighbor Index (NNI). For a city's LZ network consisting of n LZs distributed over an area A, the eucludean distance from each LZ i to its nearest (d_i) was computed. The observed mean nearest distance D_o is:

$$D_o = \sum\nolimits_i d_i / n$$

The observed distance D_o is then compared to the expected mean nearest distance D_e, which is defined as the mean nearest distance that would have been observed if the LZs had been randomly distributed through a Poisson point process within the same area A:

$$D_e = \frac{1}{2\sqrt{n/A}}$$

The NNI is then calculated as:

$$NNI = D_o / D_e$$

An $NNI < 1$ indicates clustering, $NNI > 1$ indicates dispersion, and $NNI \approx 1$ suggests a random spatial pattern (Clark and Evans, 1954; Mahajan and Argota Sánchez-Vaquerizo, 2024).

4. Results: policy and regulation analysis

4.1. Overview of CVLZ programs

Commercial Vehicle Load Zone (CVLZ) programs from 13 US cities were reviewed and compared based on their policies and regulations. Table 3 summarizes the programs, while the following subsections present a comparative analysis across six main dimensions.

The first dimension, allowed spaces, identifies the curb and non-curb areas reserved for commercial vehicle parking, including various types of curb LZs, alleys, double-parking areas, and metered or paid parking. The second, users, summarizes the primary users and permitted activities, such as loading and unloading, service operations, deliveries made with passenger vehicles, and commercial passenger transport. The third, allocation, distinguishes between city-led LZ assignment and establishment- or carrier-requested allocation. The fourth, monetization, details three main payment approaches: permit programs, pay-per-use, and installation-related fees. The fifth, penalties, describes enforcement measures and fine ranges for violations such as unauthorized use, overstays, or non-compliance with monetization rules. The sixth, maximum dwell time, captures how time limits vary by zone type, time of day, permit category, and other factors.

While Table 3 and the subsequent subsections include as much detail as possible, the comparative analysis necessarily involved summarization and interpretation. The goal is not to provide an exact depiction of each program but to highlight key similarities and differences in how cities regulate commercial vehicle parking.

4.2. Who are the load zone users?

Load Zones (LZs) are on-street parking spaces reserved for commercial vehicles performing commercial activities, though definitions of these vehicles and activities vary across jurisdictions. Table 3 identifies four main types of activities allowed at LZs: load/unload, service, car deliveries, and passenger transport.

Loading and unloading of goods, freight, and merchandise are universally permitted. Some cities, such as Washington D.C.,

Table 3
Overview of commercial vehicle load zone programs.

Allowed spaces	Users	Allocation	Monetization	Penalty[2]	Dwell time
Austin, TX					
• Commercial LZ • Double-parking[1] • Paid parking	• Load/ unload	• City	• Permit: cost varies by vehicle type and allowed dwell time (>30 min.): $125 to $1,200/year	$150 - $500	<30-120 min
Boston, MA					
• Commercial Vehicle LZ	• Load/ unload • Service • Passenger	City	None	$40 - $90	<30 min
Chicago, IL					
• Commercial LZ	• Load/ unload • Service • Car deliv.	Request	• Pay-per-use: $3.5/15 min • Permit: non-commercial $250/year[3] • Installation: $110-$500/year (+$50 per feet)	$140	<15-30 min
Los Angeles, CA					
• Commercial LZ (Yellow Curbs)	• Load/ unload • Service • Passenger	City	• Pay-per-use: free first 30 min, $1-$2/30 min	$58 - $116	<4 hr
Miami Beach, FL					
• Commercial LZ • Freight LZ • Alleys	• Load/ unload • Service[12] • Passenger	City	• Permit: $230/year (alley LZ), $458/year (freight LZ) • Pay-per-use: $2 - $4/hour	$150 - $600	<20-60 min
Minneapolis, MN					
• Commercial LZ • No parking	• Load/ unload	Request	• Installation: $700 - $1,050 • Maintenance: $250 - $375/year	$30 - $42	<30 min
New York City, NY					
• Commercial metered parking • Truck loading • Neighborhood LZ • No parking • Double-parking	• Load/ unload • Service • Passenger • Car deliv.	City[8]	• Pay-per-use[9]: $6 - $13/hour	$65 - $115[10]	<20 min. - 3 hr
Philadelphia, PA					
• Commercial LZ[4]	• Load/ unload • Service • Passenger • Car deliv.	Request	• Installation: $150 - $500 • Maintenance: $75 - $150/year	$31 - $51	<30 min
Portland, OR					
• Truck LZ • Parking meter	• Load/ unload • Passenger	City	• Permit: $321 - $844/year[11]	$300	<5 - 30 min
San Francisco, CA					
• Yellow zones • General LZ • Red capped truck LZ[6]	• Load/ unload • Service • Passenger	Request	• Installation: $882 • Maintenance: $597-$2,338/2 years[7]	$108 - $170	No limit (yellow zones),<3 min (GLZ)
San Jose, CA					
● Freight LZ[5]	● Load/ unload ● Passenger	City	None	$37.5 - $50	<1 hr
Seattle, WA					
● Commercial vehicle LZ ● Truck LZ ● Load/unload Z ● Alleys	● Load/ unload ● Passenger ● Service	City, Request	• Permit: $250/year (commercial vehicles), $1,700/ year (service vehicle)	$69 - $78	<30 min
Washington D.C.					
● Commercial LZ	● Load/ unload	City, Request	• Permit: $323/year, $25/day • Pay-per-use: up to $5/hour	$50 - $100	<2 hr

Notes:
1. When two or more travel lanes in one direction are available
2. Includes violations related to LZ: not having a permit, not being a commercial vehicle, overstaying
3. A non-commercial LZ permit is required for vehicles with a non-commercial license plate performing deliveries or services to use LZs
4. Only commercial LZs are included, excluding Smart LZs
5. Only commercial LZs ("Yellow curb") are included, excluding Special Freight LZs
6. Red-capped meter zones are reserved for six-wheeled trucks only

7. The installation/renewal fee for a general LZ varies depending on the length of the requested zone
8. New York City passed the Loading Zone Expansion Bill in 2021, requiring the NYC Department of Transportation to develop a methodology for LZ allocation
9. Only for commercial metered parking
10. New York City has special parking ticket payment programs for commercial fleets
11. Higher permit cost allows parking in any LZ, vs. lower permit cost allows only parking at two LZs
12. Service vehicles not qualifying as “commercial vehicles” are required to obtain an alley permit

Minneapolis, and Austin, explicitly restrict LZ use to vehicles involved in these activities. For example, Minneapolis defines a commercial vehicle as a “truck or other vehicle used only for picking up or delivering merchandise”; however, to qualify for a commercial permit, the vehicle cannot be intended for “private transportation, service work, delivery equipment for service work” (City of Minneapolis, “Commercial Vehicle”, , 2025).

Other cities recognize *service* activities as distinct from deliveries. Seattle defines “service parking” as “the use of parking space while rendering service in cleaning, painting, adjusting, or making minor repairs or replacements in or to buildings or building equipment or to public utilities” (§11.14.555 of (City of Seattle)), requiring a separate service permit. Boston, instead, included vehicles used for the “delivery of utility services or for field services related to maintenance or repair of buildings” within the definition of commercial vehicles (Article 1 of (City of Boston, 2025)).

Several jurisdictions—such as Chicago, New York City, and Philadelphia—extend LZ use to passenger vehicles making commercial deliveries (e.g., home deliveries for restaurant food and groceries from online shopping platforms). In Chicago, businesses that “use passenger vehicles for deliveries and fast service calls in commercial districts” may obtain a Non-Commercial Loading Zone Permit (City of Chicago, 2025). Finally, some cities also allow temporary *passenger* pick-up and drop-off within LZs. For instance, San Francisco permits vehicles without commercial plates to use yellow LZs for up to three minutes for active loading if the driver remains inside (San Francisco Metropolitan Transit Authority (SFMTA), 2025), while Philadelphia allows temporary passenger stops provided they do not obstruct commercial vehicles (§12-904 of (City of Philadelphia)).

Definitions of “commercial vehicles” in municipal codes rely on several criteria: physical characteristics, vehicle model type, activity performed, licensing status, and display of commercial logos and insignia. Washington, DC, for example, classifies any vehicle over 22 feet in length or with more than three wheels as commercial (District Department of Transportation and “Loading zones and curbside regulations”, 2025), while Chicago uses a gross weight threshold of 8,000 pounds (§9-4-010 of (City of Chicago, 2025)). Other jurisdictions consider the removal of passenger seats as an indicator of commercial use. Cities differ in which vehicle models—such as motor trucks, pickup trucks, or tow trucks—qualify as commercial. Many also require vehicles to hold state-issued commercial license plates, as in Seattle and Chicago (City of Seattle; City of Chicago, 2025), and to display permanent business logos or insignia.

