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Identifying the Challenges to Sustainable Urban Last-Mile Deliveries: Perspectives from Public and Private Stakeholders

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Abstract: While freight transportation is a necessary activity to sustain cities' social and economic life—enabling the movement and deployment of goods and services in urbanized areas—it also accounts for a significant portion of carbon dioxide (CO_2) emissions. The urban freight ecosystem is a complex network of agents, both public and private. Reducing CO_2 emissions from urban freight requires the collaboration and coordination between those agents, but the motivations behind their goals, strategies for achieving those goals, and the challenges faced by each agent may differ. In this paper, we document the strategies aimed at reducing CO_2 emissions considered by cities and private companies with the goal of understanding the challenges to progress faced by each. To accomplish this, we interviewed officials from purposefully sampled city departments in North America and private companies involved in city logistics. We found that cities face challenges related to a lack of strong leadership, resources, and policy tools. Companies must consider technological challenges, costs, and their workforce before reducing emissions. Cities and companies are challenged by the disaggregated nature of the urban freight "system"—a system that is not organized at the municipal scale and that is driven by performance and customer expectations.

Keywords: urban freight; city logistics; sustainable transportation; transportation policy

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1. Introduction

Freight transportation is a necessary activity for sustaining cities' social and economic life, enabling the movement and deployment of goods and services in and between urbanized areas. In Seattle, for instance, retail and wholesale freight movement accounts for over USD 50 billion in economic activity and employs more than 62,000 people [1]. Truck freight, though, also accounts for 24% of transportation greenhouse gas (GHG) emissions in the United States nationally, and therefore, it is a major contributor to climate change [2]. Guaranteeing an efficient and sustainable last-mile, or urban freight, transport ecosystem is necessary for cities to survive and to tackle the climate emergency.

E-commerce and, therefore, urban deliveries are growing rapidly [3]. There are more services, web applications, and companies that offer delivery to the end consumer today, and therefore, the number of goods-carrying vehicles on city streets has increased [4]. The World Economic Forum predicts that the number of delivery vehicles in major cities could increase by 36% by 2030 based on current trends [5]. Under the business-as-usual scenario, the increased volume of deliveries will be handled by gasoline and diesel vehicles, compounding the already urgent issue of climate change. Between 2015 and 2018, the number of trucks entering New York City increased by 2.5%, most of which was tied to two-axle delivery-type trucks [6]. Some cities and companies recognize that this growth is not sustainable, and both stakeholder groups have or are identifying strategies and creating climate goals related to reducing emissions from freight within metropolitan areas.

The urban freight "system" is complex and not centrally organized [5,7]. A myriad of companies are responsible for delivering parcels, palletized wholesale freight, and meals

and groceries. These companies can often be specialized to a particular good or service, operate out of their own distribution centers, may or may not employ their own drivers, and have unique groups of customers. Owing in part to competition among these companies and specialization, the challenges faced by each company—if they are even considering decarbonization—might be very different. Historically, cities have not attempted to manage the system, or have tried to manage certain aspects through restrictions [7]. These aspects include driver behavior (restrictions include anti-idling, truck routes, and parking) and siting truck movements (truck routes, industrial/warehouse districts). Pointedly, this does not include management of last-mile deliveries or sustainability. City involvement in urban freight is a novel concept with precedence in few cities worldwide. Municipal governments in London, United Kingdom, Bremen, Germany, and a number of Dutch cities have directly targeted urban deliveries with low-emission zone regulations and the closing of streets to certain vehicles based on those vehicles' emissions [8]. The U.S. and Canada have fewer examples of direct interventions by city governments. In New York City, direct subsidies are available via the city's Clean Truck Program, although this program is limited in its scale and is available to all types of trucking companies, including those moving goods regionally and within marine ports [9]. Santa Monica and Portland are experimenting with a low-emission zone and cargo bike pilot programs, respectively, demonstrating the novelty of these strategies in the U.S. [10,11].

This paper aims to identify and document the challenges that private and public stakeholders in North American cities face when trying to reduce CO_2 emissions from urban freight. Mapping these challenges will provide a basis for the rationalization and development of more collaborative approaches, help cities determine what resources they need before creating sustainable freight policies, and inform companies planning to pursue their own decarbonization. In addition to the main research question—what are the challenges to decarbonizing urban freight?—we seek to answer two additional questions: What motivates urban freight stakeholders to seek decarbonization of the last mile, and what emission reduction strategies or policies are these stakeholders currently pursuing?

The urban freight system is the deployment of infrastructure and service networks to move and store freight on its way from origins to destinations in urban areas [12]. This definition excludes movements of freight in and out of port facilities and regional freight passing through a city. For this paper, we have similarly defined urban freight as any last-mile delivery activity within a city. The definition of sustainability, too, has been limited for this study. We have focused on one environmental externality: carbon dioxide emissions and their role in moving toward a more environmentally sustainable urban transport system.

To answer the three research questions, we conducted interviews with experts from the public and private sectors. There are many strategies that companies can pursue to reduce their emissions, each with its own challenges. Rather than outlining all of the potential problems with a particular emission reduction strategy, these interviews uncover what major companies and North American cities must currently address. It should be understood that individual companies and cities have developed their approaches in isolation, so their experiences and, therefore, challenges will be different. This also means that there are more challenges than we can possibly include in this paper. However, we can categorize the most common challenges to better generalize across stakeholder groups.

This paper is organized as follows: The next section of this paper describes the existing literature related to emission reduction strategies and challenges. The following section describes the approach that the study used to identify key stakeholders and conduct interviews. Next, findings from interviews with public and private stakeholders are described and are divided into three key categories: motivations, strategies, and challenges. The results are followed by a discussion of the key findings and recommendations for the industry to work more collaboratively to address some of the most frequently cited challenges.

2. Literature Review

2.1. Strategies and Challenges in Government-Supported Reports and Roadmaps

Sustainability in urban freight is addressed by two bodies of work: government-supported reports or "roadmaps" and scientific research. Roadmaps by the World Economic Forum, the Transportation Decarbonisation Alliance (TDA), and the Alliance for Logistics Innovation through Collaboration in Europe (Alice) provide a wide range of decarbonization strategies. These strategies include both near-term emerging solutions, such as cargo bikes and electric vehicles, and long-term solutions, such as autonomous delivery vehicles and drones. Table 1 shows the strategies outlined by these reports, as well as the scientific literature.

City government interventions can be emphasized or deemphasized in these roadmaps. The authors of [5,13] described four strategies that can only be enacted by cities: commercial loading zones, congestion charging, vehicle access restrictions, and commercial vehicle access to express and bus lanes. These strategies serve as market signals to goods movement companies, rather than directly reducing emissions as vehicle electrification would. Two of the strategies, commercial loading zones and access to restricted lanes, could provide favorable market conditions for the adoption of low- and zero-emission technology, the role which the authors of [14] prescribed to government agencies. Importantly, though, the authors of [7] emphasized the need for collaboration between public entities and companies to ensure effective policies.

