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Zero-Emission Delivery Zones: Decarbonizing Urban Freight and Goods Delivery in U.S. Cities

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CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues.

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HIGHLIGHTS

- Urban freight and delivery activity contributes to harmful outcomes like air pollution and greenhouse gas emissions, which disproportionately burden low-income communities located near major road networks and distribution centers.
- To overcome these challenges, some cities have enacted a zero-emission delivery zone (ZEDZ), which is a defined area that permits unrestricted access to only zero-emission delivery vehicles.
- ZEDZ policy planning is nascent, so policymakers can look to comparable solutions like congestion pricing, off-peak delivery, and low-emission zones for applicable learnings.
- Current examples of ZEDZ implementation in Rotterdam, Netherlands, and Santa Monica, Los Angeles, and Seattle, United States, can offer lessons to accelerate the zero-emission delivery transition.
- To implement ZEDZs effectively and equitably, we recommend that cities do the following:
  - Engage stakeholders early and often
  - Take a stepwise approach and build up to a ZEDZ
  - Provide supportive policies for successful and inclusive ZEDZs
  - Pursue state and federal policy reform
  - Prioritize equity at every step along the ZEDZ process

EXECUTIVE SUMMARY

Zero-Emission Delivery Zone Context

Urban freight and delivery activity within U.S. cities has dramatically increased in recent years due to rising electronic commerce sales, especially during the COVID-19 pandemic, as residents have increasingly shifted to online shopping (Sadik-Khan 2021; Brewster 2022). This growing activity

threatens to exacerbate the existing status quo of high air pollution, greenhouse gas emissions, traffic congestion, and noise pollution, all correlated with urban freight and delivery activity (USCB 2022).

ZEDZs have become the latest policy approach to progress the zero-emission vehicle (ZEV) transition. These defined areas, through controlled access points, camera installations, or other enforcement mechanisms, grant unrestricted access to only zero-emission delivery vehicles, encouraging local businesses and carriers to switch to ZEVs. A few examples of ZEDZs have been implemented throughout the world, including in the Netherlands and United States, and over 50 cities globally have made commitments to pursue ZEDZs or similar zero-emission areas (Cui et al. 2021). Each ZEDZ is designed differently depending on local delivery characteristics and policy priorities, and they can be deployed at different scales, from loading zones to a city-wide system.

U.S. cities are increasingly interested in this policy solution, but with no state or federal support, interested cities must design their ZEDZ policies without official guidance or standards. By referencing similar policies like congestion pricing, off-peak delivery, and low-emission zones as well as early versions of ZEDZs, U.S. cities can identify best practices to implement effective and equitable ZEDZ policies.

ZEDZs have significant equity implications that particularly affect small, freight-dependent businesses like grocery stores and construction companies; carriers with small fleets; and low-income communities. For example, functioning and planned examples often focus on the city center, not necessarily where ZEDZs could produce maximum benefits, representing a clear need to reconsider how ZEDZs are developed (Cui et al. 2021). By analyzing negative freight-related externalities, the spatial distribution of small businesses, and important socioeconomic factors, policymakers can better design their ZEDZs and supportive policies to maximize effectiveness and promote social and economic equity.

About This Working Paper

This working paper serves to inform U.S. city policymakers about the status of ZEDZs and suggests strategies to maximize their benefits equitably. Our research is informed by an extensive analysis of research publications about ZEDZs; an assessment of alternative policy strategies; and a series of interviews with more than 15 city policymakers, logistics experts, industry leaders, and community-based organization stakeholders from the United States and the Netherlands.

Through a brief analysis of comparable policies and existing ZEDZ approaches, this paper identifies strategies taken by first ZEDZ adopters and provides preliminary guidance for U.S. city policymakers to consider. However, this working paper does not endorse any specific quantitative methods or prescribe the research and analysis required for cities to implement a ZEDZ. Cities will have to identify strategies to address the challenges of urban freight and delivery and evaluate how to best implement a ZEDZ effectively and equitably.

Key Findings

Analyses of policies like congestion pricing, off-peak delivery, and low-emission zones provide insights for policymakers interested in reducing the repercussions of accelerated urban freight. These insights can be applied to assist ZEDZ planning, and policymakers should prioritize maximizing benefits for neighborhoods most burdened by urban freight and delivery activity.

There is not a one-size-fits-all approach. ZEDZs can take different forms depending on the local market and policymakers' methods to minimize negative consequences for local carriers and freight-dependent small businesses. Pioneers like Rotterdam and a few U.S. cities are planning or implementing their versions of a ZEDZ to reduce emissions and increase ZEV adoption. Although it is too early to determine their effectiveness, this paper offers preliminary lessons from these examples.

Preliminary Guidance

Engage stakeholders early and often

By engaging with carriers, receivers, and residential communities, city policymakers can better understand the distribution of benefits and burdens under the urban freight and delivery status quo, which will facilitate an effective and equitable ZEDZ design. Stakeholder engagement will also help policymakers identify allies for partnerships and engage detractors to determine shared goals.

Take a stepwise approach and build up to a ZEDZ

Cities can mitigate early opposition and challenges through a stepwise approach that can quickly produce results while providing involved actors with the flexibility to begin the zero-emission transition. However, this stepwise approach has its challenges, including determining a zero-emission delivery timeline, imposing repeated upgrade costs on stakeholders, and maintaining buy-in throughout the process.

Provide supportive policies for successful and inclusive ZEDZs

Supportive policies, like purchase subsidies, can support the successful implementation of ZEDZs by addressing common challenges such as ZEVs' high capital costs. Initiatives that grow the vehicle charging network are another method to facilitate the ZEV transition and ZEDZ success. These policies should be designed to advance social and economic equity, ensuring they are used by those who most need them.

Pursue state and federal policy reform

Cities implementing ZEDZs and other ZEV policies may encounter regulatory and cost roadblocks that could threaten the success of their ZEV goals. With the support of involved businesses, cities should pursue expanded regulatory authority, funding support, and policy guidance at the state and federal levels, which would enable cohesive policy enforcement and grow the ZEV market.

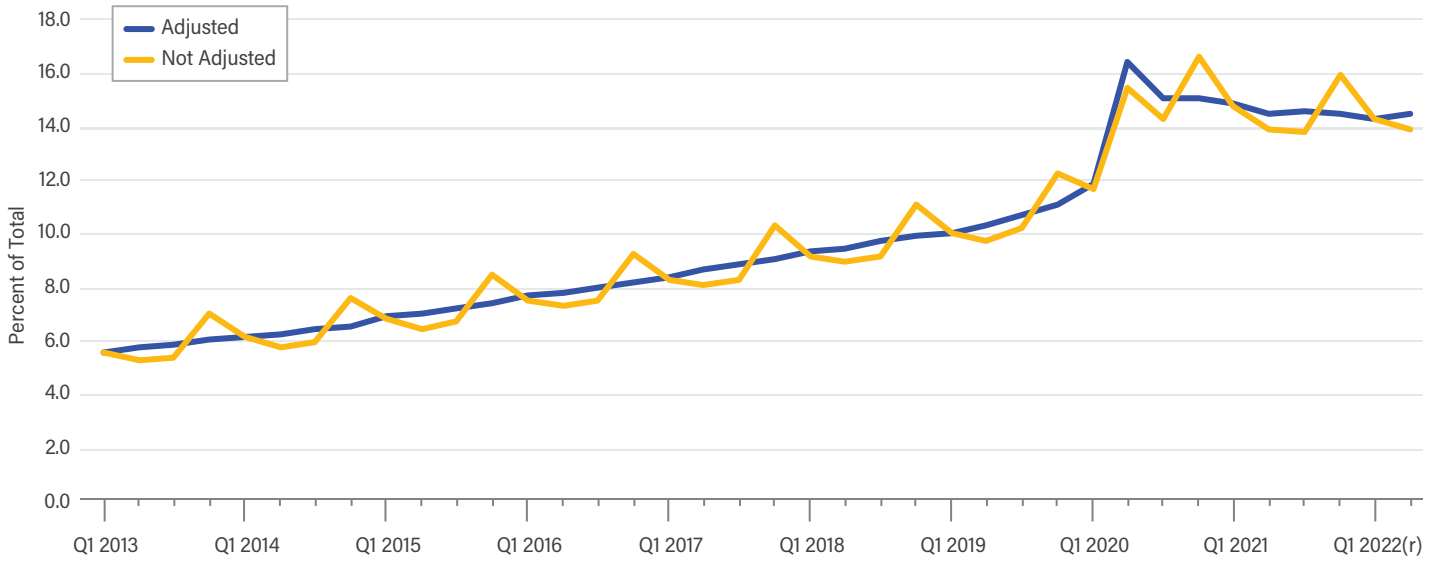
Prioritize equity at every step along the ZEDZ process

As policymakers consider the design of their ZEDZs and supportive policies, they must recognize the inequity within the freight sector and the affordability and benefit distribution challenges of the ZEV transition. Communication with businesses, carriers, and residents can help policymakers select best practices to mitigate cost challenges and ensure ZEV uptake occurs in priority areas throughout their cities.

1. INTRODUCTION

The explosive growth of the electronic (e-)commerce sector and correlated demand for urban freight and delivery during the COVID-19 pandemic is reshaping the design and impact of how goods are transported in cities (Wang et al. 2021). The e-commerce sector has thrived in recent years as the pandemic outbreak forced many businesses to close and consumers to switch to online shopping, causing the share of online retail sales in the United States to jump almost 38 percent from the start of the first quarter (Q1) of 2020 to Q2 2020 (USDC 2022; see Figure 1). Although the accelerated growth in online market activity is expected to slow once the pandemic ends, the U.S. e-commerce sector had previously been experiencing consistent annual growth of ~15 percent, influenced by demographic trends, the globalization of supply chains, and the emergence of cheap delivery services (Wang et al. 2021; USCB 2022; Viu-Roig and Alvarez-Palau 2020).