4.3. How are Load Zones classified?

Cities may allocate different types of LZs for specific commercial uses and regulate them accordingly. However, there is no standardized terminology or typology of LZs across jurisdictions. The classification summarized in Table 4 is a generalization proposed by the authors, reflecting common patterns and similarities observed among the reviewed cities.

The first distinction is between *curb* spaces and *other* spaces available for commercial vehicle parking. Among curb spaces, four main types of LZs can be identified: Commercial Load Zones (CLZs), Truck Load Zones (TLZs), General Load Zones (GLZs), and Specialty Load Zones (SLZs). In addition, some cities permit commercial vehicles to use paid (metered) parking spaces. The “other” category includes areas such as alleys, no-parking zones, and travel lanes (double parking). Each typology is described below.

Commercial Load Zones (CLZ), also called Commercial Vehicle LZs, Curb Loading Zones, or Commercial Metered Parking, are the most common LZ types. For example, Seattle designates CLZs exclusively for commercial vehicles with an annual CVLZ permit (City of Seattle Department of Transportation and “Commercial Vehicle Load Zone Permits”, 2019), while New York City allows commercial vehicles to use metered CLZs upon payment (New York City Department of Transportation and “Loading Zones”, 2025).

Truck Load Zones (TLZs), also known as Freight LZs, accommodate heavier vehicles. Miami Beach, for instance, reserves TLZs for

Table 4
Summary of Load Zone (LZ) types.

City	Curb					Other		
	Comm. LZ	Truck LZ	General LZ	Specialty LZ	Paid park	Alley	No park	Double park
Austin, TX	✓				✓			✓
Boston, MA			✓					
Chicago, IL	✓							
Los Angeles, CA			✓					
Miami Beach, FL		✓	✓			✓		
Minneapolis, MN	✓						✓	
New York City, NY	✓		✓	✓			✓	✓
Philadelphia, PA			✓					
Portland, OR			✓		✓			
San Francisco, CA	✓	✓	✓					
San Jose, CA			✓					
Seattle, WA	✓	✓	✓			✓		
Washington D.C.	✓							

vehicles with a gross vehicle weight exceeding 10,000 lbs. (City of Miami Beach), while San Francisco distinguishes six-wheel TLZs through red-capped meters (San Francisco Metropolitan Transit Authority).

General Load Zones (GLZs) allow for a wider range of uses beyond traditional freight loading, including passenger pick-up and drop-off, deliveries by passenger vehicles, and service activities. In some cities, GLZs are the only designated LZs. For instance, San Jose's Freight LZs allow deliveries, parcel drop-offs, and passenger pick-up and drop-off (§11.52.320 of (City of San Jose)).

Specialty Load Zones (SLZs) are tailored parking programs designed to support specific activities, vehicle types, or establishments. An example is New York City's Neighborhood Loading Zones, introduced in 2022 to reduce double parking and enhance safety in residential areas by facilitating package deliveries (New York City Department of Transportation). Other SLZ examples—though not listed in Tables 3 and 4—include hotel or entertainment venue loading zones, pilot initiatives such as green LZs for low- and zero-emission vehicles, and smart LZs that integrate sensor-enabled parking and information systems.

Paid (Metered) Parking refers to curb spaces where all drivers, including those operating commercial vehicles, can park upon payment of a fee. Some cities, however, grant exemptions or reduced fees for commercial vehicles. In Austin, holders of CVLZ permits can park in metered spaces for free for up to 120 minutes, depending on the permit type (City of Austin). Portland, OR, allows commercial permit holders to park in metered spaces for up to 20 minutes without payment (City of Portland, 2018).

Beyond curb areas, some cities also authorize commercial vehicle parking in *alternative non-curb locations*, including alleys, no-parking zones, and travel lanes. Miami Beach, for instance, issues annual alley loading permits for commercial vehicles under 10,000 lbs., allowing up to 20 minutes of parking provided emergency access remains unobstructed (City of Miami Beach). Other cities also permit the temporary use of travel lanes for loading activities, effectively allowing double parking under regulated conditions.

4.4. *How are Load Zones allocated?*

The allocation of LZs—the decision of how many LZs to install and where—can be handled either through a top-down approach, where city planners determine the placements, or with a bottom-up approach, where individual businesses can directly request the installation of LZs.

Most reviewed cities use a top-down approach, though few provide detailed documentation of their allocation processes. A notable exception is New York City, where the City Council passed the Loading Zone Expansion Law (local Law 168, (New York City Department of Transportation, 2021)) in 2021 requiring the Department of Transportation (NYCDOT) to *(i)* publish a formal methodology for LZs allocation, *(ii)* install 500 LZs annually for three years, with at least five LZs per Neighborhood Tabulation Area (NTA), and *(iii)* share the LZs map publicly.

Other cities employ a bottom-up approach, where businesses can request LZ installations, often by paying associated fees. For example, in Minneapolis, applicants pay both an installation and annual maintenance fee (City of Minneapolis, "Loading and limited-time curb zones", 2023). Similarly, Philadelphia charges businesses for installation and maintenance, and requires them to estimate their freight trip generation. Applicants must also acknowledge that, despite paying fees, the LZ remains available for general public use (Philadelphia Parking Authority, 2025).

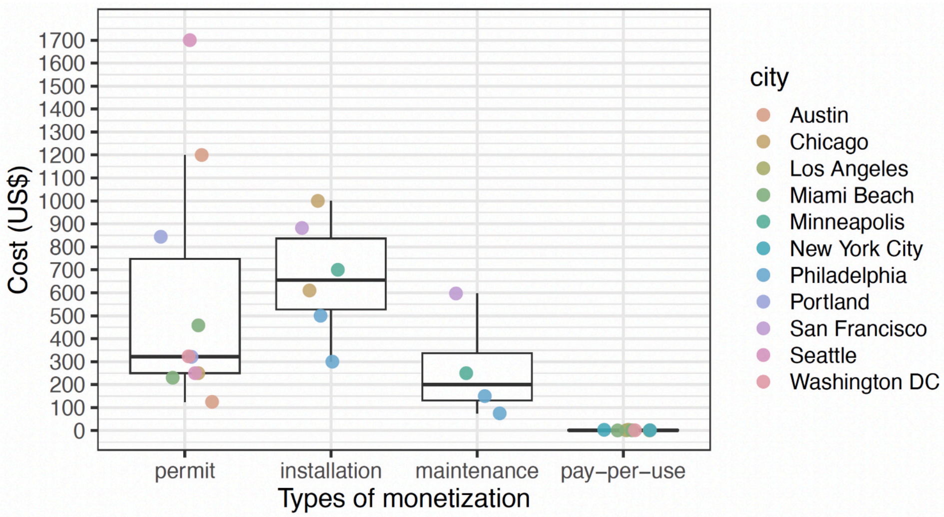

Fig. 5. Boxplots representing the empirical distribution of the four types of curb monetization for commercial vehicle parking across 11 US cities. *Permit*: annual parking permit. *Installation*: one-time fee to install a 30-foot LZ. *Maintenance*: annual fee to maintain an LZ. *Pay-per-use*: cost to park for 15 minutes in an LZ.

4.5. How are Load Zones monetized?

While paid parking for passenger vehicles is widespread in US cities, the monetization of commercial vehicle parking remains inconsistent across jurisdictions, with differences in pricing structures, payment methods, and who bears the cost. Among the 13 cities reviewed, 11 employ some form of monetization, using four main mechanisms: *(i)* pay-per-use, *(ii)* permit, *(iii)* installation, and *(iv)* maintenance. Table 3 summarizes each city's monetization method, while Fig. 5 illustrates the distribution of associated costs.

Several cities allow commercial vehicles to pay for parking on a per-use basis, similar to passenger vehicles, using pay stations or mobile apps. The p*ay-per-use* system has been adopted in Chicago, Los Angeles, Miami Beach, NYC, and Washington DC. The cost for a 15-minute parking spot ranges from $0.5 to $3.5, depending on the time and location, with a median of $1 per 15 minutes.

Because delivery operations often face strict time constraints, many cities offer permit programs allowing carriers to park without paying per event. Fig. 6 shows an example of a permit decal in Seattle. Permit costs and conditions vary widely, as shown in Fig. 5.