Challenges to decarbonization are included in the reports and roadmaps, but only one such report emphasizes challenges. The authors of [7] discussed many urban freight challenges, at least six of which are related to decarbonization efforts. These are (1) small profit margins faced by companies (coupled with high investment costs for new technology), (2) market fragmentation or many small, competing companies, (3) meeting customer expectations, (4) lack of urban freight knowledge and planning, (5) policy emphasis on passenger transport, and (6) "market inertia" or the tendency for companies to only meet the minimum requirements of regulations. The authors of [5] likewise commented on meeting customer expectations but expanded this to include maintaining efficiency and avoiding disruptions to existing operating practices.

Of particular emphasis in this body of work are fleet electrification and zero-emission vehicles. Challenges in this market are, therefore, also discussed. The immaturity of the market presents multiple challenges. Vehicle availability is limited, upfront costs are higher, and companies may have limited access to charging/refueling [13].

2.2. Strategies and Challenges in Scientific Research

The scientific research has focused on a single strategy or a handful of strategies within a single city. Examples include cargo bikes replacing diesel vehicles in Portland, OR [11], off-hours deliveries in New York City, NY [15] and Mexico City [16], low-emission zones and congestion charging in London [17], and congestion charging in Stockholm [18]. Similar to the roadmaps, the authors of [19] explain a variety of strategies using real-world examples to explain each strategy. While these studies do demonstrate the goal of emission reductions being met on small scales, they are either post hoc analyses or theoretical models without indication that the studied programs will be implemented widely in the future.

Table 1. Decarbonization strategies discussed in government-supported reports and scientific research.

Strategy	Sources
Vehicle technology	
Vehicle electrification	[5,13,19]
Alternative fuel vehicles (hydrogen, hybrids, etc.)	[5,13,19]
Cargo bikes	[11,13,19]
Drone delivery	[5,19]
Autonomous vehicles	[5,13,19]

Table 1. *Cont.*

Strategy	Sources
Operational strategies	
Urban consolidation centers and microhubs	[5,15,19]
Parcel lockers	[5,19]
Alternative delivery locations (office delivery, multi-brand parcel shops)	[5]
Reducing empty vehicle trips	[13,15]
Load-pooling (i.e., vehicles deliver for multiple carriers simultaneously)	[5,13,19]
City government interventions	
Low- or zero-emission zones	[17]
Commercial vehicle parking zones (CVLZs)	[5]
Congestion charging	[17–19]
Vehicle weight or size restrictions	[11,17]
Vehicle access restrictions or off-peak deliveries	[5,15,17,19]
Anti-idling enforcement	[11]
Truck routes and dynamic truck routing	[5,13,15]
Access to express lanes, bus lanes, etc.	[5]

The challenges described in such research are context specific, but may be applicable to more than just the study cities. Ref. [15] explained that off-hours delivery programs require balancing of economic or environmental benefits and the impacts on the general public. Policymakers must decide if increased noise at night is acceptable to its constituents, which can act as a barrier to implementation. Additionally, building trust and partnerships between cities and companies is required. The New York City off-hours program faced challenges in building this trust [16]. Ref. [11] described the issue of land availability and cost in Portland for urban consolidation centers. These problems are not limited to Portland, but apply to any dense or fast-growing city. The authors of [19] discuss the challenge faced by cities and companies of maintaining or supporting economic growth while also reducing emissions. Finally, cost was touched upon by [15,18]. Both acknowledged that new technology is more capital-intensive during early stages of implementation, but the authors of [18] went further to explain that this challenge is particularly difficult to overcome for small companies operating with small profit margins. Small companies do not have the same resources to invest in research and development that multi-national corporations have, and, thus, have to wait for new technology to reach cost parity with existing options.

2.3. Research Gaps and Contribution

City and corporate motivations for pursuing sustainable urban freight strategies are not emphasized in either government-supported reports (roadmaps) or scientific research. The stakeholder groups (cities and companies) are frequently cited as having different motivations for reducing urban last-mile delivery emissions. According to the roadmaps, cities—or, more specifically, the departments responsible for regulating the movement of goods on city infrastructure (e.g., Departments of Transportation)—are motivated to pursue policies that can reduce freight emissions by sustainability goals set by city leadership (e.g., mayors and city councils) [5,13]. It is first assumed in these reports that goals related to reducing last-mile emissions exist and, second, that cities have the resources and tools to pursue actions or strategies to achieve these goals. However, city officials cannot work towards achieving freight sustainability goals in a vacuum. There are competing goals—supporting economic growth, improving road safety, and providing equitable transportation access—and competing interests—municipal leadership, constituents, and private enterprise—that can limit the ability of city departments to take action on urban

freight emissions. Understanding how city officials prioritize or balance these goals and competing interests can aid in the understanding of the challenges faced by cities that do seek to decarbonize urban freight.

Companies, according to government-support reports, are motivated to reduce urban freight emissions in order to improve efficiency and increase profit [5,7,13]. However, many companies that have pledged to reduce carbon emissions are taking action by using technology with higher costs than traditional delivery vehicles and with unproven ability to meet customer expectations [20,21]. Both examples—city officials balancing competing goals and interests and companies pursuing technology that does not increase profit or efficiency—suggest that there are motivations behind city and corporate actions that are not captured in the literature, and therefore, a gap exists.

Strategies or actions taken by cities and companies to reduce urban freight emissions are covered at length in both roadmaps and scientific research. However, roadmaps such as those in [5,13] do not distinguish between strategies that are available to cities and companies now and those that can theoretically reduce urban freight emissions in the future. The scientific research, by contrast, focuses on strategies that have been implemented in pilot programs [11,15,17,18], but are examples of strategies in a single city, with limited discussion of how the strategies can be implemented elsewhere. Neither body of work emphasizes feedback from public and private stakeholders to understand what strategies are feasible. Decarbonization is a recent development in the urban freight space, so it is important to document what cities and companies think is practical at this time. These strategies can act as momentum builders for the industry.

Finally, none of the literature provides an overview of the common challenges faced by cities and companies seeking to reduce emissions from urban freight. Filling this gap is the main goal of this paper. Ref. [7] did provide an overview of common urban freight challenges, but these were not specific to reducing emissions from the sector. Roadmaps [5,13] were focused on actions that companies can take to reduce emissions, placing cities in a supporting role. They did not address the actions that cities can take or the limitations in resources and tools at municipalities' disposal.

This paper will identify and explain the most common challenges faced by cities and companies in the U.S. and Canada that seek to reduce urban freight carbon emissions. In doing, so we also identify the motivations behind the pursuit of urban freight emission reduction strategies from both stakeholder groups' perspectives and identify and classify the decarbonization strategies actively being pursued.