Figure 1 | **Quarterly U.S. Retail E-commerce Sales as a Percent of Total Quarterly Retail Sales**



Note: Q1 = first quarter.

Source: USDC 2022.

The recent uptick in urban freight and delivery activity during the pandemic is already exacerbating an unsustainable freight sector characterized by greenhouse gas (GHG) emissions, air pollution, noise pollution, and traffic congestion. Unfortunately, the pandemic has also further highlighted the negative economic, environmental, and health threats low-income communities face from urban freight and delivery, such as higher air pollution, which are correlated with their location near transportation networks and distribution centers (Demetillo et al. 2021; Tessum et al. 2019; Yuan 2018).

Consequently, cities have begun exploring new opportunities to mitigate transportation emissions, promote social and economic equity, reduce traffic congestion, and improve citizens' quality of life. One potential solution that has attracted interest in recent years is the zero-emission delivery zone (ZEDZ), a policy whereby delivery vehicles are allowed unrestricted road access to an area only if they are zero-emission vehicles (ZEVs) (Cui et al. 2021).

In the United States, early ZEDZ progress has been limited because cities are without enabling state or federal legislation. Therefore, U.S. cities are individually designing their policy strategies—announced ZEDZ policies vary depending on local market and political contexts. Each city must weigh how to minimize costs on freight-dependent small businesses and carriers, particularly the 91.5 percent of for-hire carriers with fewer than six vehicles in their fleets, while maximizing benefits for the communities burdened by urban freight and delivery activity (ATA 2021).

In this paper, we first describe the numerous negative externalities of urban freight and delivery to support the urgency of shifting to zero-emission delivery. Next, we provide a brief status update on ZEDZ implementation and different ZEDZ iterations. Then, we describe local policy tools that address delivery externalities so U.S. policymakers can consider best practices to inform their ZEDZ planning. Later, we analyze several cities that have implemented or are pursuing ZEDZs, assessing the key components of and strategy for their ZEDZs. Lastly, we recommend a set of ZEDZ guidelines for policymakers that prioritize maximizing effectiveness without compromising on social and economic equity.

2. METHODOLOGY

At the onset of this work, we had two main questions:

- How can early ZEDZ examples inform future deployment in U.S. cities?
- What are some considerations in effectively implementing ZEDZs that will further environmental justice and equity goals?

Due to the limited roll out of ZEDZs, there have been few attempts to quantify potential outcomes from ZEDZs or prescribe best practices (de Bok et al. 2021, TDA et al. 2020). Therefore, we performed a qualitative analysis of current ZEDZ progress through an extensive literature review on urban freight and delivery's harmful effects, developing ZEDZ examples, and comparable transportation policies. For the literature review, we referenced peer-reviewed research, published policy guidance, and federal government websites and databases.

Next, we conducted a brief analysis of three comparable policies: congestion pricing, off-peak delivery, and low-emission zones. Our selection of these policies reflects their similar design and intent compared with those of ZEDZs, such as limiting freight and delivery access to designated areas, which could suggest best practices applicable to ZEDZs. We acknowledge, however, that this is not an exhaustive list of comparable policies that could provide useful insights to policymakers interested in pursuing ZEDZs.

We then conducted more than 15 interviews with city policymakers, logistics experts, industry leaders, and community-based organizations to get a well-rounded perspective of the adverse effect of urban freight and delivery activity and how cities have been planning and deploying ZEDZs. Appendix B includes the questions that guided the interviews.

Relying on information from our research and interviews, we developed a set of preliminary guidance for city policymakers that highlights apparent best practices for the enactment of effective and equitable ZEDZs.

3. THE NEED FOR CLEANER, QUIETER URBAN DELIVERY SYSTEMS

Trucks and delivery vans produce negative social and environmental externalities like air pollution, GHG emissions, traffic congestion, and noise pollution, all of which can harm people's health and well-being. Policymakers have attempted to ameliorate these problems through pollution standards, access restrictions, and other actions, yet factors like increasing e-commerce activity, urbanization, and delivery services help perpetuate these issues (Viu-Roig and Alvarez-Palau 2020). *By studying city-specific challenges from urban freight and delivery, policymakers will understand why decarbonizing urban freight and delivery activity should be a policy priority.*

3.1 Air Pollution

Diesel commercial trucks and delivery vans disproportionately produce harmful pollution including particulate matter (PM), nitrogen oxides (NOx), and other air toxics.

- Freight trucks and delivery vehicles that run on diesel produce much of the harmful NOx and other hazardous co-emissions within cities. Heavy-duty diesel vehicles represent only 3–6 percent of total U.S. fleet distance traveled, but they contribute up to seven times more NOx per kilogram of fuel burned than gasoline (Demetillo et al. 2021). The latest estimates from the U.S. Environmental Protection Agency similarly state that in 2020, heavy- and light-duty diesel trucks produced ~4 and ~11 times more PM2.5 (particulate matter of 2.5 micrometers or less in diameter) per mile, respectively, than their gasoline counterparts (EPA 2019). Despite near-continuous improvements in PM and NOx emissions from diesel trucks, these vehicles' stop-and-start driving cycles continue to harm human health (EPA 2019).

Numerous studies have shown that there are racial disparities in exposure to air pollution from the transportation sector.

- Many low-income urban neighborhoods are located near highways and major road networks where housing costs are lower because undesirable traffic impacts like air and noise pollution are higher, resulting in inequitable pollution exposure and health impacts (Karas 2015; Katz 2012; Semuels 2016). Even in metropolitan areas, distribution centers and their fleets are increasingly sited within minority communities because of cheap land parcels, low-wage labor, and favorable sociopolitical conditions (Yuan 2018). Demetillo et al. (2021) linked heavy-duty delivery vehicles to much of the racial disparities in air pollution exposure by observing differences in NOx concentrations between weekdays and weekends in minority communities, aligning with local freight activity.

3.2 Greenhouse Gas Emissions

Medium- and heavy-duty trucks contribute disproportionately to GHG emissions.

- U.S. cities are accelerating efforts to decarbonize the transportation sector because of its significant contribution to GHG emissions. Policymakers are increasingly focused on medium- and heavy-duty trucks, given that these vehicles account for 24 percent of total transportation emissions but represent under 10 percent of the total U.S. fleet (Lowell and Culkin 2021; EPA 2021). The World Economic Forum predicts that growing global delivery traffic in the world's top 100 cities will result in an additional six million metric tons of carbon dioxide being emitted into the atmosphere in 2030 compared with delivery emissions in 2019 (Deloison et al. 2020).

Continued high GHG emissions from urban freight and delivery particularly threaten less resilient communities.

- Low-income communities are more vulnerable to climate change because it exacerbates existing health and social inequities (APHA 2018). These communities are more likely to have preexisting health conditions, may lack quality and resilient infrastructure and housing conditions, and usually need more resources to adequately plan for and respond to climate change (Ebi et al. 2018; Shonkoff et al. 2011; Thomas et al. 2019).

3.3 Traffic Congestion

The duty cycles of delivery vans and freight trucks contribute to urban traffic congestion.

- Delivery vehicles can contribute to traffic congestion because they drive at low speeds, averaging just 13 miles per hour, and make frequent stops every mile, often over 100 stops per day (AFDC 2021; NREL 2022). Traffic congestion is also influenced by other drivers' behavior and limited dedicated

delivery parking and loading zones (Hammami 2020). While searching for parking, delivery vehicles can cruise for 28 percent of total trip time, which can contribute to 15–74 percent of downtown traffic (Jaffe 2020). If no parking is found, delivery vehicles will also double-park, which can back up traffic and block bike lanes.

Congestion from urban freight and delivery is costly and expected to become worse.

- Traffic congestion prolongs commuter times and increases local GHG emissions and air pollution, costing urban areas around the country (Bharadwaj et al. 2017; Zhang and Batterman 2013). For example, a 2018 analysis estimated traffic congestion was costing New York City US$20 billion annually (PNYC 2018). By itself, U.S. truck congestion was estimated to have resulted in $11.3 billion in wasted fuel and time in 2020 (Schrank et al. 2021). Congestion costs are likely to rise because the number of delivery vehicles in the world's top 100 cities are predicted to increase by 36 percent between 2019 and 2030, raising congestion by over 21 percent (Deloison et al. 2020).

3.4 Noise Pollution

Noise generated by urban freight and delivery vehicles can degrade citizens' quality of life and health.

- At moderate speeds, a diesel truck can produce noise levels above 70 decibels (dB), well above the World Health Organization's recommendation of 53 dB, which can not only irritate those nearby but create negative health outcomes (WHO 2018; Zurek 2012). Noise pollution can interrupt sleep, impair concentration, and increase stress on people's cardiovascular systems (Jacyna et al. 2017; Münzel et al. 2021). Low-income communities are often located near major road networks and urban freight and delivery activity centers, so they disproportionately suffer from daytime and nighttime noise pollution that can compound the ailments resulting from their exposure to transportation air pollution (Casey et al. 2017; Han et al. 2018).

4. ZERO-EMISSION DELIVERY ZONES

Many cities have implemented regulatory policies and incentives to address the challenges of urban freight and delivery and advance zero-emission delivery. Despite ongoing efforts, the transition to zero-emission delivery is moving slowly and remains years behind the state of passenger electric vehicles. The increasing urgency of mitigating climate change warrants a new strategy, one with the potential to quickly progress zero-emission delivery.