In Seattle, a Commercial Vehicle Load Zone (CVLZ) permit costs $250 per year, allowing up to 30 minutes of parking per event (City of Seattle Department of Transportation and "Commercial Vehicle Load Zone Permits", 2019). Vehicles performing service activities requiring longer dwell times can obtain a $1,700 annual permit (Seattle Department of Transportation, "Service Zone Permit", 2025). In Austin, TX, the permit cost varies depending on the vehicle type and maximum dwell time, ranging from $125 per year for vehicles up to 10 feet in length with a 30-minute limit, to $1,200 per year for vehicles over 26 feet long with a 120-minute maximum stay (City of Austin). Other permit costs depend on the type of LZ used. In Miami Beach, an alley permit costs $230 per year, and a freight LZ permit costs $458 (City of Miami Beach, "Alley and freight loading zone permit", 2025). Other cities offer discounts for specific LZ choices. Portland offers a $321 permit for two pre-selected LZs (City of Portland, 2018). In Chicago, passenger vehicles performing deliveries must purchase a $250 Non-Commercial Loading Zone Permit to access LZs (City of Chicago, 2025). Across all cities, permit costs range from $125 to $1,700, with a median of $322.

Some cities require receiving establishments to pay for LZ placement through installation and maintenance fees. In San Francisco, installation costs $882, and the maintenance fee, paid every two years, scales with LZ length: $597 for up to 22 feet and $2,388 for 66 feet or longer (San Francisco Metropolitan Transit Authority (SFMTA), 2025). Fig. 5 shows empirical distributions of installation and maintenance fees standardized to a 30-foot LZ, with installation fees ranging from $300 to $1,100 (median $655) and maintenance fees from $75 to $597 per year (median $200).

4.6. How are Load Zones enforced?

Regulating LZs involves setting time restrictions, maximum dwell times, and enforcement procedures. Most commercial LZs operate Monday through Friday or Saturday, generally from 7–8 am to 6–8 pm.

Dwell time limits vary by city, LZ type, and permit—commonly 30 minutes to 1 hour, though some extend to four hours. In Austin, TX, permits allow vehicles up to 26 ft. to extend dwell time from 30 to 120 minutes for $200–$600 (City of Austin). Miami Beach allows 30–60 minutes in Freight LZs and 20 minutes in alleys (§106.47 of (City of Miami Beach). Portland permits 30 minutes at truck LZs or 5–20 minutes at metered spaces (City of Portland, 2018). Some cities allow brief non-commercial use: San Francisco permits 3-minute deliveries (San Francisco Metropolitan Transit Authority), and San Jose allows 5 minutes for passenger loading/unloading (§11.52.330 of (City of San Jose)).

Enforcement is crucial to LZ program effectiveness. Penalties and fines vary across cities, ranging from $30 to $600 (see Table 3 and Fig. 7). They generally fall into three categories:

Fig. 6. Examples of Commercial Vehicle LZ permit decals placed on the windshield of a commercial vehicle in Seattle, WA.

- *Abuse of commercial permits*, such as illegal transfers or violations of permit conditions. Portland imposes $300 fines and may suspend permits (City of Portland, 2018), while Seattle may deny future permit issuance (§11.28.010 of (City of Seattle).
- *Violations of LZ regulations by commercial vehicles*, including exceeding time limits, parking outside allowed hours, failing to pay fees, parking at expired meters, or improper display of permits. Fines range from $35 in New York for exceeding time limits to $500 in Austin for lacking a permit (City of Austin; New York City Department of Finance and "Violation codes, fines, rules, and regulations", 2025).
- *Non-commercial vehicle misuse*, including unauthorized parking at LZs or violating time restrictions, with fines generally similar to commercial violations. Several cities also impose late fees and escalate penalties for repeat offenses.

5. Results: infrastructure analysis

5.1. Overview of load zone networks

This section analyzes and compares the LZ networks of the observed cities. Table 5 presents key summary statistics for each city's LZ network, including subnetworks by LZ type.

Four types of summary statistics are presented. First, individual curb zones are analyzed, showing empirical distributions of LZ lengths across cities and LZ types. Second, network-level statistics report the total number of LZs and their density per square kilometer and per thousand residents. Third, spatial distribution is described using the mean nearest distance and the Nearest Neighbor Index (NNI), indicating whether LZs are clustered or evenly dispersed across the city. Finally, the total curb space allocated to LZs is compared with space for other vehicles, and the share dedicated to commercial use is reported. The following sections provide a more detailed analysis of each type.

5.2. How long is a typical load zone?

Using curb data, the lengths of individual LZs were analyzed for eight cities with available data (Table 2). The median LZ length in the US is 15 meters (≈50 ft), with a mean of 18 meters (≈60 ft). After removing outliers, most LZs fall between 9 and 21 meters (30–70 ft). Given that a typical parcel van is 26 ft long, a standard LZ could accommodate up to two vans. However, adding 5 ft for safe handling, as suggested by McCormak et al. (2020), reduces capacity to roughly one van (McCormak et al., 2020).

City-specific differences are shown in Fig. 8, which presents boxplots of LZ lengths by city and LZ type. Table 5 reports median and standard deviation values for each city and LZ type. Median lengths range from 22 meters in Miami Beach to 9.5 meters in Seattle, with Minneapolis showing the greatest variation. Freight and truck LZs, designed for heavier vehicles, are generally longer than standard LZs. For example, in San Francisco, a truck LZ is 2.5 meters longer than a general LZ, and in Miami Beach, a Freight LZ is 7.4 meters longer.

5.3. How much curb is allocated to Load Zones?

This section examines LZ network size at the city level. Table 5 reports summary statistics of the observed LZ networks.

First, using sign data, the total number of LZs per city was estimated, showing wide variation from 82 in Minneapolis to over 10,000

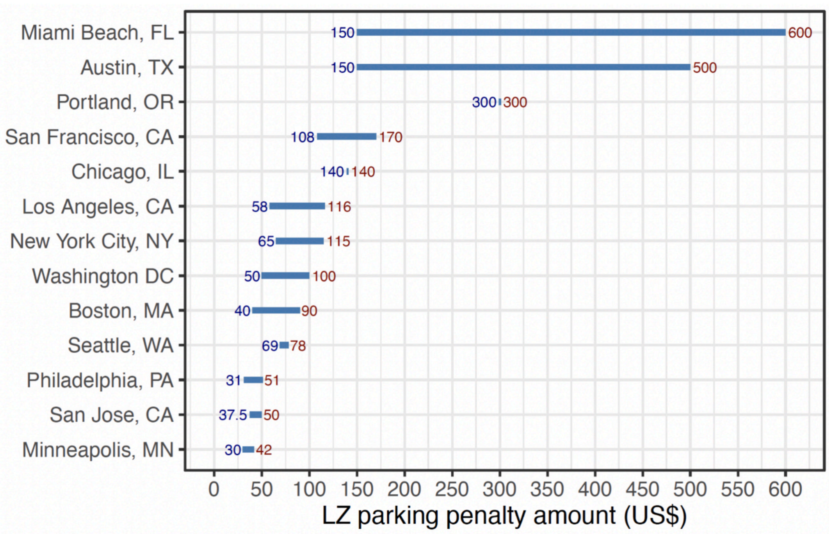

Fig. 7. Minimum and maximum amount charged for LZ-related parking penalties.

Table 5
Descriptive statistics of Load Zone networks.

City & LZ type	No. LZ	LZ length (m.)		Curb allocated		Mean nearest dist (m)	NNI	Density	
		Med.	Sd	km	% curb allocated			LZ/1000 people	LZ/km^2
Austin	283	/	/	/	/	66.75	0.08	0.26	0.36
Boston	179	/	/	/	/	39.21	0.09	0.26	1.34
*Miami B.***	*171*	*22.0*	*11.86*	/	/	*81.76*	*0.48*	*1.56*	*8.77*
• CLZ	59	14.6	12.82			165.50	0.58	0.54	3.02
• FLZ	112	22.0	9.51			104.97	0.50	0.10	5.75
Minneapolis	82	20.5	30.9	2.6	0.1%	36.30	0.07	0.25	0.81
New York	*10,170*	/	/	/	/	*129.80*	*0.88*	*1.18*	*11.59*
• CMP	4,112					69.02	0.30	0.48	4.69
• TLZ	5,463					173.62	0.87	0.63	6.22
• NLZ	595					633.86	1.04	0.07	0.68
Philadelphia	517	16.8	14.4	10.3	4.1%	63.68	0.15	0.33	1.40
Portland	1,158	14.3	10.5	19.6	0.5%	92.59	0.33	1.70	3.11
San Franc.	*2,808*	*15.1*	*13.2*	*49.1*	*2.8%*	*51.72*	*0.50*	*3.31*	*23.67*
• YZ	2,336	15.1	11.6	39.1	2.2%	51.69	0.46	2.76	19.69
• GLZ	324	13.9	16.8	7.3	0.4%	194.32	0.64	0.38	2.73
• TLZ	148	16.4	19.6	2.7	0.2%	280.24	0.63	0.17	1.25
San Jose**	312	16.5	12.0	/	/	219.57	0.36	0.25	0.67
Seattle	*4,009*	*11.3**	*8.1**	*17.4**	*10%**	*45.89*	*0.36*	*4.94*	*15.54*
• CVLZ	570	15.3*	6.5*	6.3*	3.6%*	39.41	0.12	0.70	2.21
• TLZ	388	16.2*	9.6*	0.5*	0.3%*	155.01	0.38	0.48	1.50
• L/UZ	3051	9.5*	8.7*	10.6*	6.1%*	55.93	0.39	3.76	11.83
Wash. DC	616	16.8	24.4	14.3	0.6%	108.38	0.41	0.92	3.50

Notes:
* Summary statistics are representative only for the Seattle urban core and not for the whole city, as curb data is available only for those areas.
** Only curb data for LZs is available.