3. Materials and Methods

The overall goal of this study is to identify and apply a framework to the challenges to decarbonizing urban freight from the perspectives of city officials and companies. The study is focused on strategies and the implementations thereof that cities and companies are pursuing, rather than every idea that may or may not gain traction in the industry. We used purposeful and convenient sampling to solicit and conduct qualitative interviews with the relevant stakeholders to collect this information, from which we applied a structure to the responses in order to group similar challenges together. The interviews were semi-structured and questions were open-ended. Each interview sought to answer three questions: (1) What motivates cities and companies to reduce carbon emissions? (2) What emission reduction strategies are stakeholders currently pursuing? (3) What are the most common challenges to decarbonizing urban freight? Field notes were compared across all interviews to identify and categorize the most commonly cited motivations, strategies, and challenges.

3.1. Identification of Stakeholders and Solicitation of Interview Subjects

This study categorizes private stakeholders into five groups: carriers, wholesalers or distributors, vehicle manufacturers, property owners, and drivers (represented by a labor union). We used pre-existing contacts to request interviews from manager- or corporate-level employees that would be knowledgeable about their company's carbon emission

reduction goals and strategies for achieving those goals. Snowball sampling was also used to identify potential interview subjects: Each interviewee was asked to share contacts at the end of the interview period. Nine of seventeen companies (53%) agreed to be interviewed, two of which participated in two interviews. Table 2 shows the interview participants by stakeholder group.

Table 2. Stakeholders interviewed for this study.

Sector	Stakeholders Group	Number of Interviews
Private	Carriers	4
	Vehicle Manufacturers	3
	Wholesalers/Distributors	2
	Property Owners or Developers	1
	Labor Unions	1
Public	Departments of Transportation	6
	Planning Department	3
	Offices of Sustainability	3
	Departments of Economic Development	1
	Municipal Utilities	1

To identify public stakeholders (city agencies) that are involved with urban freight planning, a comprehensive review of city planning documents related to the topic of urban freight decarbonization was conducted. The review was limited to the densest, most populous, and fastest-growing cities, which are most likely to face growing emissions from last-mile deliveries [5]. A total of 58 such cities were identified. Planning documents from these cities were scanned for mentions of sustainable urban freight strategies or goals. The city departments responsible for producing the most of such documents were: Departments of Transportation (29.3%), Departments of Planning (22.7%), and Offices of Sustainability (16.0%).

These departments, then, were the targets of our interviews. Individuals identified as contributors in the planning documents or through solicitation of general department email addresses were contacted, and snowball sampling requests at the end of interviews were used again. Nine of sixteen cities (53%) contacted agreed to participate. In four cases, separate interviews were conducted with two different departments from the same city. These included a Department of Economic Development and a municipal electric utility, which were identified by other interviewees as having direct ties to urban freight policies. Public-sector interview participants are shown in Table 2.

3.2. Interviews

Each subject was interviewed for approximately one hour. Separate questions were created for city agencies and companies. Table 3 shows examples of questions asked to each stakeholder group. Interviews opened with questions pertaining to context or background, followed by motivations behind seeking to reduce freight emissions within the city environment, then specific strategies undertaken by the stakeholder, and, finally, a discussion of the challenges faced by the company or city when attempting to achieve certain goals or enact an emissions reduction strategy.

Both the semi-structured nature of the interviews and purposeful sampling of interview subjects allowed for identification of and insights into the challenges to decarbonizing urban freight faced by public and private stakeholders. The literature lacks an overview of this subject, instead identifying barriers to implementing specific strategies in specific metropolitan areas (e.g., [11,12]). Our purpose is to identify challenges common to multiple stakeholders, strategies, and locales. Expert interviews also help identify the strategies that cities and companies are actually pursuing as opposed to those that are theoretically possible.

Table 3. Example interview questions.

Public Stakeholders (Cities)		**Private Stakeholders (Companies)**	
Category	**Sample Question(s)**	**Category**	**Sample Question(s)**
Contextual questions	What is the definition of urban freight?	Contextual questions	What are the main markets and customers of the company?
	What are the primary issues related to urban freight in your city?		What is the fleet makeup? (what share of the total fleet serves urban environments?
	What is your department's role in addressing these issues?		Does the company have sustainability goals?
Motivations	What are the city's or department's sustainability goals, and do they include specific freight goals?	Motivations	Why does the company have sustainability goals, and who is responsible for making and evaluating progress toward those goals?
	Who decides these sustainability goals and/or defines the urban freight issues?		Do sustainability goals bring business value to the company?
	Is the city attempting to improve freight efficiency, reduce emissions, or are they considered the same thing?		
Strategies	What are the strategies the city is pursuing?	Strategies	What emissions reduction strategies is the company currently using?
	What is the overall framework for freight goals (command-and-control versus incentivization)?		What strategies does the company plan to pursue in the future?
			What type of support is needed from government agencies to achieve sustainability goals or initiate strategies?
Challenges	What have been the most challenging parts of reaching your sustainability goals?	Challenges	What have been the most challenging parts of reaching your sustainability goals?
	What have been the most challenging parts of implementing sustainability strategies?		What have been the most challenging parts of implementing sustainability strategies?

This interview approach allows the interviewee to identify what is important to their organization, as opposed to having the interviewer apply their priorities through selection of topics to be discussed. The authors learn what strategies are being considered and how the organization views challenges by listening to the interviewee. Semi-structured interviews allow subjects to elaborate on topics that they think are important, leading to a breadth of motivations, strategies, and challenges, but also to observe what is not discussed. Without a rigid questionnaire, we were able to ask follow-up questions and understand the details of each topic. However, this could also occur at the expense of discussing other challenges faced by a given city or company. This study could not, therefore, identify every possible challenge—there are, in actuality, too many to identify in a single paper—but instead focuses on those mentioned by multiple interviewees.

Purposeful sampling of interview subjects allowed us to limit outreach to those companies that had started working towards reducing their CO_2 emissions. These companies had already experienced challenges tied to specific strategies or had researched strategies enough to understand the difficulties in implementation and scaling. A limitation of this approach is that our contacts of convenience were exclusively national or multinational companies. The urban freight industry is actually comprised of myriad companies, from individual owner–operators to companies operating hundreds of vehicles within a single city. First-hand perspectives of small companies are missing from this study. While we did identify challenges faced by those small companies based on the conducted interviews, there may be others that were missed. Similarly, there are other types of companies—gig-economy delivery services and infrastructure companies, to name just

two—that were not included in the interview sampling. Small cities, too, are missing from the interview sampling.

4. Results

The following three sections discuss motivations, emission reduction strategies, and challenges mentioned by the interviewees. Responses were synthesized and categorized by the authors. Subjects are not quoted to protect anonymity. Rather than reporting the findings from each interview, responses have been grouped together and categorized according to commonalities among the stakeholders' responses. These findings can help identify what issues are pressing for each stakeholder group and who needs to contribute to the solutions to these challenges.

4.1. What Motivates Cities and Companies to Reduce Carbon Emissions?

Companies reported that reducing emissions often equates to improved efficiencies, e.g., reducing empty trips or fuel consumption, and increased revenue by reducing the cost per delivery. While these savings might be offset by the capital expenses of purchasing or retrofitting new vehicles, they can also reduce risk related to fuel cost volatility. A few of the companies interviewed stated that their green initiatives (mostly improving the fuel efficiency of gas and diesel vehicles at the time) started in the early 2000s, corresponding to a period with high gas prices.