4.1 Zero-Emission Zones and Zero-Emission Delivery Zones

Zero-emission zones (ZEZs) are areas where only ZEVs, pedestrians, and cyclists are granted unrestricted access, with other vehicles either prohibited or forced to pay a fee for limited access (Cui et al. 2021). By making internal combustion engine vehicles (ICEVs) more costly and inconvenient, policymakers intend to disincentivize their use and create increased demand for ZEVs. Most announced ZEZs are to cover their respective city centers, usually enforced by license plate recognition cameras at controlled access points or inside the zone (Cui et al. 2021). Thus far, ZEZ examples are currently under development or in the early stages of implementation in European cities (Cui et al. 2021). First adopters have had to establish a legal framework to deploy ZEZs because there are unique regulatory, equity, and economic concerns regarding the limited ZEV market and ZEZs' broad impact on traffic (Cui et al. 2021).

Most cities have elected to pursue a phased strategy, first targeting urban freight and delivery vehicles with later ambitions to expand to the larger vehicle market (Cui et al. 2021). Early iterations of ZEZs are known as zero-emission delivery zones (ZEDZs), which specifically hinder the operation of diesel and other fossil-fueled delivery vehicles within a designated area, typically through ICEV access fees and complementary incentives for operating zero-emission delivery vehicles like electric (e-) trucks, e-vans, and e-cargo bikes. ZEDZs are being implemented before full ZEZ enforcement because cities have prioritized regulating urban freight and delivery activity due to its significant negative externalities and because delivery vehicles, as a relatively small portion of the total vehicle market, represent a more manageable vehicle class to target.

4.2 Types of Zero-Emission Delivery Zones

Cities around the world are taking different approaches to achieve zero-emission delivery. Strategies reflect restrictions on city government regulatory abilities, their transportation systems' characteristics, and policy priorities. U.S. policymakers can evaluate these ZEDZ iterations and decide which strategy best fits their needs.

Voluntary Restricted Access Zone

A voluntary ZEDZ is a zonal policy in which a specific area is designated for zero-emission delivery vehicles only, but compliance is voluntary for urban freight and delivery businesses. This strategy may be chosen to introduce local carriers to the ZEDZ concept and could be a precursor to a more stringent future policy. A voluntary ZEDZ could also reflect cities' regulatory restrictions, such as being unable to prohibit delivery vehicle access.

ZEV Microhub

Set near a final delivery point, a microhub is a drop-off/pick-up location that serves a small service area and can be targeted to different types of ZEVs. Microhubs are particularly useful for serving areas where delivery vehicle access is challenging, possibly due to limited curb space or areas with restricted traffic conditions (UoW 2020). Microhubs enable consolidated last-mile delivery trips that can be made using zero-emission, short-range vehicles like e-cargo bikes or small e-vans. Additionally, customers can pick up their packages from parcel lockers.

ZEV Parking Spots and Loading Zones

Cities can designate parking spots or commercial loading zones as being for ZEVs only, possibly employing new signage, curbside markings, and video monitoring to ensure compliance. This strategy increases the convenience of using ZEVs in delivery operations by providing valuable curbside access. However, the effect of this policy depends on the scale of deployment. Concentrating many ZEV-only parking spaces and loading zones within a priority area may more strongly encourage local ZEV adoption than a few distributed parking spots or loading zones.

Mandatory Restricted Access Zone

A mandatory ZEDZ prohibits or charges ICEVs for entry into a defined area and penalizes violators. Entrances to the ZEDZ can have toll booths or unmanned electronic stations, and license plate cameras can be placed within the ZEDZ to detect violators. A mandatory ZEDZ would most likely require enabling legislation at the state or federal level due to commerce and trade legal protections that make it difficult to impose restrictions on urban freight and delivery (SoC 2022).

5. INFORMING ZEDZ PLANNING VIA ALTERNATIVE POLICY ANALYSIS

Before ZEDZs, cities were already implementing policies like delivery time restrictions and variable parking pricing to mitigate the negative effects of urban freight and delivery (NASEM 2011). With ZEDZ deployment just beginning, policymakers can analyze comparable policies to inform their ZEDZ policy planning. This section briefly analyzes congestion pricing, off-peak delivery, and low-emission zones, which have design features and impacts comparable to those of ZEDZs. We provide evidence of their effectiveness in Table A1 of Appendix A and suggest some potential lessons that can be applied to ZEDZ planning, although we do not provide an exhaustive list of takeaways from analyzing these and other alternative policies.

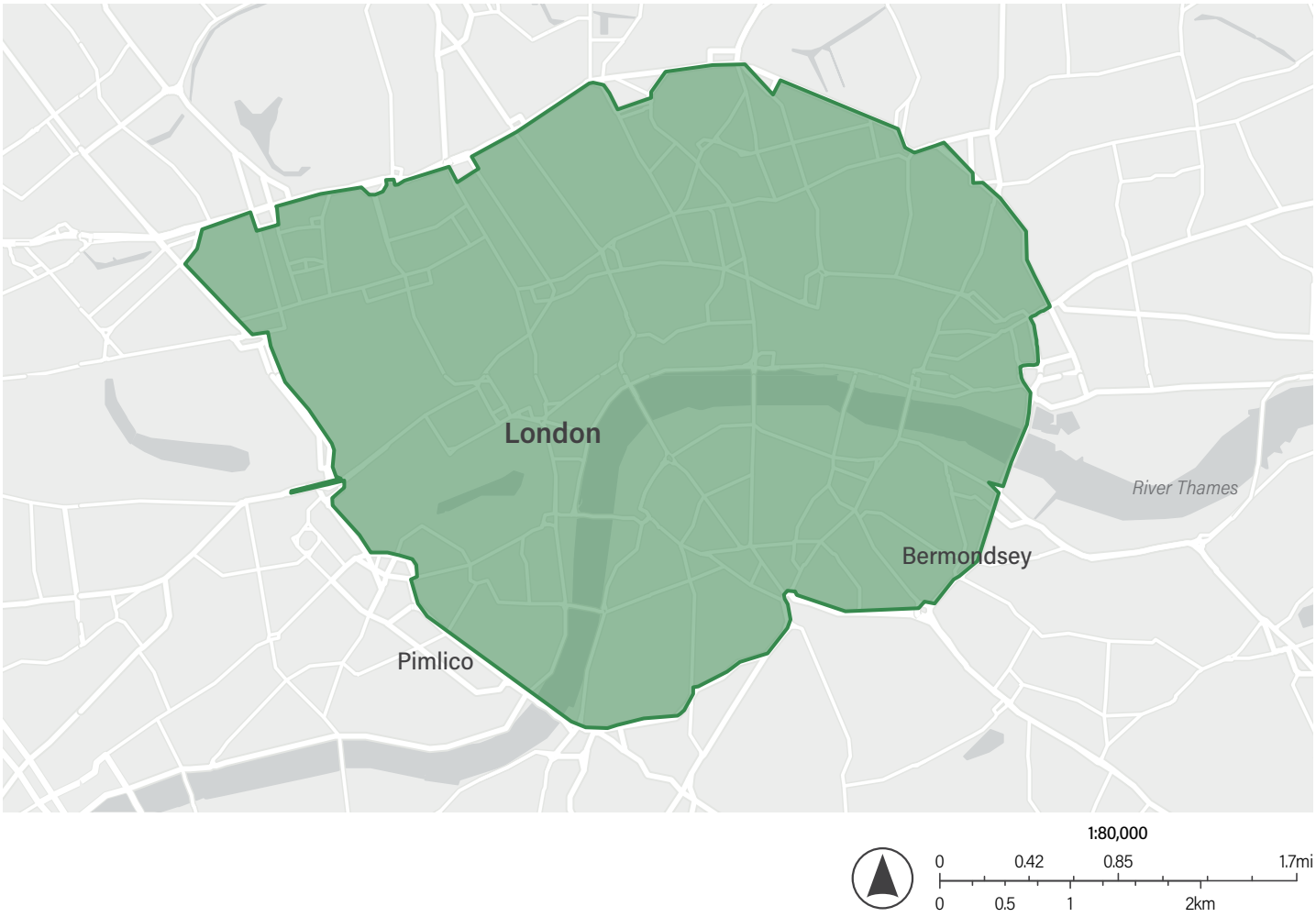
5.1 Congestion Pricing

Background

To alleviate traffic congestion in their city centers, some cities have implemented a traffic demand management policy known as congestion pricing (Chen et al. 2018; see Appendix A). Congestion pricing places a price on vehicle usage within a defined area to shift discretionary traffic to more sustainable modes or off-peak periods (Chen et al. 2018; FHA 2008). Congestion pricing includes time-, distance- and area-based pricing (AbuLibdeh 2017).

Congestion pricing schemes, like London's Congestion Charge Zone, shown in Figure 2, are designed to address each area's particular needs. Policy planners set the boundaries of the congestion zone, depending on the location of congested areas and local air pollution. They need to identify the numerous access points into the zone and install the necessary enforcement infrastructure like automatic license plate readers. Additionally, they must decide on operating hours and designate affected vehicle types and exemptions (Holguín-Veras et al. 2015).

Figure 2 | **Map of London's Congestion Charge Zone**



Source: WRI authors based on TfL 2021.

5.2 Off-Peak Delivery

Background

To reduce the problems associated with freight traffic, some cities have implemented off-hour delivery incentive programs, encouraging urban freight and delivery activity within a designated area to shift to a time with reduced traffic congestion (Stütz and Kirsch 2020; see Appendix A). The shift to off-peak delivery might be outside of regular business hours, such as overnight or during periods of the day with reduced traffic congestion. This approach seeks to improve transport efficiency so that deliveries can occur more quickly at higher speeds and reduced costs (Holguín-Veras et al. 2018; Stütz and Kirsch 2020).