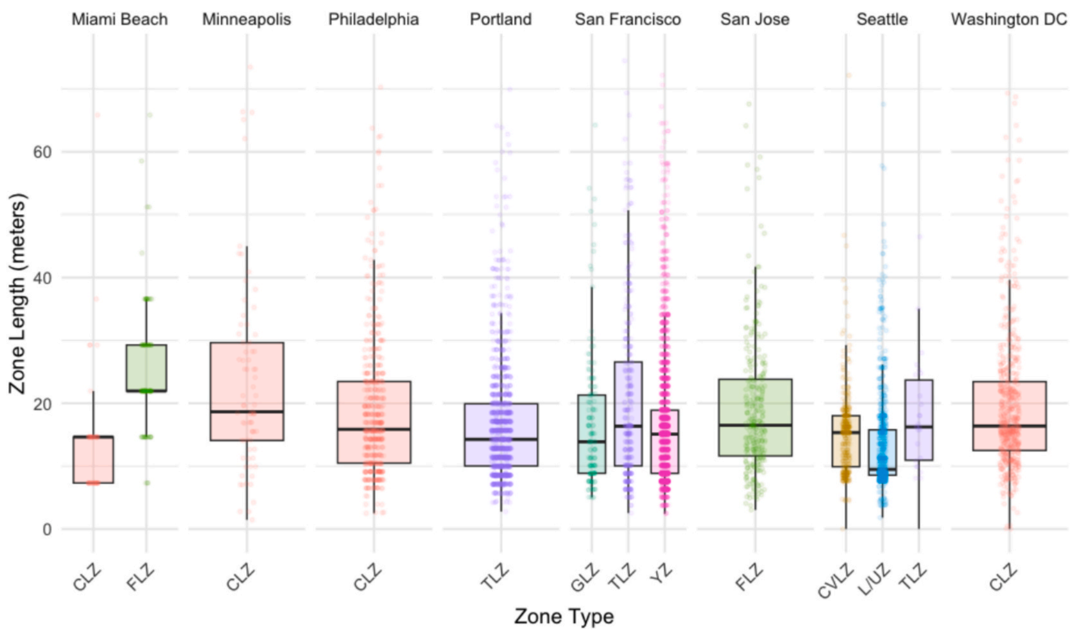

Fig. 8. Empirical distributions of LZ lengths for each city and type. The horizontal lines represent the interquartile ranges of the empirical distributions and the medians.

in New York City. Fig. 9 represents each city's LZ network as a circle, with most networks in the hundreds, except Portland, Seattle, San Francisco, and New York City, which exceed 1,000 LZs.

Geographical and population densities of LZs were calculated by accounting for city land area and population, measured as LZs per square kilometer and per thousand people. In Fig. 9, Austin, Minneapolis, and San Jose form a cluster with both densities below 1. Boston, Philadelphia, and Washington DC have population densities below 1 but geographical densities between 1 and 4. Remaining cities have both densities above 1, with San Francisco reaching 24 LZs/km^2 and Seattle the highest population density, with 5 LZs per thousand people.

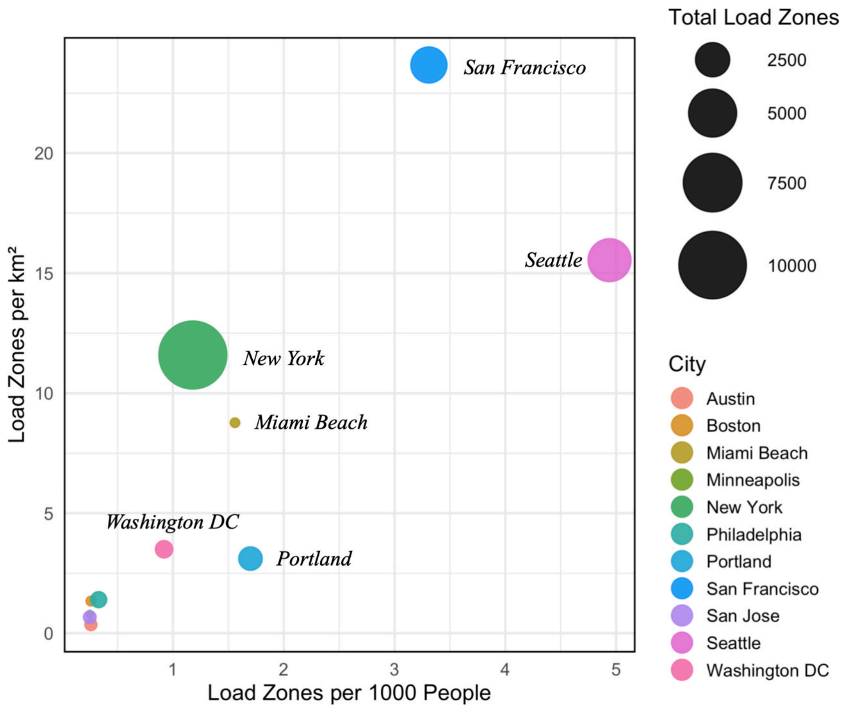

Fig. 9. Load zone densities (number of LZs per km^2 and per thousand people) and total number of LZs, for 13 US cities. See Table 5 for related values.

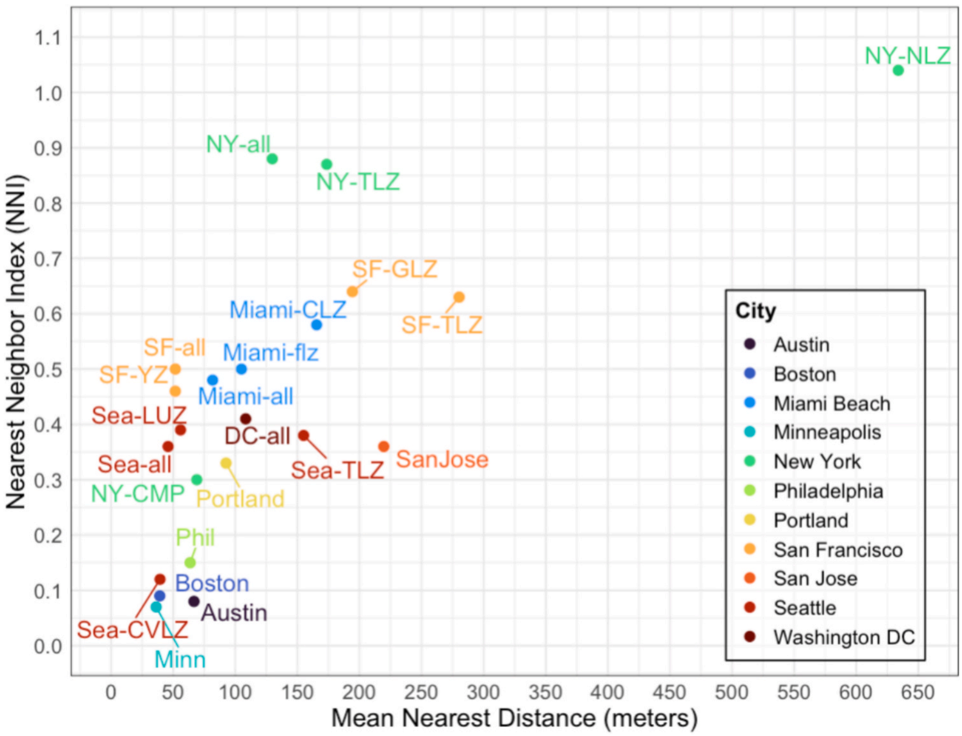

Fig. 10. The x-axis reports the mean nearest distance (in meters) and the y-axis the Nearest Neighbor Index (NNI) for each combination of city and LZ type.