Companies are not strictly motivated by increasing revenue or reducing costs, however. Many cited top-down decisions made by company executives who recognized their companies' contributions to climate change and exhibited a desire to reduce that impact. All three carriers and three vehicle manufacturers interviewed cited corporate vision or leadership as a reason behind reducing emissions from last-mile vehicles or replacing those vehicles with more sustainable modes altogether.

Cities likewise have multiple motivations for pursuing strategies to reduce emissions from urban freight. As with companies, many of the climate goals set by cities in their Climate Action or Sustainability Plans derive from strong top-down leaderships. Sustainability offices often create sustainability plans at the behest of the mayor's office. In turn, the mayor works at the behest of the public. City officials often (six out of nine cities interviewed) cited their reason for pursuing pilot programs or setting sustainability goals as fulfilling the will of their constituents. However, this reaction to public sentiment is not always related to reducing urban freight emissions. Three cities mentioned other priorities expressed by their residents. These include the desire for reduced truck traffic and noise on local streets and even road degradation due to heavy truck traffic. In some cases, these views intersect. Creating strict truck routes does not directly reduce urban freight emissions as considered in this study because delivery vehicles are almost universally exempt from using those routes. However, anti-idling laws can reduce both noise pollution and carbon dioxide emissions.

There are also cities that do not prioritize urban freight at all. Of the nine cities interviewed, one stated that they did not have anyone dedicated to freight planning, and two others stated they did not have enough resources dedicated to this area. That is not to say that the city was not focused on sustainability. Rather, their resources were allocated towards developing public transit and reducing passenger vehicle miles traveled. Urban form plays a role in whether or not urban deliveries become an issue. When a city has broad streets and ample off-street parking, other urban freight issues, such as congestion, are not as critical or obstructive to the general public. Without public feedback, the department then directs resources elsewhere.

4.2. What Emission Reduction Strategies Are Stakeholders Currently Pursuing?

According to the interviews, each stakeholder group was considering a fixed set of strategies that could be categorized into five groups: vehicle technology, land use, alternative delivery methods, operations, and enforcement. The first three were being

considered by both stakeholder groups and required at least some collaboration to succeed. Operational strategies were most often entirely in the hands of private companies, whereas enforcement strategies were most often the focus of city governments. Each of the individual strategies discussed during the interview process is shown in Table 4.

Table 4. Urban freight decarbonization strategies identified during interviews.

Category	Strategy	Public Stakeholders (Cities) [1]	Private Stakeholders (Companies) [1]
Vehicle Technology	Vehicle electrification	√	√
	Public charging	√	√
	"Bridging" or alternative fuel vehicles		√
Land use	Curb space management	√	
	Microhubs/urban distribution centers	√	√
Alternative delivery methods	Cargo bikes	√	√
	Parcel lockers	√	√
	Final 50 feet alternatives (drones, remote-operated delivery robots, etc.)		√
Operations	Efficient routing		√
	Packaging and vehicle loading		√
Enforcement	Off-peak deliveries	√	
	Vehicle size restrictions	√	
	Low- or zero-emission zones	√	

[1] A check mark (√) in these columns indicates the stakeholder group that was pursing the strategy.

4.2.1. Vehicle Technology Strategies

The emission reduction strategies categorized as vehicle technology include vehicle electrification, public charging, autonomous vehicles, "bridging" or alternative fuel vehicles, and autonomous vehicles. One city has a program to help subsidize the cost of electric or low-emission trucks, and eight of nine have plans to expand their charging networks in public space. However, despite the emphasis put on delivery vehicle electrification by municipal governments, it is the carriers, wholesalers, and retailers that must ultimately procure and use these new vehicles. Six of the nine cities went as far as to say that their role in electrifying the delivery vehicles in their cities was to incentivize their use rather than subsidize purchases or mandate replacement of fossil fuel vehicles.

Vehicle electrification was the most commonly discussed strategy in this category. Officials from all nine cities, all nine companies, and the union representative cited this as the key strategy for achieving zero emissions from urban deliveries. With the exception of New York City, which runs a rebate program for clean truck purchases called the Clean Trucks Program, none of the cities are currently offering or plan to offer direct financial assistance to companies seeking to purchase electric vehicles. Rather, most cities are considering policies that indirectly lower the cost of electric delivery vehicles. Four cities are considering offering free parking for electric commercial vehicles.

None of the interviewed companies expressed interest in public charging. By contrast, every city interviewed perceived additional charging infrastructure as a policy that would incentivize delivery vehicle electrification. Each of the companies explained that charging would likely occur overnight at their existing facilities. A carrier and real estate company both cited low electricity rates at night and security as reasons for this being desired. Additionally, companies can take advantage of renewable energy to charge their vehicles. One company mentioned adding solar panels to their facilities to reduce their overall electricity load, but the benefits of renewable energy to companies are two-fold.

Finally, "bridging" or alternative fuel vehicles were cited by three companies and zero cities. For the purposes of this paper, these vehicles are defined as those that consume a fuel other than gasoline or diesel (e.g., natural gas, biodiesel, or hydrogen). According to the interviewees, hybridization and improving fuel efficiency of gasoline and diesel

vehicles are no longer long-term goals. Notably, here, alternative fuels do not include EVs (though electricity is an alternative to petroleum fuels) because companies view these as different solutions that have different challenges. A carrier, a wholesaler, and an OEM all referenced this strategy with regards to large Class 7 and 8 trucks. These are typically used to make large or heavy deliveries, such as deliveries of furniture, beverages, or office supplies. Simply put, though, the battery technology and electric truck models that have the capability of hauling these heavy loads while meeting the companies' performance requirements or operational efficiencies are not currently available.

4.2.2. Land-Use Strategies

Emissions from urban deliveries can be reduced with two land-use-related strategies: curb space management and urban consolidation centers (or microhubs). Related to delivery vehicle electrification, four cities want to use curb space to incentivize battery electric truck and van use. Cities can offer free or discounted parking rates for electric vehicles while still charging fossil fuel vehicles standard rates. These cities are also considering reserving curb space exclusively for the use of zero-emission delivery vehicles, further incentivizing adoption by making parking more difficult for traditional vehicles, but also signaling to companies the city's desire for them to change their fleets over. More broadly, all nine cities either have or are exploring designating curb space for the exclusive use of commercial vehicles. The desired results are less congestion and higher efficiency for delivery drivers. With commercial vehicle loading zones, drivers can find parking more reliably, thus reducing cruising.

All three carriers and two cities discussed the values of urban distribution centers or microhubs. Urban distribution centers are plots of land or sometimes buildings that can be used to stage deliveries. Urban distribution centers require the assistance of city governments to engage multiple private-sector partners, but also for zoning variances so that they can be located near a concentration of delivery destinations. Microhubs can reduce emissions by facilitating cargo bikes or other small, low-emission vehicle trips. These vehicles are range-limited and volume-limited compared to delivery vans, so the microhub must be placed in close proximity to destinations.