Policymakers need to identify the target congested areas, the preferred delivery periods, and the participating businesses. Some cities have focused on fostering the participation of the businesses that receive deliveries, known as "receivers," because they generate demand for delivery services (Holguín-Veras et al. 2018). For example, New York City's Off-Hour Delivery (OHD) program, as seen in Figure 3, created a Trusted Vendor Program that provides receivers with information about trustworthy carriers to encourage participation (Holguín-Veras et al. 2019).

Figure 3 | **New York City's Off-Hour Delivery Focus Areas**

Source: WRI authors based on Diaz 2022.

5.3 Low-Emission Zones

Background

A low-emission zone (LEZ) is described as a "defined area where access for the most polluting vehicles [is] regulated, either by forbidding the most polluting vehicles to access the zone or by demanding a fee for the polluting vehicles to enter or drive in the zone" (Amundsen and Sundvor 2018; see Appendix A). This policy tool has been widely adopted across Europe for the primary purpose of improving air quality. Between 2019 and 2022, the number of active LEZs increased by 40 percent to 320 zones; by 2025, there will be 507 LEZs (Azdad et al. 2022).

LEZ schemes are customizable and usually sited within city centers where traffic flows are highest (see Figure 4). When implementing an LEZ, policymakers need to install an extensive system of enforcement infrastructure, typically license plate cameras; decide on operating hours; and determine which vehicle types to restrict and what emissions standard is required for each vehicle type (Amundsen and Sundvor 2018). The LEZ boundaries and covered vehicles and pollutants can be expanded depending on policymakers' priorities and current air quality conditions.

5.4 Lessons for ZEDZ Planning

Locally and nationally coordinated ZEDZ schemes could have different effects on urban freight and delivery businesses.

Cruz and Montenon (2016) compared London's local LEZ scheme with Berlin's, which is part of a national program in Germany. They found that the local scheme minimally influenced fleet renewal in London because large carriers shuffled their fleets and simply redeployed their cleanest vehicles to London. In contrast, Berlin carriers had to upgrade their fleets.

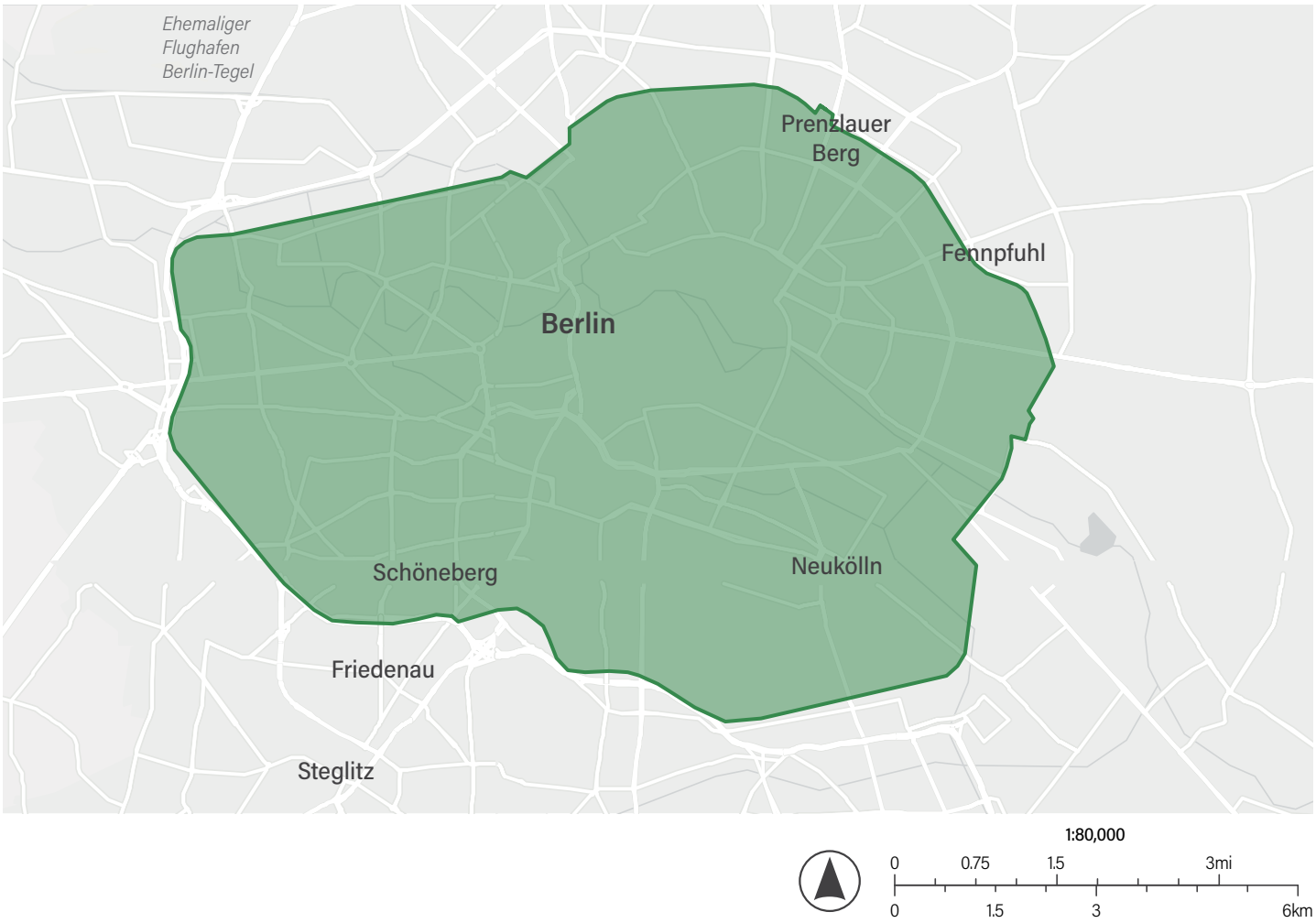
These findings could have significant implications for ZEDZ planning in the United States. The researchers suggest that national schemes are better suited to encourage fleet renewal and ensure uniformity in the criteria to be met, but local schemes take better account of a city's specific characteristics, such as the most economically vulnerable businesses and their locations within the zone. To prevent large carriers from simply relocating their ICEVs elsewhere, cities should coordinate ZEDZ development with other cities and towns to ensure uniformity for carriers and businesses while retaining their ability to refine the policy to fit each city's needs.

City governments must be wary of managing costs, particularly those imposed on stakeholders.

LEZs, off-peak delivery, and congestion pricing schemes can have regressive or inequitable effects on commuters and carriers. For example, Broaddus et al. (2015) noted that freight trips are often not discretionary and that carriers have limited flexibility with their delivery times because these are mostly determined by receivers. This means if carriers cannot make deliveries during off-peak hours or outside of congestion charge hours, they will be unable to capitalize on favorable traffic conditions or avoid congestion charges (Stütz and Kirsch 2020; Mahendra 2010).

As they plan their ZEDZ timelines, policymakers should be aware of their carriers' operational constraints as well as key variables like the spatial distribution of noncompliant vehicles, carriers, and receivers. Research suggests that schemes like off-peak delivery programs, which change receiver freight demand, can achieve immediate environmental and transport efficiency benefits without requiring mass ZEV adoption (Holguín-Veras

Figure 4 | **Map of Berlin's Low-Emission Zone**



Source: WRI authors based on SenUVK 2022.

et al. 2018). Policymakers can also provide purchase subsidies in addition to lengthy notice periods and exemptions, giving businesses and carriers the time and ability to adapt their operations (Dablanc and Montenon 2015). To maximize equity and efficiency, subsidies and exemptions should be designed to benefit small carriers, which will struggle the most to transition to cleaner vehicles (Sheldon et al. 2017).

Poorly planned equity measures might compromise ZEDZ effectiveness.

Exemptions are one common equity measure intended to reduce costs on specific stakeholders. Travel and vehicle exemptions mitigate the financial penalty for drivers entering the regulated area, importantly minimizing regressive impacts on low-income commuters and small businesses. However, analyses of congestion pricing schemes have found that if not enough vehicles are charged, exemptions can incentivize vehicle use, sustain traffic congestion, and reduce raised revenues for public transit investment (Cohen D'Agostino et al. 2020; Lehe 2019; Whitehead et al. 2014).

ZEDZ planners should consider which equity measures are appropriate, tailoring them to support small freight-dependent businesses and carriers that might be unable to afford ZEVs at their current prices. ZEDZs should be as equitable as possible, but equity measures like exemptions should not compromise the ZEDZs' ability to accomplish their primary purpose of encouraging ZEV uptake and reducing ICEV entry.

6. CITY PROFILES

As emerging policy solutions, ZEDZs are mostly in the planning or beginning stages, with European cities, mainly those in the Netherlands, leading in ZEDZ commitments. However, interest in ZEDZs has grown in the United States, and several cities have implemented or are planning to implement ZEDZs and related policies.

We connected with private, government, and university stakeholders in cities around the United States and the Netherlands to discuss ZEDZs and the implementation status of local examples, with questions seen in Appendix B. Our brief analysis covers Rotterdam, which pioneered the ZEDZ in the Netherlands, and Santa Monica, Los Angeles (LA), and Seattle, which are the only U.S. cities currently pursuing ZEDZs. Each city has an innovative strategy to combat the social and environmental problems created by urban freight and delivery.