Third, the total curb length allocated to LZs was compared to other allocated curb. Table 5 shows networks ranging from 3 km (Minneapolis) to 50 km (San Francisco). For several cities, curb data were unavailable. The share of allocated curb for commercial vehicles ranges from less than 1% in Minneapolis, Portland, and Washington DC to 3–4% in San Francisco and Philadelphia. Seattle allocates about 10%, though this reflects only the urban core, where commercial use is higher.

5.4. How are Load Zones distributed?

This analysis examines how LZs are spread within cities. Fig. 10 shows full and partial (by LZ type) networks using two summary statistics: mean nearest distance and Nearest Neighbor Index (NNI).

The mean nearest distance is the average distance, in meters, between each LZ and its closest neighbor. Larger distances indicate more dispersed LZs, while smaller distances show clustering. Across cities, average distances range from 40 meters (131 ft.) in Minneapolis, Boston, and Seattle to 220 meters (722 ft.) in San Jose. One extreme sub-network is New York's neighborhood LZ (NLZ), with a mean nearest distance of 634 meters (2,080 ft.).

The NNI compares the observed mean nearest distance to a hypothetical random distribution. Values near 1 indicate randomness, above 1 indicate dispersion, and below 1 indicate clustering. Fig. 10 shows NNIs from 0.05 to 1.04. All city networks are below 1, except New York's NLZ network. Fig. 11 compares five cities by increasing NNI. Austin and Seattle's commercial LZ networks (NNI $\approx$ 0.1) show high clustering in few census tracts. Miami Beach and San Francisco's General LZ networks (NNI $\approx$ 0.5) are more evenly distributed. New York's NLZ network (NNI $>$ 1) is highly dispersed, with almost no clusters.

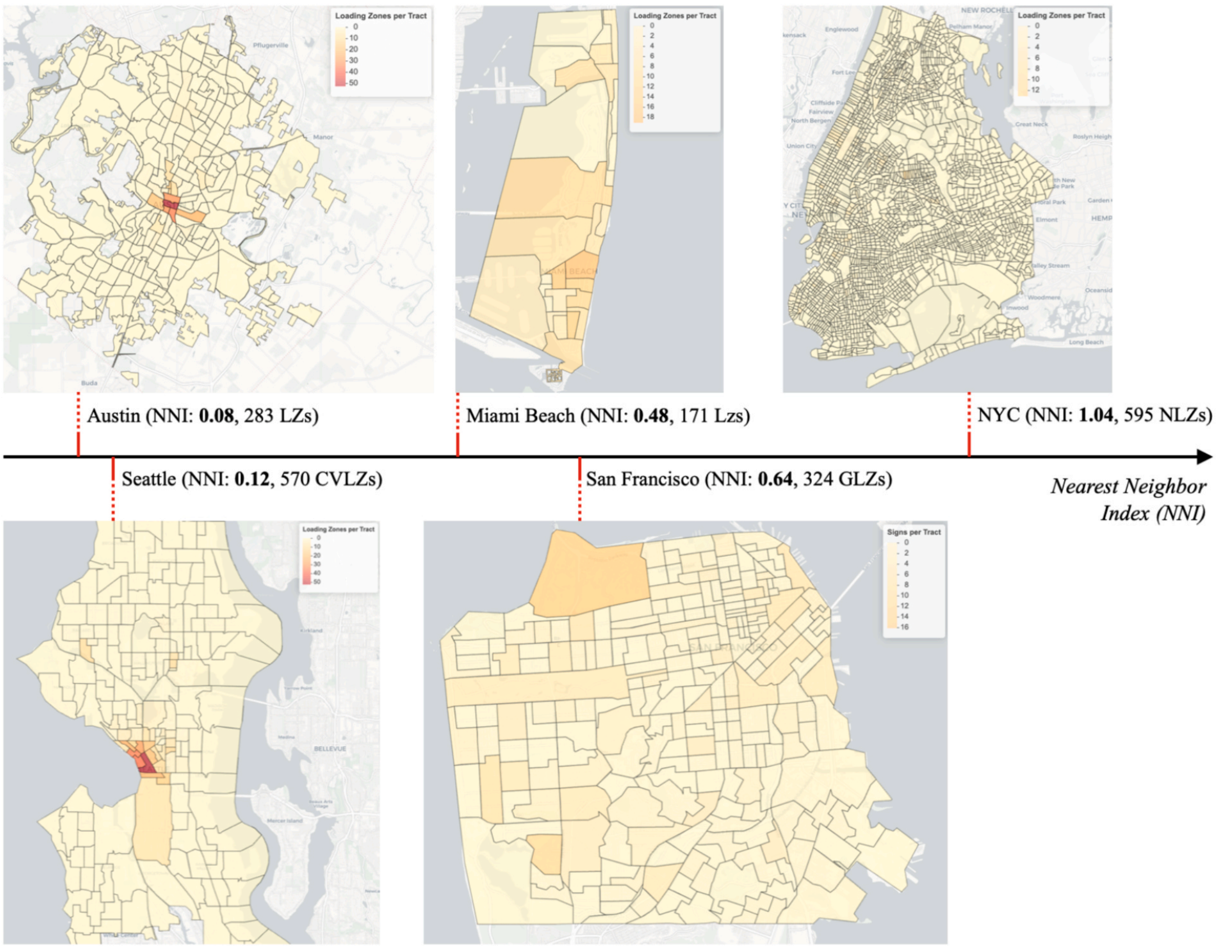

Fig. 11. Map of five cities' LZ networks ordered by increasing Nearest Neighbor Index (NNI), the color intensity shows the number of LZs per census tract.

6. Results: case studies

6.1. Seattle, WA: pioneering CVLZ permit program

Seattle operates one of the oldest CVLZ permit programs in the US, established in 1990 to improve truck LZ access for bona fide commercial delivery vehicles and restrict non-delivery vehicles. A 1980s change in Washington vehicle licensing allowed any vehicle to be registered as a truck for commodity transport, leading to widespread misuse of truck LZs. The CVLZ program replaced TLZs in business districts and introduced a permit for non-truck commercial vehicles. Initially free, the permit cost has gradually increased to $250 since 1997. Fig. 12 shows annual permit issuance and prices, ranging from 2,663 permits in 2023 to 6,539 in 1999, with an average of 5,260 per year. The city faces decreasing permit demand and misuse by non-permit holders and is planning to modernize the program using curb sensing technology to improve allocation and engage communities in shaping the LZ network.

6.2. Portland, OR: piloting zero-emission Load Zones

Zero-Emission LZs (ZELZs), also called Green LZs or Zero-Emission Delivery Zones, are curb spaces reserved for zero- and low-emission commercial vehicles, including cargo e-bikes and electric or alternative-fuel trucks. ZELZ programs aim to (i) encourage carriers to adopt zero-emission vehicles and (ii) reduce local exposure to vehicle pollutants. Portland, OR, piloted the first regulated ZELZs in the US through a SMART federal grant, converting five downtown truck LZs into ZELZs (Fig. 13) (Portland Bureau of Transportation, 2024). Zones were marked with signs and regulated via a free zero-emission vehicle permit, separate from existing Truck LZ permits, established under §16.90.220 of the municipal code (City of Portland). The pilot ran six months, from September 9, 2024, to March 31, 2025, during which PBOT engaged 40 stakeholders and issued 66 permits (Sherman et al., 2025). Video monitoring showed that 75 percent of ZELZ parking events were by unauthorized vehicles.

6.3. New York City, NY

Passed in December 2021, Local Law 168 required the NYC Department of Transportation (DOT) to develop and publish a methodology for identifying locations in need of LZs (City of New York, 2021). This law defined an LZ as: “a portion of curb space at which a vehicle may stand or park for the purpose of making pickups or service calls, or loading or unloading goods, tools, materials, or other items.” The law also mandated the department to install at least five LZs annually in every neighborhood tabulation area and to install at least 500 LZs annually for three years following the implementation of the law.