4.2.3. Alternative Delivery Methods

Cargo bikes, parcel lockers, drones, remote-operated delivery robots, and related technology are all alternative delivery methods that carriers are exploring to reduce their emissions within urban environments. Cargo bikes with electric-assist motors can replace fossil fuel vans as long as the topography is conducive and the distance between origin and destination is minimized. Parcel lockers can reduce the number of stops made by a delivery vehicle and, therefore, the mileage and the associated carbon emissions from those miles. Lockers act as a form of delivery consolidation, ensuring rapid delivery to the customer, as well as the security of the packages. Seven of the nine interviewed cities wanted to see more parcel lockers in their jurisdictions. Drones and other autonomous or driverless delivery devices were mentioned by two OEMs and a carrier as components of an overall approach to reducing emissions. In the future, they can be paired with vehicles that act as roaming microhubs, so these devices can cover a wider range. These are, however, long-term solutions in the design and testing phase, and they face their own set of challenges that are not discussed here.

4.2.4. Operations-Based Strategies

This pair of emission reduction strategies—vehicle routing and package consolidation—can be utilized by companies independently of municipal support. Both strategies have actually been in use by companies for decades to reduce transportation costs and continue to be used because they make good business sense. Today, special attention is being paid to the carbon emission reductions associated with these strategies to meet corporate goals. Vehicle routing can reduce emissions in a couple of ways. First, carriers, wholesalers, and retailers

can modify their routes to avoid congestion during the busiest parts of the day, provided that the scheduling of those deliveries does not interfere with commitments made to customers. In addition to fixed time of delivery to reduce congestion, companies can utilize dynamic routing to adjust their routes based on real-time data instead of historic congestion data. Second, since destinations are grouped densely together in urban environments, companies can plan their routes to allow for the most walking between destinations to eliminate making stops at every location. Pre-positioning delivery goods can also help reduce emissions and changes the way that companies design their routes.

All three carriers and one wholesaler referenced package consolidation as a way to reduce emissions. This category includes reducing the size of packaging (or right-sizing) to fit more parcels on a single vehicle. Consolidation can have an impact on parcel deliveries and larger goods. A wholesaler with two distinct products—one lightweight and voluminous, the other dense and heavy—discussed the concept of consolidating multiple products together. Instead of sending two trucks specialized for each product, the company is considering delivering both products from a single truck. This would allow the company to potentially utilize fewer trucks in urban areas, but also to replace diesel trucks with battery electric and alternative fuel technologies that cannot currently accommodate their heavy loads.

4.2.5. Enforcement Strategies

Enforcement strategies are entirely carried out by cities. Companies must comply with these types of strategies, and they serve to act as pricing signals or disincentives to fossil fuel vehicles. Beginning with off-peak deliveries, the idea is that trucks making deliveries at night or at least before and after peak periods are subject to less congestion and more reliably available parking. The two contribute to reducing emissions by (a) allowing trucks to drive at more optimal speeds, (b) idle less when stopped by traffic, and (c) reduce vehicle miles traveled as a result of cruising for parking.

Because cities in the U.S. have the jurisdiction to determine the types of vehicles on their streets, size restrictions have been considered by at least three of the interviewed cities. Smaller vehicles emit less carbon than large vans and trucks, but there is also the sentiment expressed by one city that if size restrictions are put in place across entire neighborhoods, companies will purchase new vehicles to comply. Given the growth of the electric vehicle market, the city believed that many companies would opt to electrify this fleet. None of the interviewed cities have attempted this strategy to date, however. In the longer term, four cities are exploring ways to create low-emission zones. These are multi-block or neighborhood-wide zones where only low-emission or alternative delivery vehicles (e.g., cargo bikes) can operate. Low- or zero-emission zones have been implemented in European cities, including Barcelona [22], London, Paris, and thirteen Dutch cities [8]; U.S. cities face significant hurdles with this strategy.

4.2.6. Significance of the Strategies

The strategies being pursued by cities and companies in the U.S. and Canada can be categorized into five groups: vehicle technology, land use, alternative delivery methods, operations, and enforcement. This list is noticeably different from that in the literature, reflecting the strategies that are practical now. Vehicle technology, land use, and alternative delivery methods require some form of collaboration between public and private entities, whereas operational and enforcement strategies can be implemented with little input from other stakeholders. Each strategy faces similar challenges, though, as will be discussed in the next section.

4.3. What Are the Most Common Challenges to Decarbonizing Urban Freight?

Interview subjects identified myriad challenges to decarbonizing urban freight. We have categorized the most commonly cited challenges according to our interpretation of the interview responses. There were four such categories comprised of eleven unique

challenges. These are shown in Figure 1, along with the stakeholder group(s) facing the challenges. In some cases, barriers were specific to an individual city or company, but were still applicable to the stakeholder group as a whole. The structure applied to this section uses these specific examples while also demonstrating that the challenges are not necessarily unique to a certain municipality or company type.

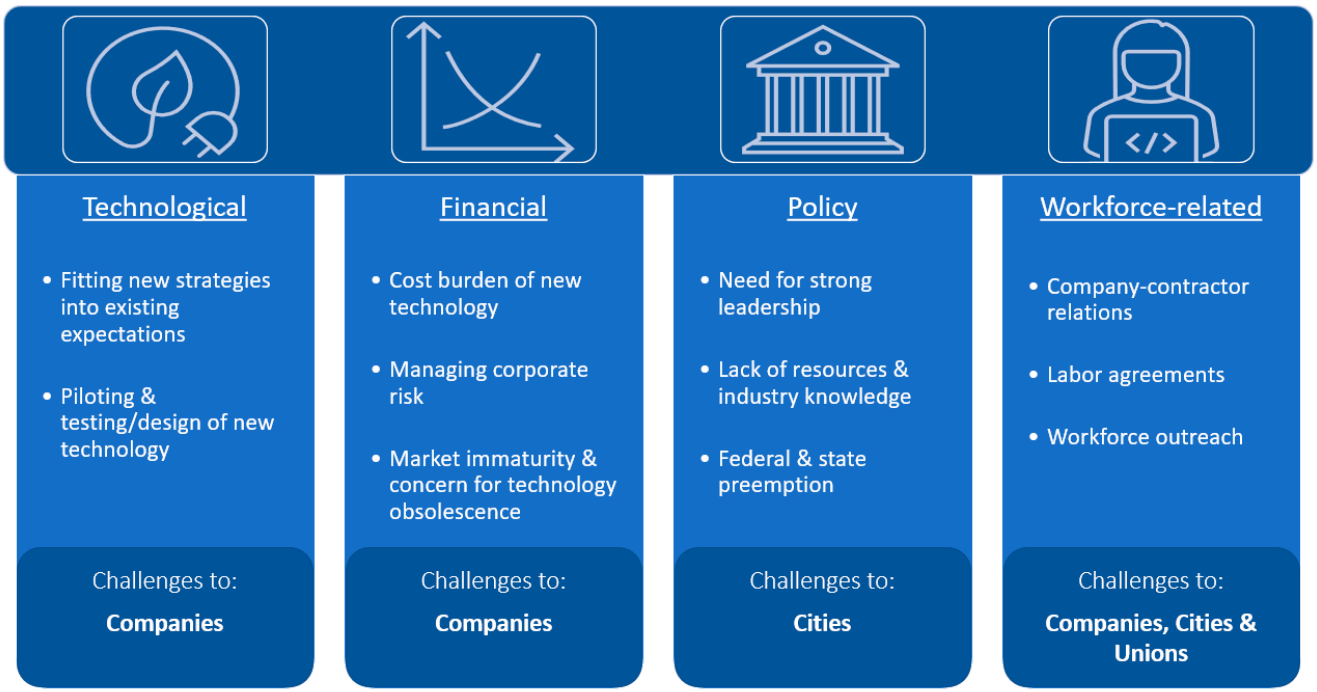

Figure 1. Challenges to achieving sustainable urban freight by category.