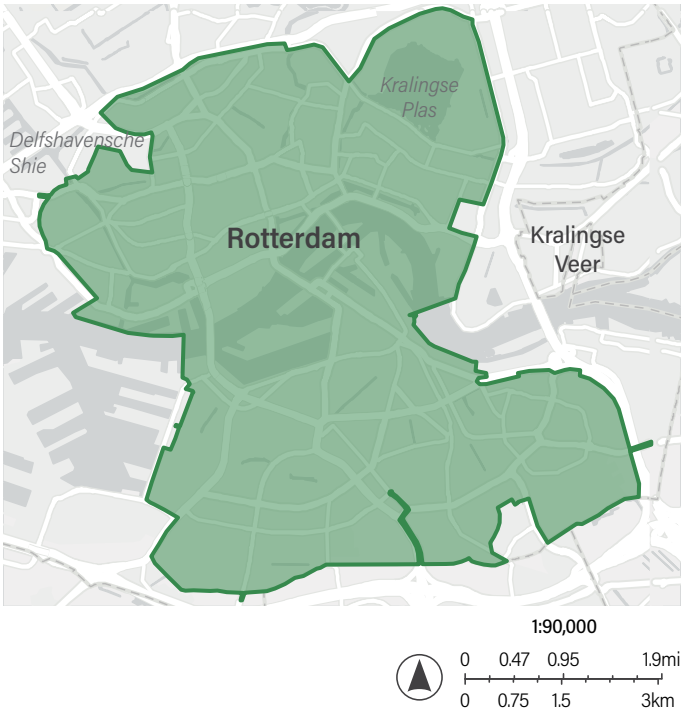
6.1 Rotterdam, Netherlands

Background Information

Mitigating the disproportionate environmental and health impacts of urban freight and delivery has long been a priority for Rotterdam. The city set goals in 2014 to make delivery activity within the city center emission free, and soon after, it launched one of the first examples of a ZEDZ along a 1.6-kilometer street to demonstrate zero-emission delivery vehicles (CoR 2019). Following the Dutch National Climate Agreement in 2019, the city announced its roadmap strategy to achieve zero-emission delivery by 2025, culminating in a mandatory ZEDZ at the city center (GoN 2019; CoR 2020; see Figure 5). The city's strategy includes its *Covenant ZECL* (Zero-Emission City Logistics) with local businesses and organizations and plans for multiple other solutions, like urban consolidation centers, that support zero-emission delivery (CoR 2020).

Rotterdam has formed a strong business and policy bloc through years-long partnerships with local businesses to promote delivery efficiency and, more recently, advance zero-emission delivery (CoR 2019). Admitted businesses share information and collaborate on their zero-emission progress and solution opportunities, and the city connects partners with pilot programs and ensures that policy development is cohesive and clear (CoR 2020). Table 1 contains examples of potential benefits and challenges of the city's strategy.

Figure 5 | **Map of Rotterdam's Zero-Emission Delivery Zone Area**



Notes: The planned ZEDZ will remain within the Rotterdam Ring (surrounding highways) so that all vehicles can access nearby business parks and industrial hubs.

Source: WRI authors based on CoR 2022a.

Key Finding

Businesses can play a key role in forming a cohesive zero-emission policy strategy.

- Through its collaborative approach, Rotterdam has connected with fresh produce, general cargo, construction, and other businesses to support pilot projects, design its ZEDZ, and identify challenges (CoR 2020). For example, our stakeholder interviews revealed that covenant partners led the push for an expanded ZEDZ to make deliveries simpler and more efficient. Businesses have advocated for the city to implement a cohesive, enforceable strategy while they develop their long-term fleets and operations plans. While every city government's relationship with its respective business community varies, the Rotterdam example illustrates how a collaborative policy environment can simultaneously further ambitious sustainability and economic goals.

Table 1 | **Potential Benefits and Challenges of Rotterdam's Zero-Emission Delivery Zone**

POTENTIAL BENEFITS	POTENTIAL CHALLENGES
Rotterdam's comprehensive ZECL strategy reflects strong economic, equity, and environmental principles. Rotterdam has focused on achieving zero-emission delivery while avoiding negative economic consequences. The city's policy strategy identifies supportive solutions like microhubs and consolidation centers, which offer zero-emission delivery pathways to each logistics subsector by improving delivery efficiency and promoting newer types of delivery vehicles like e-cargo bikes.[a] The successful implementation of these solutions and the ZEDZ is expected to reduce carbon dioxide emissions by 186 kilotonnes within the target area by inducing ZEV adoption and improving transport efficiency.[b] Although ZEV adoption remains low, it is over twice as high as in 2019.[c] The city has planned for the ZEDZ to extend beyond the city center to produce air quality benefits for residential communities in the southern part of the city, which are outside the boundaries of the current LEZ.[d] The prioritization of air quality benefits for residents demonstrates Rotterdam's emphasis on promoting sustainability.	**Rotterdam and other Dutch cities will need to resolve the affordability challenges facing the many logistics subsectors.** Currently, ZEVs are more expensive than their fossil-fueled counterparts, yet with some Dutch cities planning their ZEDZs for 2025, businesses must begin their fleet transitions soon. ZEV adoption in Rotterdam may be increasing, but as of 2021, only 1.20% of delivery vans and 0.73% of freight trucks were zero-emission within Rotterdam's LEZ.[e] Rotterdam identifies most transport activity within the city as being done by small transporters, emphasizing the need for zero-emission solutions for small businesses that might be unable to afford a ZEV without financial assistance.[f] Alternative solutions like microhubs, bundling, and coordinated delivery can be easily identified, but businesses will have to determine which options fit with their operations. Large businesses may more easily purchase ZEVs, but they are also struggling to afford the expensive ZEV options that are available. If these businesses have a national market, they might more simply relocate ICEVs to cities without ZEDZs, limiting environmental and air quality benefits to only those cities with ZEDZs.

Source: Based on authors' stakeholder interviews; a CoR 2020; b CoR 2020; c CoR 2022b; d CoR 2020; e CoR 2022b; f CoR 2019.

6.2 Santa Monica, California

Background Information

In 2021, Santa Monica launched the first operational ZEDZ in the United States (LACI 2021; see Figure 6). The ZEDZ was heavily influenced by the Los Angeles Cleantech Incubator (LACI) and its Transportation Electrification Partnership, a multiyear public-private partnership to accelerate transportation electrification in greater Los Angeles (LACI 2021). Wanting to explore the ZEDZ solution further, LACI selected Santa Monica from a list of applicants, and they collaborated to develop a voluntary pilot ZEDZ in the Downtown and Main Street commercial districts, which are the hubs of the city's commercial and social activity (LACI 2021).

Located within the city's commercial activity core, the ZEDZ is a one-square-mile area in which partners can use the following innovative zero-emission delivery technologies (LACI 2021):

- ZEVs
- Commercial electric vehicle car sharing
- Micromobility for food and parcel delivery
- Priority zero-emission loading zones and curb management

Figure 6 | **Map of Santa Monica's Zero-Emission Delivery Zone Area**

Source: WRI authors based on LACI 2021.

Cameras have been placed at each priority loading zone to gather data and measure how the ZEDZ and restrictions are performing. Due to state regulatory limitations and concerns about costs on businesses, the ZEDZ is voluntary, with participants having to opt in (SoC 2022). Examples of potential benefits and challenges are in Table 2.

Key Finding

The metrics for success for Santa Monica's ZEDZ have not yet been determined.

- With Santa Monica as the first city to implement a ZEDZ in the United States, there is a lot of attention on the pilot project and its findings. At the time of interviews, the metrics of success were more anecdotal from businesses than quantitatively supported. Several innovative last-mile delivery technologies and zero-emission loading zones have been implemented, but there have been a number of challenges. For example, the city has struggled to obtain useful data, gain the interest of risk-averse businesses, and achieve zone compliance. Pilot planners would like to continue the project past its scheduled end date in late 2022, but they will need city council approval and additional funding. A report on ZEDZ impacts and final recommendations will be shared with the city council and public at the end of 2022.

6.3 Los Angeles, California

Background

Well-known for its traffic congestion and air pollution, Los Angeles has prioritized transforming its transportation sector to reduce the city's GHG emissions and improve local air quality. Urban freight and delivery activity has been specifically targeted by the city, which has pledged to establish a ZEDZ by 2030 and has committed to 100 percent zero-emission delivery by 2035 (C40 Cities 2022; Garcetti 2019).

Instead of enacting a large access restriction area, Los Angeles has focused solely on curb management, and, in 2021, passed an enforceable ordinance that governs curbside access for delivery vehicles (CoLA 2021). The pilot initiative created five exclusive commercial loading zones across the city that are to be used only by zero-emission delivery vehicles (Reynolds 2021; see Figure 7). These locations were selected based on traffic density; loading zone demands; air pollution burden; and the city's ability to install, enforce, and monitor the loading zones (Reynolds 2021). Compared with a traditional ZEDZ, LA's action was much simpler and cheaper, costing about $2,000 per loading zone for signage and curb markings (Reynolds 2021).