NYC DOT was also required to publish a report outlining their methodology, which included prioritizing areas where (1) LZs were missing and (2) existing loading issues, while balancing other community and business stakeholder needs (New York City Department of Transportation, 2021). They also acknowledged the need for context-sensitive signage and enforcement. Their approach differentiates LZs – which can be used for both freight and passenger loading/unloading — from truck loading zones, which are solely

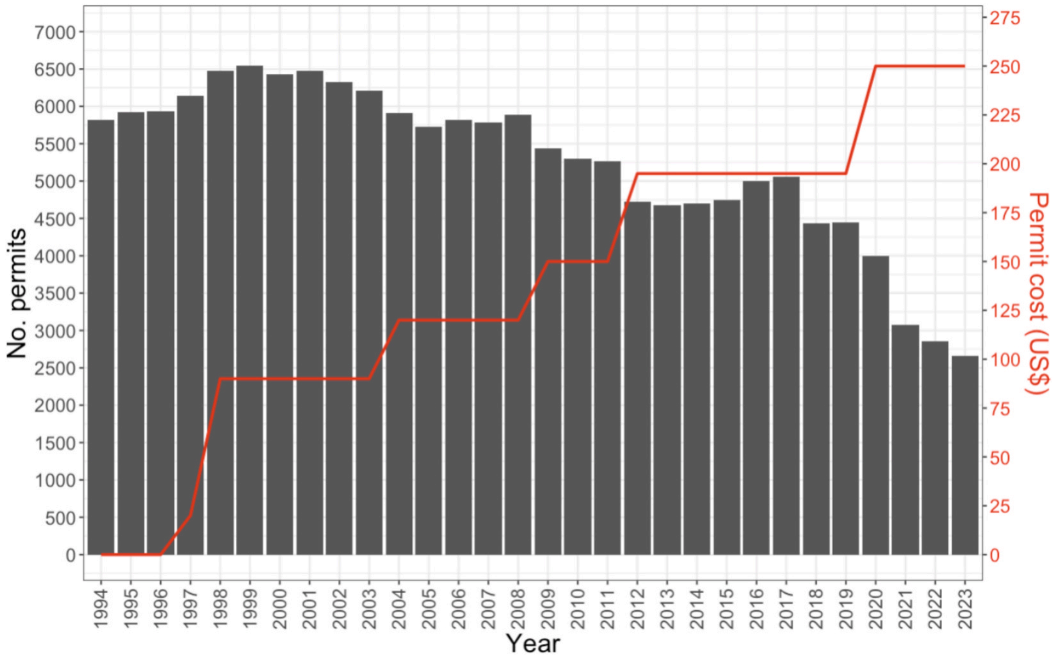

Fig. 12. Number of CVLZ permits issued per year and related permit cost.

Fig. 13. (left) Parking sign displayed at Zero-Emission Load Zones (ZELZs) in Portland, OR. (right) Map describing the locations of the ZELZs (Portland Bureau of Transportation, 2024).

designated for commercial vehicles to park "for the purpose of making pickups or service calls, or loading or unloading goods, tools, materials, or other items." They created a quantitative approach for prioritizing NTAs for installation; this method used population density, residential, commercial/industrial, and retail land use density, along with the number of active loading zones, as inputs to compute a weighted score. Once priority neighborhoods are identified, they are evaluated to find (1) areas of multi-modal safety concern and (2) high traffic locations and zones with frequent violations. When necessary, data collection is conducted.

By March 2023, NYC DOT had installed over 2,000 loading zones, including 1,200 in high-priority areas. By November 2024,

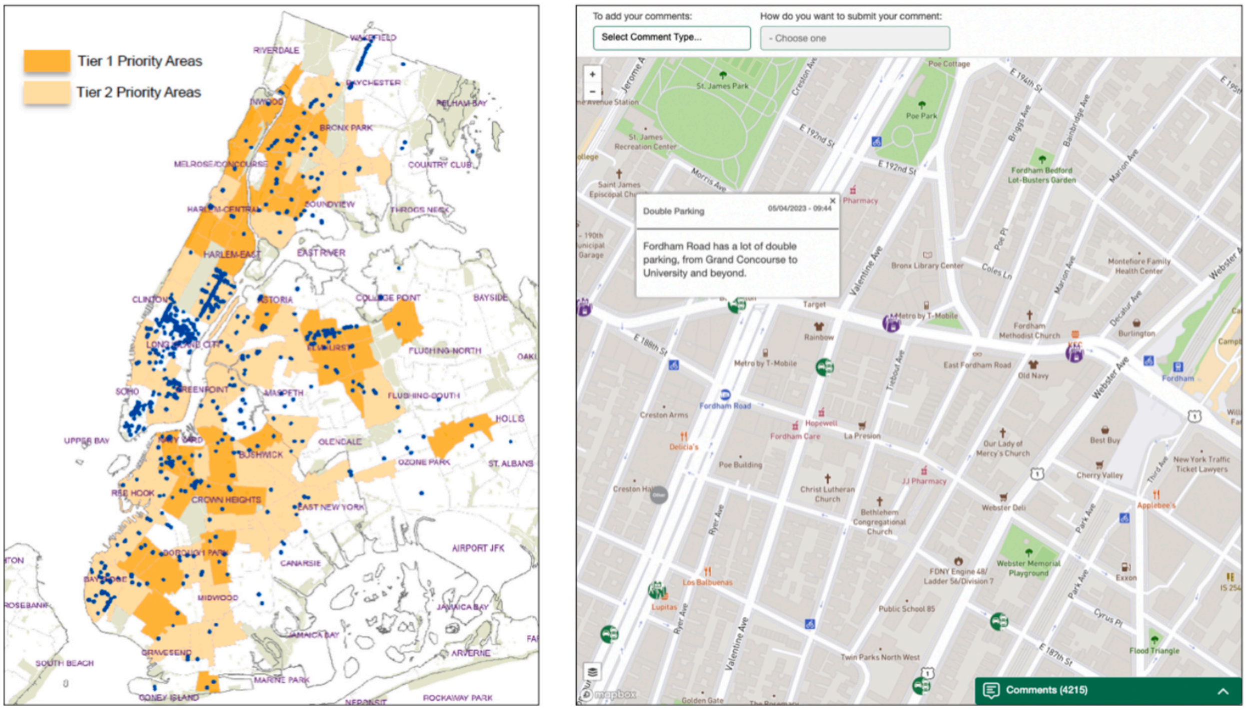

Fig. 14. Left: three-tier prioritization system published by NYCDOT to allocate LZs (New York City Department of Transportation, 2021); right: web-portal to receive public comments on LZs in NYC (New York City Department of Transportation and "Loading Zone Feedback Portal", 2023).

nearly 3,000 zones had been implemented, with more than 500 informed by public feedback through an interactive web portal that allowed users to identify locations of frequent freight-related disruptions (Fig. 14) (New York City Department of Transportation, 2024).

7. Discussion: implications for policy and practice

7.1. A comparative analysis of CVLZ programs

In reviewing the Commercial Vehicle Load Zone (CVLZ) programs of the 13 selected U.S. cities, one overarching commonality emerges: a high degree of heterogeneity in approaches to managing commercial vehicle access to the curb. This diversity was somewhat unexpected, given that cities are subject to similar market forces and that policy transfer across jurisdictions has been documented in other sectors. Despite this heterogeneity, several shared traits and recurring patterns can be identified.

From a policy perspective, two broad approaches to CVLZ management emerge. Several cities adopt a relatively laissez-faire approach, designating load zones (LZs) for non-specified users to load and unload. Examples include Boston, Los Angeles, and San Jose, where a single, general LZ type is available to any vehicle requiring curb access for loading or unloading, including service and passenger vehicles. Other cities, such as Chicago and Minneapolis, also rely on a single type of LZs but apply a stricter definition of eligible users, reserving these spaces exclusively for freight and merchandise loading and unloading.

A third group of cities—including Seattle, New York City, and San Francisco—has adopted a more differentiated approach by developing multiple LZ networks tailored to distinct use cases of commercial vehicles. For example, in response to limited curb space for e-commerce deliveries in residential areas, New York City established a network of neighborhood LZs. These are more sparsely distributed than other LZ networks, which are typically concentrated in downtown areas and urban villages. Seattle provides another illustrative example separating commercial vehicle load zones from general load/unload zones: the former require a permit to park, while the latter allow free loading and unloading. Austin presents an interesting hybrid approach that maintains a single LZ type while offering different levels of curb access through a tiered permitting system. Annual permit prices range from $125 to $1,200, depending on the maximum allowable dwell time. Users requiring longer dwell times—such as service vehicles or vehicles with high delivery densities—can purchase higher-cost permits that allow parking for up to two hours.