4.3.1. Technological Challenges

The company interviews identified two major technological barriers to implementing sustainable urban delivery strategies. The first, fitting new strategies into existing expectations, relates to companies' ability to deliver the same number of packages in the same time at costs expected by their customers. The second, piloting and testing, identifies a key barrier to reducing emissions from urban freight quickly.

The carriers and wholesalers interviewed require efficiency to achieve their business goals and meet customer expectations. For that reason, new technologies or strategies must have a strong business case before they are adopted widely (in many cities). Efficiency can have many meanings—volume of packages per vehicle, deliveries per hour, and cost per package, to name just a few. Barriers to adopting electric vehicles, cargo bikes, and other strategies exist when the measures of efficiency cannot be met by these new technologies. The interviews highlighted three specific examples. First, a single cargo bike cannot carry the same payload or volume of packages as a traditional step-side van. They are also limited in terms of range, speed, and topography. As such, multiple bikes (and operators) are needed to make the same number of deliveries as one van in a time period acceptable to the customer. Cargo bikes may also require an urban distribution center. If these requirements can be met with minimal or no revenue loss for the company and minimal or no cost increase for the customer, then cargo bikes do have a good business case. That being said, the companies adopting cargo bikes are still testing the technology and determining where they make sense. It is by no means expected that operational efficiencies can be achieved in every North American city.

The second example relates to vehicle electrification. The two wholesalers both expressed concerns about the payload capacity of electric trucks. The vehicles on the market today cannot achieve the same payload or range as the diesel vehicles in their fleet. In the long term, this can be improved, if not overcome, by improvements to battery technology.

In the short term, however, these companies are considering whether to use more vehicles to make the same number of deliveries or to develop a system in which lighter products are delivered by electric vehicles and heavier products are delivered on smaller fossil or alternative fuel vehicles. Both solutions will increase costs simply by introducing more vehicles into the fleet.

Piloting or testing new technologies or emission reduction strategies is a necessary aspect of reducing emissions from urban freight. Eighty percent of the companies interviewed stated that cargo bikes and electric vehicles—among other technologies—must be tested for extended periods to ensure that these technologies can, at worst, maintain the operational efficiencies expected by those companies. Given the time required to organize and conduct a pilot, this process acts as a barrier to rapid decarbonization of urban freight activities, rather than a general challenge.

There are even challenges to beginning a pilot test. Strategies such as electric vehicles require long-lead infrastructure (e.g., charging stations and electricity grid upgrades). Often, private companies and cities must forge agreements before new vehicle types are introduced to city streets. In most cases, city councils must approve additions or revisions to the city ordinances to allow these vehicles to use city infrastructure. A case in point is electric-assisted cargo bicycles. One city limited the width of cargo bikes so that they would fit within bike lanes, but this restricted the number of cargo bike manufacturers available to delivery companies. Likewise, installing chargers and storing batteries often requires approval from city fire departments, adding to the time before testing can begin.

4.3.2. Financial Challenges

Financial challenges faced by companies include the cost burden of new technology, managing corporate risk, and market immaturity. All of these challenges were mentioned by multiple companies. The challenges extend beyond capital costs or cost of ownership and touch upon the rate at which new technology can or is being adopted.

Certain technologies—electric vehicles in particular—have high costs associated with them. This is a barrier particularly to owner–operators and small businesses. The interviewed carriers and wholesalers, all of which operate globally, universally stated that they are purchasing electric and alternative fuel vehicles despite their higher costs simply to meet corporate goals. These companies have the financial resources to do so, but also desire more government incentives, such as purchase subsidies, until such a time when the EV and alternative fuel vehicle costs reach parity with those of fossil fuel vehicles. Only one state—California—currently subsidizes electric truck purchases, and federal tax credits have typically focused on passenger vehicles. Even with subsidies, one OEM stated that electric trucks would not reach cost parity until 2030 at the earliest. The high cost of electric and alternative fuel vehicles leaves cities with few options to subsidize their purchases. Most cities do not have the financial resources to offer purchase incentives, with New York City's Clean Trucks Program being the lone exception.

Difficulties with installing charging equipment also exist. One carrier noted that upgrading the electric grid infrastructure near its distribution center to facilitate charger installation cost more than the chargers and is an undesirable sunk cost because the company does not own the infrastructure. If the carrier moved facilities, it cannot recuperate any of the money invested in grid upgrades. According to the municipal utility, these upgrades are not necessary when only a handful of trucks are being charged—so small companies do not face similar costs—but the interviewed companies all operate dozens or even hundreds of vehicles out of a single distribution center servicing a city. The real estate company and two carriers also related the difficulty in coordinating these upgrades with local utilities. The permitting process is long (often in excess of six months), and scheduling construction is as well.

Corporate leadership was one of three motivators for companies to seek carbon reductions. Of the companies that were interviewed, all three OEMs stated that entering the electric delivery vehicle market was motivated by their board of directors, president, or

CEO independently of the current demand for electric trucks and vans. Most companies are risk-adverse, and entering a new market is certainly a risky venture. Historically, demand for electric and alternative fuel trucks faltered, leading to at least one of the companies making unrealized investments in the early 2000s. The interviewed companies do not represent a majority share of the urban delivery vehicle market, and so the lack of similar corporate risk taking with regards to entering the electric truck market acts as a barrier. The immaturity of the electric vehicle market will be discussed in more detail later, but resistance to moving beyond fossil fuel vehicle manufacturing must be overcome for the market to be attractive to purchasers of the vehicles.

Outside of the purchasing cost, the immaturity of the electric and alternative fuel vehicle market poses challenges to companies seeking to reduce their urban emissions. In the past, the market was filled with start-ups that have since gone out of business. This poses a problem for vehicle maintenance and purchasing new parts. As stated by one carrier, these start-ups also lack the production capacity of a legacy OEM. With more last-mile companies seeking to purchase electric vehicles, these leave a supply-side deficit. Subsequently, orders must be placed years before the vehicles are delivered, making it difficult for companies to meet emission reduction goals set by cities.