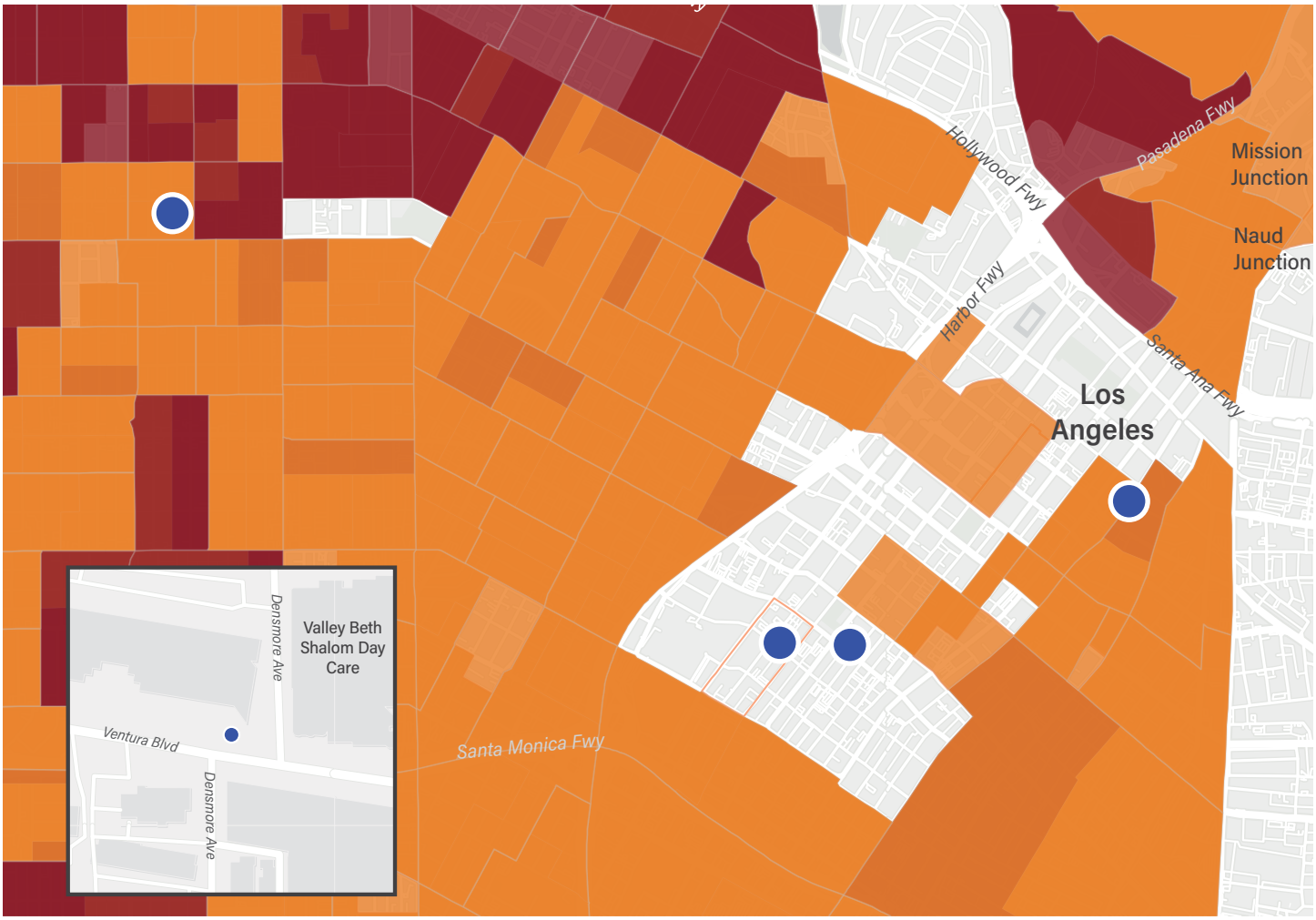
Table 3 describes potential benefits and challenges of LA's strategy, although it is currently difficult to gauge the policy's effects because of its recent enactment and limited rollout. If the planned pilot expansion for 100 zero-emission loading

Table 2 | **Potential Benefits and Challenges of Santa Monica's Zero-Emission Delivery Zone**

POTENTIAL BENEFITS	POTENTIAL CHALLENGES
The Santa Monica pilot will provide valuable information for U.S. cities and carriers. Despite its imperfections, Santa Monica's pilot provides an opportunity for other U.S. cities and delivery partners to study how a ZEDZ and zero-emission loading zones will affect local ZEV adoption and delivery activity. For example, the pilot will demonstrate the value of various zero-emission delivery technologies like e-scooters and sidewalk delivery robots. The pilot's use of cameras will enable data collection to assess whether the policy solution reduced air pollution, GHG emissions, and traffic congestion. The pilot will also inform the necessary coordination between public-private partners and city departments to enact a ZEDZ. Business improvement districts, neighborhood associations, and technology partners have remained involved with the zone's implementation through an advisory committee with LACI. City departments have also coordinated to plan and install new infrastructure like new traffic signs and video cameras.	**Santa Monica's ZEDZ success is limited by its voluntary designation.** The city prioritized minimizing negative effects on businesses operating in the downtown area, especially during the pandemic, and made the zone voluntary. The city was especially concerned about food delivery businesses and wanted to make the ZEDZ appealing to those that use small light-duty vehicles. Unfortunately, the decision to make the ZEDZ voluntary has limited the pilot's efficacy. Businesses have no real pressure to switch from ICEVs, and police cannot ticket ICEVs parked in the "ZEV-reserved" loading zones, which were supposed to attract participation by promising curbside access. The city is considering solutions such as painting the curb to make the distinction more obvious and enabling police to issue citations to deter violators. Even if the city wanted a mandatory zone, it would have to first obtain state approval due to route restriction procedures regarding deliveries and pickups.[a]

Source: Based on Authors' stakeholder interviews; a SoC 2022.

Figure 7 | **Map of Los Angeles's Zero-Emission Loading Zones**



Note: Orange and red colors depict disadvantaged communities with an annual median household income (MHI) that is less than 80 percent of California's statewide annual MHI.
Source: WRI authors based on Samulon 2022; CDWR 2022.

zones comes to fruition, there might be more clearly discernible impacts that could be assessed due to the large effect on parking availability.

Key Finding

LA's curbside access regulation can be scaled up to create a de facto ZEDZ without an official ZEDZ policy in place.

- Currently, there are only five zero-emission loading zones in LA, in locations prioritized due to their high air pollution burden and traffic density. Even though the current rollout is limited, the city can identify and convert other loading zones around the city to be for only zero emission delivery vehicles. If hundreds or thousands of parking and loading areas were converted to ZEV-only spaces, this could create a near-ZEDZ situation where urban freight and delivery businesses would be compelled to convert their vehicles to ZEVs because using ICEVs would become too inconvenient or expensive. The policy could be scaled citywide to encourage ZEV use throughout the city, or policymakers could concentrate the zero-emission loading zones in priority areas, possibly as part of a larger strategy to bring air quality and traffic benefits to heavily polluted neighborhoods.

Table 3 | **Potential Benefits and Challenges of Los Angeles's Zero-Emission Loading Zones**

POTENTIAL BENEFITS	POTENTIAL CHALLENGES
LA's approach illustrates how cities can quickly implement an enforceable policy solution. Traffic access restrictions are complicated for U.S. cities because of state- and federal-level regulations. For example, California does not allow cities to "prohibit any commercial vehicles coming from an unrestricted street…by direct route to and from a restricted street…for the purpose of making pickups or deliveries."[a] Instead of waiting for state approval of a ZEDZ, LA capitalized on its ability to regulate curbside access, something that is extremely valuable to carriers, and enacted an ordinance that could potentially influence ZEV adoption. Unlike Santa Monica's ZEDZ pilot, which currently has no enforcement capabilities, LA's pilot is enforceable. Enforceability was important to policymakers because with the ability to penalize violators, the city will hopefully achieve high compliance. With city council authority, the city can ticket and punish violators who park in the exclusive loading zones. This deterrent effect is very important, especially if the policy is later scaled up.	**The zero-emission loading zones reflect an incremental approach compared with a ZEDZ.** In the near term, LA's limited policy approach does not disrupt local deliveries or force expensive fleet-wide transitions. The city can then add additional loading zones to increase pressure on urban freight and delivery businesses at a rate that matches the city's policy goals or technological advancements. This approach may be more welcomed by carriers, especially small businesses, who can more easily adjust their fleets and do not have to worry about rerouting their deliveries. While this policy strategy enables flexibility, until a majority of parking spaces or loading zones are reserved for zero-emission delivery vehicles, it is unlikely to produce a measurable increase in ZEV adoption or decrease in GHG emissions and air pollution. Operating carriers are not yet compelled to accelerate their fleet transitions since there is still ample parking availability, and carriers can easily adapt by parking elsewhere. Scaling up this solution could be challenging as the city will need to work with local carriers and freight-dependent businesses to determine the location and concentration of future zero-emission loading zones.

Source: Based on authors' stakeholder interviews; a SoC 2022.

6.4 Seattle, Washington

Background

In its GHG inventory report, Seattle identified the transportation sector as the largest contributor to its GHG emissions, and the city has committed itself to adopting a ZEDZ by 2030 (C40 Cities 2022; Farrell et al. 2022). In pursuit of this goal, Seattle partnered with a transportation solutions consultancy firm to analyze the city's freight movement and assess suitable ZEDZ locations (Fehr & Peers 2021). Additionally, the city commissioned an opinion research firm to contact businesses and residents to gauge their opinions on the implementation of a future ZEDZ. While no concrete plans have been established, the report and supportive outreach efforts have provided useful information for city policymakers. Examples of potential benefits and challenges are in Table 4.