Another common feature across all reviewed CVLZ programs is the monetization of commercial vehicle curb parking. Three primary pricing mechanisms were identified: (i) permit-based programs, in which carriers purchase annual permits to park in LZs; (ii) pay-per-use programs, similar to passenger vehicle parking, where payment is required per parking event and dwell time; and (iii) LZ installation programs, whereby commercial establishments pay for the installation and maintenance of LZs near their premises. From the passenger vehicle literature, both research and practice suggest that pricing can serve as an effective demand management tool, increasing turnover, encouraging mode shifts, and reducing cruising for parking. In contrast, there is limited evidence that pricing effectively addresses parking-related externalities for commercial vehicles, and no prior studies have empirically documented pricing-induced behavioral changes among freight carriers. This suggests that cities may have extended established passenger vehicle parking pricing frameworks to commercial vehicles without a clear evidence base specific to freight activity. Seattle exemplifies this approach: only LZs located in areas with priced curb parking require a commercial vehicle permit, while LZs outside these areas remain free of charge. Moreover, the Seattle CVLZ permit case study indicates that carriers are willing to pay for curb access, with more than 5,000 annual permits purchased on average each year. However, no comparable evaluations or data on the effectiveness or adoption of commercial vehicle parking pricing schemes were identified in other cities.

Despite the diversity of parking strategies and policies, their effectiveness ultimately depends on adequate enforcement. Enforcement of curb parking regulations remains a well-documented challenge in commercial vehicle management, both in terms of

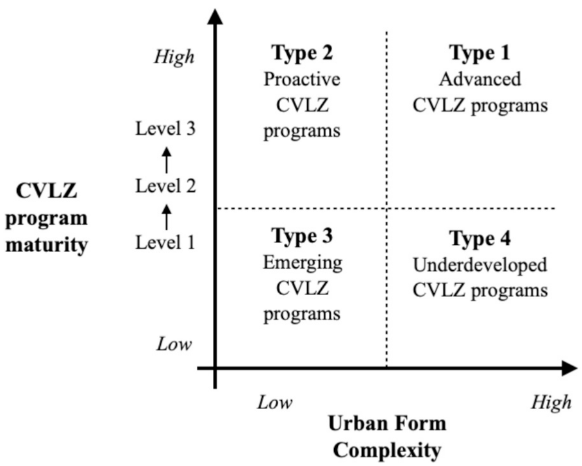

Fig. 15. Typology of CVLZ programs according to program maturity and urban form complexity.

delivery drivers double-parking or violating parking rules and the misuse of LZs by non-commercial vehicles. Although all reviewed CVLZ programs include some form of enforcement, it is largely limited to monetary fines. In more than half of the reviewed cities, maximum fines are below $150. Compared to penalties applied in other parking enforcement contexts, these levels are relatively low and may undermine the overall effectiveness of CVLZ programs.

Finally, from an infrastructure perspective, substantial heterogeneity is observed in the spatial and topological characteristics of LZ networks. Cities facing greater land constraints tend to develop denser LZ networks, with San Francisco, Seattle, New York City, and Miami Beach exhibiting the highest LZ densities. Despite the absence of formalized allocation methodologies, all cities display a pronounced concentration of LZs in selected urban centers and villages. This pattern suggests that LZ placement responds to areas with high curb competition and an increased likelihood of conflicts among road users. Such areas are typically commercial or mixed-use districts, while relatively few cities provide LZs in residential or suburban neighborhoods.

7.2. An operational typology of CVLZ programs

To translate the comparative findings into an operational framework, this section proposes a typology of CLVZ programs by linking their infrastructure, policy, and regulatory dimensions to urban form. Fig. 15 presents the typology, identifying four program categories across two dimensions: urban form complexity and CVLZ program maturity.

Urban form complexity reflects the degree to which spatial, demographic, and infrastructure conditions generate conflicting demand for urban road and curb infrastructure. Cities with high urban form complexity are often characterized by *(i)* high population density, *(ii)* historically-constrained road network and street infrastructure that might not meet the modern freight vehicle needs, *(iii)* land-constraint, often surrounded by bodies of water or other natural landscapes, and *(iv)* a high degree of co-located dissimilar land uses.

Program maturity reflects the degree to which a city has an established, well-developed CVLZ program from an infrastructure, policy, and regulatory perspective. In reviewing the CVLZ programs of the 13 cities identified in this study, we identified three main maturity levels, defined below and ordered from lowest to highest complexity.

- *Level 1 – Foundational allocation.* Clear definition of commercial vehicles, separately from passenger vehicles, and consequently the allocation of street and off-street infrastructure to commercial vehicles, including curb space, alleys, and off-street loading bays.
- *Level 2 – Commercial users differentiation.* Recognition of multiple demands of commercial activities, including service vehicle and online deliveries (often performed using passenger vehicles and not trucks or vans), and the consequential separation of CVLZ programs across different types of "freight."
- *Level 3 – Active management.* Active management of infrastructure allocated to commercial vehicles through monetization, regulations restricting users or parking dwell time, deployment of IT infrastructure, and enforcement.

All the cities analyzed in this study met at least level 1 maturity level, as one criterion of selection was the presence of a CVLZ program, which, at the most basic level, requires the recognition and distinction of commercial vehicles from passengers, and the allocation of infrastructure. Furthermore, program maturity is not strictly hierarchical, and some cities might exhibit advanced practices such as active management of infrastructure through IT deployment, without having a solid foundation of regulation and policies recognizing different commercial users.

Combining these two dimensions yields four categories (Fig. 15). The first category includes cities with a high degree of complexity in their urban form that have developed a CVLZ program with a high maturity level to address intense curb competition and a high level of heterogeneous freight demands. Several of the reviewed cities, including New York City, Miami Beach, Seattle, and San Francisco, belong to this category.

Cities with lower urban-form complexity but relatively high program maturity have developed structured CVLZ programs despite less acute spatial constraints. In these cases, program development may reflect proactive policy approaches or institutional capacity rather than reactive responses to congestion or conflict.

While the study focused on cities with existing CVLZ programs, the typology conceptually extends to cities with limited or no formal programs, which were excluded from the policy and infrastructure analyses. Cities with low urban form complexity and low program maturity may rely on informal or flexible curb use, as freight demand has not yet necessitated a structured intervention. Conversely, cities with high urban form complexity but low program maturity are contexts in which the absence of structured CVLZ programs is likely to lead to significant curb conflicts, inefficiencies, and safety concerns.

Each category can be associated with a set of strategies to develop a CVLZ program. Cities with high complexity and maturity should focus on maintaining and modernizing their existing programs, identifying gaps in their infrastructure, and better managing hot-spot areas through policy and regulatory actions. Cities with low complexity and high maturity may prioritize maintaining flexible and cost-effective systems while avoiding unnecessary regulatory complexity. Cities with low complexity and maturity may begin with foundational steps, such as defining commercial vehicle categories, designating basic load zones, and implementing simple time restrictions. Finally, cities with high complexity and low maturity should prioritize the rapid deployment of load zone infrastructure in high-demand areas, supported by clear regulatory frameworks and scalable enforcement mechanisms.

7.3. The future of CVLZ programs

The lack of homogeneity and uniformity in approaches to managing commercial vehicle curb access can be attributed to several factors. First, there is limited coordination and collaboration among cities on curb management practices. Second, there is a shortage of comprehensive data and resources documenting existing policies and implementation strategies. While the review revealed considerable experimentation in testing and deploying different infrastructure, policy, and regulatory strategies, it also highlighted a general lack of publicly available data and systematic evaluations of curb pilots. Third, there is an absence of consistent guidelines and direction from national or federal authorities, as well as from formal cross-city collaborative frameworks.

Although the present study focused on documenting existing approaches to managing commercial vehicle curb parking rather than evaluating their effectiveness, several insights emerge that can help guide the future development of CVLZ programs.

First, effective management of commercial vehicle curb parking requires a holistic approach that goes beyond the allocation of load zones. Active management through pricing, enforcement, and regulatory mechanisms is essential. In many cities, CVLZ programs have been developed as extensions of broader curb parking management systems that also govern private and commercial passenger vehicles. The authors argue that a well-functioning passenger vehicle parking management program provides a necessary foundation for an effective CVLZ program. A well-managed curb can reduce misuse of LZs by non-commercial vehicles and limit cruising traffic in high-demand commercial areas.

Second, planning an efficient LZ network requires a continuous and systematic process to inventory curb infrastructure, associated assets, and the policies governing their use. Not all cities provide updated or accessible open data on their LZ networks. Moreover, the wide variation in policies and regulations—including definitions of commercial vehicles, eligibility criteria for LZ use, pricing structures, and enforcement mechanisms—creates confusion for carriers operating across multiple jurisdictions. Cities would benefit from adopting a shared terminology and standardized framework for coding and monitoring curb assets, while still allowing flexibility to adapt policies to local conditions. Such a framework could improve transparency, reduce compliance burdens for carriers, and facilitate cross-city learning.