One OEM made the point that electric trucks and vans are not viable for all last-mile applications. Heavy goods require a higher class of trucks that do not currently have either the range or payload capacity required. These companies (including both wholesalers interviewed) are looking at alternative fuel vehicles. Currently, these technologies do not have the same demand as EVs to spur rapid scaling of production or price drops, leaving many companies priced out of that option.

Finally, at least one company is hesitant to transition its fleet to all electric because prices have dropped so drastically in the last decade or so. The concern exists that a vehicle order will be placed and prices will continue to drop before or as soon as those vehicles are delivered. This is viewed as a waste of financial resources, but since electric trucks are not readily available (in stock) and fleet vehicles must still be replaced according to their useable life schedule, the company will continue purchasing fossil fuel vehicles.

4.3.3. Policy-Based Challenges

City-specific challenges to decarbonizing urban freight can be grouped into three categories: (1) a need for strong leadership, (2) lack of resources or industry knowledge, and (3) federal and state preemption. Strong, consistent leadership was shown by the interviewees to be a requirement before effective policy can be made. Limiting city agencies' ability to address urban freight emissions is the lack of personnel, policy tools, and understanding of urban freight operations. Finally, federal and state preemptions limit the policies that cities are legally allowed to implement, or at least slow down the policymaking process.

As described in the section on motivations, city agencies often prioritize their work based on direction from the executive (mayor) or city councils. To properly allocate resources to the area, departments need direction and funding approval from these entities. The challenge, then, is leadership that does not view urban freight as a priority for city resources. The six cities with pilot programs have received direction, or at least approval, from city leaders to take these actions. Overall city goals, such as Seattle's electrification by 2050, are also made at the behest of city leadership.

Departmental leadership also plays a role in policy implementation. Describing their department's lack of action on sustainable urban freight as a result of the "leadership turnstile," one city explained that relationships with key private stakeholders could not be maintained because the department had four directors over the course of a decade. The department finds it difficult to establish partnerships for pilots or feedback on policy decisions because personal relationships are frequently lost. By comparison, another department in the same city achieved success in reducing emissions from other commercial

activities in part because they had consistent leadership (a single director) over the same time period.

Regarding resources dedicated to urban freight, only four of the cities interviewed had planners or transportation experts in urban freight. This deemphasis of the sector is a significant barrier to cities reducing urban freight emissions. One sustainability official stated that, historically, urban freight has not been part of the emission reduction equation. TNCs, passenger vehicles, and even heavy-duty trucks are a concern, but urban freight delivery vehicles do not typically fit into those models. Cities that lack freight planning and personnel are unable to create policies that would incentivize companies to adopt emission reduction strategies. Further, those cities do not, then, have the capacity to manage outreach to the fragmented sector. In the five cities with freight planners (Minneapolis, New York City, Portland, Seattle, and Vancouver), sustainable freight pilots are being carried out or pursued. Only one of the four cities without urban freight planners (Baltimore, Bellevue, Montreal, and Salt Lake City) is similarly pursuing pilot programs.

The definition of urban freight matters. Baltimore's Department of Transportation has a focus on freight, but not at the intersection of sustainability and urban deliveries. Rather, the city's focus is on port and industrial freight. Recalling the "responsiveness to constituents" motivation, enforcement and policymaking are focused on responding to residents who want quieter streets and less road degradation that is perceived to be caused by commercial truck activity. Salt Lake City's DOT does not have a freight planner at all. Because they receive few complaints about trucks and their sustainability plans have focused on increasing transit ridership and reducing passenger vehicle VMT, no action has been taken at the city level to reduce emissions from last-mile deliveries.

Within single agencies, sustainability can be added to a number of existing priorities that are defined either by elected officials or as voiced by the public. Infrastructure maintenance was most often cited as an area for concern to the public, and there are few, if any, tools related to road repair that can impact emissions coming from freight vehicles. Curb management was suggested as a policy lever that agencies can use to incentivize low-emission vehicle adoption. However, cities cannot dedicate all curb space to low-emission vehicles without hindering business operations, angering business owners, and potentially stymying economic growth, the last of which conflicts with overall city goals in every interviewed city. Seattle also emphasized that this type of policy—or, more specifically, zero-emission zones—has the potential to disenfranchise some consumers. As equity is a metric used to evaluate policy alternatives in the city, reducing freight emissions may conflict directly with that measure.

Six of the cities interviewed described their lack of urban freight data as a barrier to implementing efficient carbon reduction policies. Cities lack two types of data: (1) last-mile vehicle counts and those vehicles' characteristics (e.g., age); (2) operational data (e.g., how vehicles are used: mileage, number of stops, and number of daily trips in and out of the city). Without vehicle counts, cities cannot inventory emissions from urban freight or set measurable goals for reducing those emissions over time. Further, because vehicles are registered at a state level, it is challenging to evaluate the age of the vehicles making last-mile deliveries. The age of a vehicle can be a determining factor in computing emissions [23]. Compounding the issue is the rise of gig-economy vehicle trips. None of the nine cities interviewed were able to comment on the number of passenger vehicles making food or package deliveries, but all acknowledged that they include these vehicles in their definition of urban freight. Without a clear understanding of the size of the urban freight fleet, cities cannot inventory carbon emissions or set realistic timelines for reducing emissions.

Seattle, Minneapolis, and Vancouver cited their lack of familiarity with urban freight operations as a roadblock. Operations in this context strictly mean the average daily duty cycle of a vehicle making deliveries in a city. These three cities want to make policy decisions supporting cargo bikes and micro-consolidation centers, but find it difficult to make recommendations when they do not clearly understand if these strategies can effectively replace traditional vans and trucks. Characteristics of an average duty cycle,

including the number of stops and packages deliveries per stop are perceived as important metrics in measuring the success or feasibility of emerging strategies. Seven of the nine cities want to support vehicle electrification, and most have plans to install vehicle chargers as a way of incentivizing their EV purchases. The scale and location of these networks, though, are dependent on the typical duty cycle. Cities want public chargers placed in locations where they will be used, but also want to ensure that there will be demand for public charging before they are installed.

The third challenge to cities is federal or state preemption. This is the legal principle that if Congress or a state legislature grants a federal or state agency regulatory powers over a subject, that regulatory power cannot be assumed or exceeded by lower levels of government—in this case, municipal agencies. Federal preemption was cited as a barrier by three cities, all relating to zero-emission zones. Cities cannot make laws that regulate emissions. However, by disallowing fossil fuel vehicles, zero-emission zones do just that, counter to powers granted to the federal government by the Clean Air Act, Interstate Commerce Clause, and FHWA/EPA CAFE/fuel efficiency standards.

A second example—this one of state preemption—was mentioned by a fourth city. There is a state law that bans private revenue-generating activity on public land or structures. The city located in this state wants to install parcel lockers at a transit hub and power-assisted cargo bike chargers and corrals inside a public parking garage. The city cannot pilot these strategies because the locker, cargo bike, and charging station owners will all generate revenue while on public property. Even using the parking garage to house cargo bikes overnight is considered revenue generating because the bike owners do not need to rent or purchase other property, resulting in savings that will not be transferred to the city.