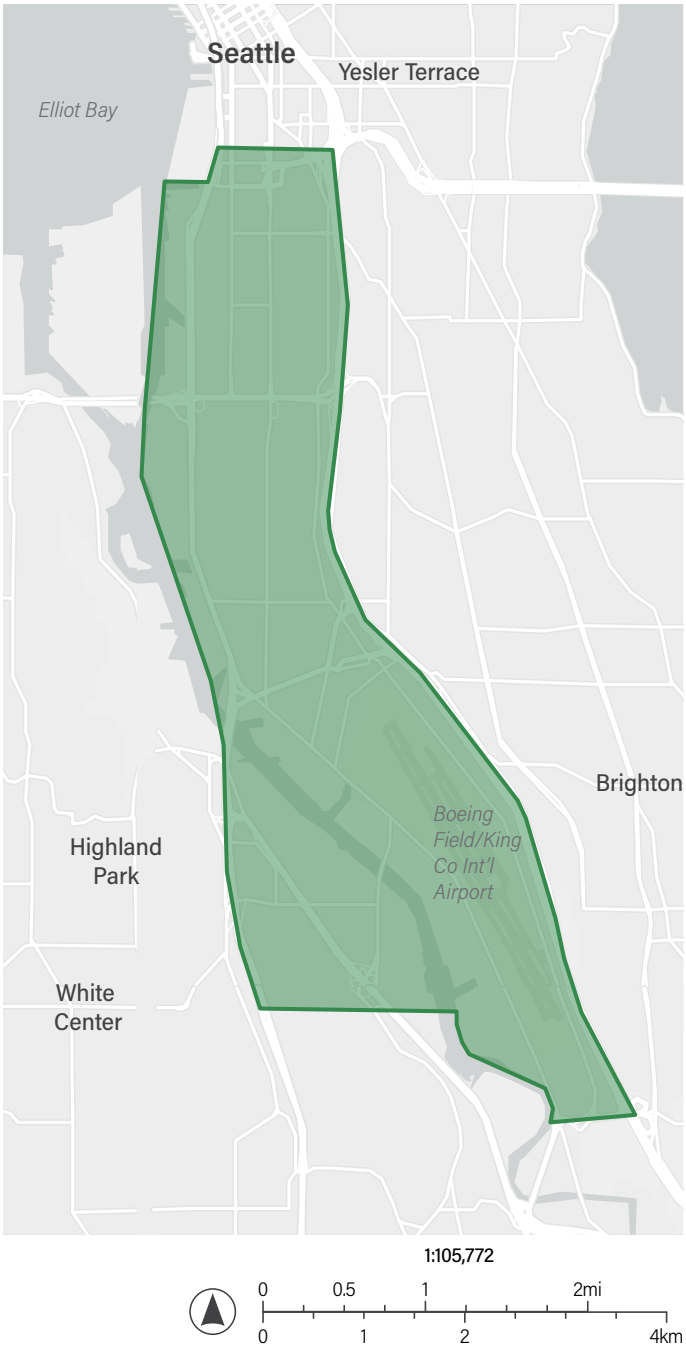
The freight analysis report includes various data sources such as video data and cordon counts as well as travel metrics data to evaluate delivery activity and vehicle types in Seattle (Fehr & Peers 2021). This information was used to identify congested areas of interest, vehicle composition, freight distribution, and goods movement (Fehr & Peers 2021; see Figure 8). Identifying the Duwamish Valley area as a potentially suitable location for a ZEDZ, the report noted the following (Fehr & Peers 2021):

- Over 50 percent of medium- and heavy-duty trucks are involved in freight movement, correlated with the Duwamish Valley having a high proportion of distribution centers for major carriers such as UPS (United Parcel Service), FedEx, the United States Postal Service, and Amazon.
- Most trips were found to be short in length and within the city, and the Duwamish Valley had the highest medium- and heavy-duty freight activity.

Having to educate businesses and residents about ZEDZs, the stakeholder research effort also evaluated local impressions of a ZEDZ in the Duwamish Valley area, including the following:

- Residents were concerned with the ongoing pandemic and other immediate issues like homelessness, and they did not believe the city should prioritize a ZEDZ.
- Businesses expressed interest in a ZEDZ but would want an incremental approach to minimize any potential negative impacts on their operations.

Figure 8 | **Map of Area for Potential ZEDZ in Seattle**



Note: Map represents the area in which a potential ZEDZ in the Duwamish Valley area could be placed. No official plans have been announced.

Source: WRI authors based on Fehr & Peers 2021.

Key Finding

Effective and equitable ZEDZs do not have to be at the city center.

- The city freight report identified the Duwamish Valley area, which is not located in the city center, as a top candidate for the future ZEDZ. Although the downtown area also has high delivery activity, the Duwamish Valley area has a high concentration of distribution centers and resulting medium- and heavy-duty freight traffic, which contributes to air pollution and GHG emissions. Many planned ZEDZs in Europe and similar policies in U.S. cities are focused on the city center with plans for the zones to expand outward over time and encompass additional vehicle types. Seattle and other cities could follow an alternative path that prioritizes maximizing positive benefits in highly polluted, often diverse areas, which may or may not be located at the city center.

7. PRELIMINARY GUIDANCE FOR EFFECTIVE AND EQUITABLE ZEDZS

ZEDZs are increasingly viewed as potentially effective policies that can advance zero-emission delivery and benefit residents and local businesses. Our interviews reveal that ZEDZ success depends on both near- and long-term measures, such as supportive policies that encourage ZEV adoption, extensive engagement across broad coalitions of various actors, and legislative authority to enable successful deployment. A major gap in implementation is the need for cities to center social and economic equity while designing and implementing ZEDZs—that is, to benefit low-income communities that surround urban freight and delivery hotspots as well as small businesses and carriers that might find it challenging to afford ZEVs and hence be burdened by fines or loss of revenue from this policy.

The guidelines below for U.S. cities focus on centering equity within best practices for ZEDZs, relying on lessons learned from projects underway.

Engage Stakeholders Early and Often

It is crucial for cities to engage involved parties early to gain their support for upcoming ZEDZ and ZEV plans. Connecting with affected carriers, small businesses, and community organizations will help city policymakers conduct comprehensive problem assessments, perform freight activity analyses, and develop best-fit ZEDZ strategies for their communities. Out-

Table 4 | **Potential Benefits and Challenges of Seattle's Potential Zero-Emission Delivery Zone**

POTENTIAL BENEFITS	POTENTIAL CHALLENGES
A ZEDZ in the Duwamish Valley area could effectively mitigate transport-related emissions and accomplish equity priorities. As a hub for Seattle's distribution centers and delivery activity, the Duwamish Valley area represents an ideal location for a potential ZEDZ. It is also one of the most diverse areas in the city and has a well-known history of pollution and poverty, reflecting environmental injustice trends seen in other areas with high distribution center concentrations.[a] As of 2018, over 90% of the South Park neighborhood and 100% of the Georgetown neighborhood live within a contaminated site, Superfund site, or freight corridor.[b] If a ZEDZ in the Duwamish Valley area could regulate freight traffic to local distribution centers and incentivize the use of cleaner and quieter ZEVs, it could be an effective and equitable solution that would benefit the polluted neighborhoods burdened by loud and dirty delivery activity.	**Seattle still requires additional information to determine the optimal location of a future ZEDZ.** Seattle is still in the beginning stages of its ZEDZ planning process, and the location and design of its ZEDZ have not been decided. Like other cities, Seattle needed to gather information about its local urban freight and delivery activity, which makes the completion of the freight analysis report an important first step. The study identified goods movement and vehicle composition, but the city could better evaluate potential ZEDZ locations and their outcomes by learning what vehicles are carrying and the location of their end destinations. Furthermore, Seattle will need to determine whether its policy scheme will require enabling legislation and how that will influence implementation. For example, a voluntary ZEDZ in the Duwamish Valley area could have limited effectiveness if it cannot restrict delivery traffic from distribution centers or through traffic on Interstate 5.

Source: Based on authors' stakeholder interviews; a Yuan 2018; Gregory 2020; Ryan 2020; b DVP 2018.

reach efforts can identify the current distribution of benefits and burdens, establish the policies' scopes, and determine potential barriers to success.

Crucially, stakeholder engagement can help policymakers identify new partners and potential opposition. Roundtables and other outreach efforts, like Rotterdam's *Covenant ZECL*, reveal local business opinions on ZEDZs and ZEVs and identify advocates interested in helping their cities progress the ZEV transition. Partnerships and pilot programs with urban freight and delivery businesses can influence the final ZEDZ and supportive policy designs by providing valuable performance data and evaluating which ZEDZ policy features work best.

As cities cultivate buy-in for their ZEDZ and ZEV goals, they also need to listen to concerned stakeholders. These important conversations provide opportunities to determine shared goals and ways to mitigate burdens created by the planned policy. Discussions with the opposition might lead to new solutions that could produce more effective and equitable policy outcomes. For example, this could look like allowing for a transitionary period before ZEDZ implementation or granting a temporary hardship exemption. If policymakers can mitigate harm and convert detractors into champions, they might increase the political support necessary to create lasting change.

Take a Stepwise Approach and Build Up to a ZEDZ

A ZEDZ represents a new strategy to tackle the social and environmental problems of urban freight and delivery activity. U.S. cities would benefit from a stepwise approach that quickly deploys effective solutions while preparing stakeholders for later ZEDZ adoption. Directly implementing a mandatory ZEDZ policy would be challenging as carriers, businesses, and local communities would need to transition their operations rapidly and find the upfront capital to transition to ZEVs. This sudden disruption of the status quo can cause opposition and result in a policy freeze and inaction.

A stepwise approach can offer viable solutions to this challenge by achieving immediate benefits and demonstrating proof of concept. Policies like off-hour delivery, which target freight demand, can quickly reduce emissions and demonstrate the benefits of sustainable urban freight and delivery (Sánchez-Díaz et al. 2017). Meanwhile, U.S. cities could consider small-scale solutions, like zero-emission loading zones or a voluntary ZEDZ, that prepare carriers and businesses for zero-emission delivery. Cities might pursue a stepwise approach based on ZEV affordability challenges, political viability, community engagement, and buy-in from businesses, among other factors. These strategies can mitigate obstacles while producing tangible benefits, granting urban freight and delivery companies the flexibility and time to evolve their operations and strengthen their capacity to transition their fleets.

Although a stepwise approach may improve later ZEDZ feasibility, there are associated challenges. Primarily, cities will have to form their zero-emission delivery timelines, deciding which policies and initiatives to enact first and how they will build upon one another. Second, an incremental strategy might create new cost challenges, with businesses having to repeatedly change their operations or switch to cleaner vehicles before their fleets' end of life. Additionally, a stepwise approach takes time, and city policymakers will need to maintain supporter buy-in throughout the process.