Third, the review of CVLZ programs has shown a general lack of enforcement. While not directly linked to the current study, the authors suggest that a stronger and more consistent enforcement mechanism would benefit not only general traffic conditions—by reducing double parking—but also freight operators, by limiting the misuse of dedicated curb space by non-commercial vehicles. At the same time, cities should carefully balance the complexity and scale of their LZ networks with their capacity to manage and enforce them effectively.

Fourth, the review identified a growing number of pilots and experimental programs, particularly in recent years, alongside the emergence of technology-driven solutions offered by private firms. While such technologies may enhance the operational efficiency of LZ networks, they should complement rather than replace well-designed infrastructure and clearly defined CVLZ policies.

Fifth, most cities currently rely on ad hoc processes for allocating LZs. In some cases—such as Minneapolis, Philadelphia, and San Francisco—commercial establishments can request the installation of LZs near their premises, typically in exchange for installation and maintenance fees. However, few cities have systematic mechanisms to engage freight carriers, who are the primary users of these curb spaces. New York City represents a notable exception, having developed and documented a data-driven methodology for LZ allocation and a public-facing online dashboard that allows users to submit geolocated feedback. Whether this approach is the most effective means of capturing carrier input remains an open question, and alternative outreach and engagement strategies warrant further testing and evaluation.

Finally, there is a clear need for greater collaboration and research in this area, particularly to document existing programs and pilots and to evaluate their outcomes. Such efforts would help distill lessons learned and provide actionable guidance for cities seeking to implement or refine CVLZ programs. There are substantial opportunities for academic researchers to support urban planners and public agencies in designing curb management strategies that promote more efficient urban freight systems and safer, healthier streets. Several important research questions remain unresolved, including the effects of pricing on delivery driver behavior, carriers' willingness to pay under different pricing schemes, optimal methods for allocating LZs within urban road networks, appropriate network size relative to enforcement capacity, and the role of technology—such as monitoring systems, automated enforcement, and information platforms—in supporting effective CVLZ programs.

8. Conclusion

8.1. Summary of findings

Historically, curb management strategies in US cities have been designed primarily for passenger vehicles. These initiatives—ranging from time restrictions and parking pricing to residential permits—aimed to manage travel demand and mitigate externalities such as congestion and cruising for parking. In contrast, commercial vehicle trips represent mandatory activities that sustain urban economies and are less responsive to such demand-management measures. Yet, as e-commerce and on-demand delivery have expanded, competition for curb space has intensified. In response, cities across the US have independently developed what are defined here as Commercial Vehicle Load Zone (CVLZ) programs. Through these programs, cities not only allocate portions of the curb to LZs—dedicated spaces for commercial vehicle parking and loading/unloading—but also actively manage them through various policies and regulations.

This study contributes to this emerging field by systematically documenting and comparing CVLZ programs across 13 US cities. The analysis reveals that approaches to allocating and regulating curb access for freight vehicles vary widely in both design and implementation. Differences arise in how cities classify LZs, define eligible users, and determine allocation processes. While several cities restrict LZs to traditional freight vehicles, others have diversified their allocation to support curb access for delivery services, prepared meals, and service providers. This differentiation has also enabled cities to pursue environmental and operational goals—for instance, incentivizing cleaner vehicles through green loading zones in Portland, OR, or addressing rising residential delivery demand through neighborhood LZs in New York City.Cities also differ in how they allocate LZs: some follow top-down, ad hoc planning processes, while others rely on requests from local businesses. Notably, New York City remains the only case where a data-driven methodology has been published to inform LZ expansion. Monetization strategies vary substantially—from pay-per-use pricing to annual permits and business-funded installations—with costs differing by more than an order of magnitude. Enforcement mechanisms are equally heterogeneous, though limited mainly to monetary fines ranging from $30 to $600. The infrastructure analysis further highlights the uneven provision of curb space for freight: while most cities dedicate less than one percent of their allocated curb to loading zones, a few—such as Seattle and San Francisco—reserve a considerably higher share and exhibit denser, more clustered networks.

8.2. Future directions and limitations

Several research questions emerge from these findings. First, while pricing strategies for passenger parking are well established, much less is known about how to effectively price freight curb access. Despite limited evidence, some cities have begun experimenting with monetization to recover parking revenue, manage demand, reduce dwell times, and incentivize cleaner vehicles. Second, the optimal allocation of LZs—both in terms of location and network size—remains an open question, particularly given the need to accommodate multiple types of commercial users. Finally, commercial vehicle activity is rapidly evolving, with shifts in vehicle types, technologies, and operational models. The increasing adoption of electric and autonomous vehicles, as well as micromobility for freight (such as e-bikes and cargo bikes), raises new questions about whether and how CVLZ programs should adapt to these emerging demands.

The present study has several limitations that should be acknowledged. First, the study relies on a purposive, non-probability sample of cities rather than a statistically representative sample of U.S. municipalities. The 13 cities were selected because they had a documented Commercial Vehicle Load Zone program, accessible policy or infrastructure data, and evidence of one or more curb management strategies, such as monetization, enforcement, regulation, or infrastructure allocation. As a result, the findings should not be interpreted as representative of all U.S. cities. Instead, the sample is more likely to reflect cities with relatively visible, mature, or better-documented curb management practices. Cities with less formalized programs, limited public documentation, or no open data infrastructure may be underrepresented. This sampling approach is appropriate for identifying and comparing emerging practices, but it limits the generalizability of the results.

Second, the analysis was constrained by the availability, completeness, consistency, and policy relevance of municipal curb data. Many cities do not maintain open data portals for curb infrastructure, and even when data are publicly available, their structure, terminology, spatial format, attribute definitions, and level of detail vary substantially across jurisdictions. In some cases, data were available only for sign inventories, or only for selected areas of the city. For example, Chicago and Los Angeles were included in the policy and regulation review but could not be included in the infrastructure analysis because spatial curb data were not sufficiently available.

In addition, several datasets lacked clear metadata, contained outdated or duplicated records, used ambiguous labels, or did not correspond directly to the regulatory categories described in municipal codes and public-facing program documents. These inconsistencies made it difficult to link observed curb assets to the policies that govern their use, including eligible users, applicable time restrictions, permit or payment requirements, and enforcement rules. Information on ongoing pilots or recently modified programs was also difficult to verify when municipal websites were not updated or did not provide sufficient detail. As a result, the infrastructure measures reported in this study, such as the number of load zones, total curb length, and spatial distribution, should be interpreted as comparative estimates rather than complete inventories for all cities. More broadly, this limitation reflects the absence of standardized, regularly updated, and policy-linked curb data across U.S. cities.

Moreover, the study is descriptive and comparative in scope. It is not designed to evaluate the effectiveness of existing CVLZ programs, rank cities, or prescribe a single preferred approach to commercial vehicle curb management. The analysis does not directly measure outcomes such as double-parking reduction, delivery efficiency, carrier compliance, safety impacts, emissions, or changes in curb turnover. Instead, it provides a systematic and impartial documentation of current CVLZ practices, highlighting the heterogeneity in program design, regulatory maturity, monetization strategies, enforcement structures, and infrastructure provision across U.S. cities. In doing so, the study clarifies the range of approaches currently implemented and establishes a consistent basis for future evaluation.

Taken together, freight curb management is transitioning from ad hoc regulation toward systematic, evidence-based planning. By documenting existing CVLZ programs and their infrastructure, this study provides a foundation for future research to evaluate their effectiveness and guide cities toward more equitable, efficient, and sustainable curb use.

CRediT authorship contribution statement

Giacomo Dalla Chiara: Writing – original draft, Visualization, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yu-Chen Chu:** Investigation, Formal analysis, Data curation. **Kelly Rula:** Resources, Project administration, Funding acquisition. **Arsalan Esmaeili:** Methodology, Investigation, Formal analysis, Data curation. **Brian Hamlin:** Writing – original draft. **Alison Conway:** Writing – original draft. **Anne Goodchild:** Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors acknowledge funding from the Open Mobility Foundation (OMF), technical support from several City Department of Transportation officials in the selected cities, and data support from INRIX Parking.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

The authors used Grammarly (version 1.141.2.0) and ChatGPT (GPT-5, OpenAI) to assist with language editing, grammar correction, and style improvement. All edits were reviewed and verified by the authors, who take full responsibility for the final manuscript.

Data statement

With the exception of curb data layers for San Francisco, Minneapolis, Philadelphia, and Portland, all other data layers could be made available upon request to the corresponding author.

Data availability

Data will be made available on request.

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