Provide Supportive Policies for Successful and Inclusive ZEDZs

ZEDZs are most effective as part of a supportive system of policies outlined to increase ZEV adoption. By themselves, ZEDZs can effectively incentivize ZEV adoption by prohibiting access to ICEVs, which will compel carriers to transition to ZEVs if they want to continue their business operations. However, urban freight and delivery businesses will need support to overcome the numerous challenges that impede ZEV adoption.

One of the biggest challenges to ZEV adoption remains ZEV prices, which have yet to achieve parity with those of ICEVs. Most carriers are small companies with few vehicles, so they will be particularly hard-pressed to switch to ZEVs in the near term compared with their larger competitors, which have more capital. Hence, policymakers should consider a stepwise policy approach in addition to financial assistance to make the switch to ZEVs more manageable and affordable. Financial assistance like purchase subsidies will be more cost effective if tailored toward smaller carriers and businesses (Sheldon et al. 2017). Policymakers can also promote the adoption of more affordable, short-range delivery modes like e-cargo bikes and e-scooters through purchase incentives, bike lanes, and microhubs.

The costs and complexities of charging infrastructure also present a challenge to businesses' ZEV adoption. Businesses will need to purchase costly charging infrastructure, and the installation and interconnection process can take months. Electric utilities, through "Make-Ready" programs, can support the build-out of charging infrastructure through fleet planning services and by paying for costs like transformer upgrades and new meters. Cities and higher levels of government can also provide subsidies for equipment purchase and installation, install chargers within the planned ZEDZ, and enable a faster permitting and interconnection process.

Pursue State and Federal Policy Reform

For many cities, a mandatory ZEDZ might be the end goal for their zero-emission delivery efforts because it places the highest pressure on businesses to switch to ZEVs. Unfortunately, many cities considering ZEDZs may hit a regulatory roadblock: They most likely require enabling legislation from the state government to prohibit vehicle access and penalize violators.

As seen in Section 6, City Profiles, cities without legislative authority have either been limited to a voluntary ZEDZ or have pursued alternative options. A stepwise policy approach may be the best strategy for various reasons, but cities should simultaneously pursue state policy reform to ensure they can impose a uniform, stringent policy strategy. State legislation provides a means for more effective measures that incentivize ZEV adoption, such as the ability to prohibit ICEV access to restricted areas. Importantly, it can also set up a standardized ZEDZ framework, which can identify base ZEDZ features, like affected vehicle types and notification timelines, eliminating uncertainty for carriers and businesses that operate in different cities.

Additionally, cities can employ their conversations with stakeholders to petition their states and the federal government for increased funding for ZEV purchase subsidies and charging infrastructure. City budgets may be unable to supply the funds needed to boost ZEV adoption, but states and the federal government can provide grants, tax incentives, and other support, especially within low-income communities that lack financial and technical capacity. With cities as hubs for vehicles from around the country, increased ZEV incentives and supportive policies at the state and federal levels will further ZEDZ success.

Prioritize Equity at Every Step along the ZEDZ Process

Throughout the ZEDZ planning and implementation process, city policymakers should prioritize advancing social and economic equity. The freight sector produces clear winners and losers, and transportation policy mechanisms like ZEDZs will produce both challenges and opportunities. As policymakers consider adopting ZEDZs and supportive policies, it is important they first recognize how the current delivery system gives rise to inequitable health and environmental burdens and then determine how their zero-emission policy strategy can be sustainably and equitably developed.

Our interviews with city policymakers reveal that they recognize that the transition to zero-emission delivery will particularly burden small businesses and carriers, and they are striving to balance these equity concerns with policy performance

expectations. For cities pursuing ZEDZs, many have adopted supportive purchase incentives or temporary exemptions, and other cities have instead adjusted their policy approaches, pursuing low-impact solutions such as zero-emission loading zones that can be scaled up over time. Early engagement with stakeholders can help cities resolve key concerns such as what kind of ZEDZ is needed, what supportive policies should be adopted, and where the ZEDZ should be located.

It is also important that cities prioritize benefiting low-income communities that often suffer the worst impacts during final delivery or by being located near distribution centers. ZEDZs in city centers may benefit areas with heavy commercial activity, but policymakers should also consider aligning ZEDZ locations with the distribution of air pollution, household income, race, and other relevant factors. An equity-centered approach could entail doing one of the following:

- Expanding the ZEDZ to provide zero-emission last-mile delivery to residential areas, as was done in Rotterdam
- Placing the ZEDZ in areas known for historic air pollution, like Seattle's consideration of the Duwamish Valley area
- Using an approach like LA's zero-emission delivery zones to encourage ZEV uptake in priority areas without imposing financial burdens

8. CONCLUSION

Efforts are underway across the United States to advance zero-emission delivery. However, U.S. cities are not as familiar as those in Europe with access restriction policies like ZEDZs, and without proper design and implementation, ZEDZs could exacerbate existing inequities in pursuit of decarbonizing urban freight and delivery activity.

This working paper encourages U.S. policymakers to refer to comparable transportation policies and existing ZEDZ examples to inform their policy planning and apply best practices to address their city-specific problems. Several pioneering cities in the United States and the Netherlands have implemented or planned their versions of ZEDZs, so other U.S. cities can review and learn from the real-world benefits and challenges of ZEDZs.

Based on our comprehensive research and interviews, we believe ZEDZs can be implemented effectively and equitably if policymakers consider the basic guidelines outlined above. Nevertheless, ZEDZ progress is still in a nascent stage, so these guidelines are likely to evolve as additional cities in the United States and around the world adopt this policy solution. Although there have been some attempts to anticipate the outcomes of upcoming ZEDZs, future research regarding the performance of completed ZEDZ pilots and early iterations is necessary to provide quantitative evidence about which design features and supportive policies most successfully advance zero-emission delivery.

APPENDIX A. ADDITIONAL INFORMATION ON ALTERNATIVE POLICIES

Table A1 | **Alternative Policies Comparable to Zero-Emission Delivery Zones**

	MAIN PURPOSE	SECONDARY BENEFIT EXAMPLE	TARGETED VEHICLES	EXAMPLES	EVIDENCE OF BENEFITS
Low-emission zones	Reduce air pollution	Increase AFV and ZEV uptake	Freight and passenger vehicles	Berlin's Low-Emission Zone	A study of LEZs in 17 German cities concluded they produced a significant but small reduction in NOx emissions of 4%.[e] A different study of LEZs in five countries found that only those in Germany, which restricts both passenger and freight vehicles, have produced long-term reductions in PM10 and NO_2 emissions.[f]
Off-peak delivery	Reduce traffic congestion	Reduce GHG emissions	Freight vehicles	New York City's Off-Hour Delivery Program	Pilots in New York City, London, and Paris demonstrate that off-peak delivery can result in faster travel times and service time savings.[c] Stockholm's off-peak pilot achieved an increase in average driving speed of 31%, reflecting the less congested road conditions at night.[d]
Congestion pricing	Reduce traffic congestion	Reduce air pollution	Freight and passenger vehicles	London's Congestion Charge Zone	The congestion pricing schemes in London; Milan; Gothenburg, Sweden; and Bergen, Norway reduced vehicle entries into their congestion areas by 33%, 14.5%, 8.6%, and 4.8%, respectively.[a] An analysis of Stockholm's system determined that subsequent charge increases have diminishing effectiveness since price-sensitive drivers are priced off the roads first.[b]

Notes: AFV = alternative fuel vehicle; PM10 = particulate matter of 10 micrometers or less in diameter; NO_2 = nitrogen dioxide.

Source: a Lehe 2019; Isaksen and Johansen 2021; b Börjesson and Kristoffersson 2018; c Sánchez-Díaz et al. 2017; d Fu and Jenelius 2018; e Morfeld et al. 2014; f Holman et al. 2015.

APPENDIX B. INTERVIEW QUESTIONS

To help guide interviews, we developed questionnaires to discern stakeholders' involvement in ZEDZ development or policy decision-making. While similar questions were asked of all interviewees, each questionnaire was tailored to each interview. We have captured some of the core questions below.

For policymakers and other stakeholders

- What made you decide to pursue a ZEDZ? What problems were you trying to solve?
- Why was a ZEDZ policy chosen over other policy alternatives?
- What indicators are you analyzing for the ZEDZ?
- What influenced the design of your ZEDZ policy?
- How did you determine the size and location of the ZEDZ policy?
- How were stakeholders consulted before implementation? Who did you consult with?
- When planning the ZEDZ, how were equity and access to benefits considered?
- What has been the feedback from businesses and the residential community?
- How is your ZEDZ approach different from other examples?
- What costs were there to implement the ZEDZ?
- What are the enforcement mechanisms for the policy?
- Is additional infrastructure needed?
- Has any evaluation been performed? Are there any conclusions from the ZEDZ?
- What should cities that are thinking about implementing a ZEDZ know beforehand?

For businesses

- How are your freight electrification goals progressing?
- Are you tracking how cities are considering policies like ZEDZs, which might affect your business?
- What is your involvement with the ZEDZ policy? Has the city involved you in policy planning?
- How are you looking to support the regulation?
- What impacts might a ZEDZ have on your business?
- What are the challenges of switching to alternative delivery modes?
- Does the ZEDZ affect your freight electrification plans?
- How do ZEDZs impact small versus larger businesses? Should more be done to address small business concerns?
- If you could influence the design of the ZEDZ, what features and supportive policies would you want to include?

LIST OF ABBREVIATIONS

AFV	alternative fuel vehicle
dB	decibel
EV	electric vehicle
GHG	greenhouse gas
ICEV	internal combustion engine vehicle
LACI	Los Angeles Cleantech Incubator
LEZ	low-emission zone
NOx	nitrogen oxides
PM2.5	particulate matter of 2.5 micrometers or less in diameter
ZEDZ	zero-emission delivery zone
ZEV	zero-emission vehicle
ZEZ	zero-emission zone

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ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.