4.3.4. Workforce-Related Barriers

Private and public interviewees outlined three main challenges related to the urban freight workforce: (1) the company–contractor relationship, (2) temporal barriers dealing with labor agreements, and (3) difficulties in workforce outreach.

All but one of the interviewed carriers, wholesalers, and retailers uses contract drivers to make urban deliveries. This can take the form of gig-economy workers using their own personal vehicles or operators that use company-branded, but not company-owned, vehicles. Both groups are contractors rather than employees, which was described as a barrier because companies have limited ability to influence the types of vehicles used by contractors. They cannot dictate that only low-emission vehicles are to be used because they recognize (a) that many of these contractors can ill afford to purchase a new electric, hybrid, or alternative fuel vehicle, (b) contractors may not have the same access to charging and re-fueling infrastructure as a company-owned vehicle housed and operating out of a local distribution center, and (c) the sector is so competitive that they risk losing drivers to other companies. While five of the interviewed companies are actively testing electric and alternative fuel vehicles with which to replace their owned assets with, these vehicles make up only a fraction of the overall fleet making deliveries within cities.

The company–contractor relationship can be described as a structural barrier. Internal workforce challenges are temporal in nature, as they only slow down the process of reducing carbon emissions. There are two such temporal challenges: renegotiating labor agreements to incorporate new technology and locating a potentially new workforce. The first is specific to companies with union workforces. To introduce new technology, such as cargo bikes, it is necessary for some companies to define a new operator category in the collective bargaining agreement (CBA). Negotiating wages and benefits for these operators can take months, and the process must be repeated in every city or for every union chapter if the company does not have a national or master agreement with the union. Similarly, the temporal challenge extends to maintenance workers. While renegotiating a CBA might not be necessary, training on the new vehicles is. This is not to suggest that training itself is a barrier. The OEMs and carriers all conveyed that maintenance training is expected

and occurs even with new models of fossil fuel vehicles. However, the learning curve on a vehicle with a new powertrain, such as an EV, can lengthen the time it takes for companies to turn over their entire fleet.

The second temporal difficulty is locating new workforces. Some strategies, such as cargo bikes, require operators that do not fit into defined employee classes. As one carrier stated, drivers are not necessarily the same demographic as cargo bike operators. Companies have to adapt their hiring practices to access this new workforce and develop new ways to attract employees. Moreover, it may take time for the workforce as a whole to develop enough experience to meet customer expectations in the same way that drivers currently do, a challenge that will be discussed in more detail later.

Workforce-related challenges are not limited to companies. During their interview, the union representative expressed particular concern for gig-economy drivers and owner–operators slipping through the cracks of government intervention and corporate goals. If cities and companies determine that only zero-emission vehicles can be used to deliver goods, these individuals should not be shut out of their livelihoods simply because they are not able to afford a zero-emission vehicle. Individual drivers lack the purchasing power of large carriers or wholesalers, so replacing older fossil fuel vehicles is more challenging. Moreover, many of these gig-economy drivers might have other jobs, raising questions about their qualifications for government subsidies. How to reach out and assist or receive input from this growing sector of the urban freight workforce is a challenge that most cities do not yet have a solution for. Contrasting the freight space against livery vehicles in Vancouver, their representative stated that it was much easier to create taxi regulations than freight regulations. All taxicab companies in the city are part of an industry association that the city can easily communicate and negotiate with. As a result, they were able to pass a law defining the year by which all taxicabs had to be zero emissions vehicles. The freight industry is not so organized. While trucking associations exist and may represent many of the small companies in a city, they likely do not include gig-economy workers, who remain essentially invisible to city officials.

4.4. Synthesis of Results

The challenges faced by cities are related to a lack of leadership, resources, and industry knowledge, in addition to hurdles caused by federal and state laws. Cities desire to influence the urban freight market by offering incentives rather than through restrictive policies. It is difficult, however, to create effective policies without an understanding of how many trucks operate within city limits and what their operational needs are. Dedicated resources are required by every city to tackle urban freight challenges, which must be mandated by city leadership.

Companies face challenges related to technology, cost, and workforce. There is a strong desire to maintain commitments to customers, which can drive the types of strategies and technologies that a company pursues. These expectations—the cost and timeliness of deliveries—can be a challenge to technologies such as cargo bikes and electric vehicles if they do not obtain the same capacity or efficiency of existing delivery vehicles. Companies are also worried about making investments in technology that may become obsolete in a short amount of time. Finally, workforce relations pose a challenge to companies. The company–contractor relationship sometimes does not allow companies to choose which vehicles are available. Workforce recruitment when a new type of worker is required is also challenging for companies that are used to recruiting drivers.

5. Discussion

Urban freight is still an emerging topic. Only in the last few years have city governments and corporate leaders in the freight industry begun setting goals for freight emission reductions in cities (e.g., [6,20,21,23,24]). These municipal governments have little knowledge about the industry and are using existing tools to address emissions that were not originally intended to solve that issue. For example, anti-idling laws have been in

place for years. While it can be understood that eliminating idling can reduce emissions, if drivers are observing the laws already, reductions would be limited, or there would be no reductions at all, in fact, if every truck observes the laws. Likewise, the industry has to balance the immaturity of emission reduction technology against the expected and existing performance. Companies are trying to replace a highly functioning system, at least with regards to speed and customer expectations, and yet must do so with relatively new and less tested technologies.

Some of the strategies discussed in the literature were not mentioned in any interviews. Off-hours deliveries, vehicle automation, congestion pricing, and anti-idling policies were those that were not discussed in the interviews. Congestion pricing is not being pursued by any of the interviewed cities except for New York City, and we can also speculate that this is not perceived as a freight-specific strategy. As Ref. [17] suggested, though, emissions from freight can be indirectly reduced by reducing other traffic on major roads or in the urban core. Vehicle automation is a long-term strategy that might not have any near-term applications in urban freight. Most of the research and development being performed by OEMs is related to truck platooning on highways, which generally involves different vehicles from urban freight vehicles. In terms of off-peak deliveries, these have less potential to drastically reduce CO_2 emissions, and as detailed by [15], they require end-customer buy-in. Finally, anti-idling laws are already in place in most of the interviewed cities; stricter enforcement would require more financial resources from the cities, which already have fewer resources than those required to address sustainable urban freight.

This disconnect between relatively theoretical research and practical implementation acts as a barrier to progress. Strategies such as those listed above may not have the political or industry support required to make implementation possible in many cities. Cities can benefit from future research focused on solving the challenges outlined here.

Many of the challenges described by the interview respondents are directly related to the disaggregated or unorganized nature of urban freight. There are myriad companies operating in any given city, any number of which might be pursuing different decarbonization strategies. However, many are also not pursuing those strategies. Cities have yet to identify all of these companies, let alone find a way to communicate with them to better understand industry practices. This could lead to ineffectual policies. Setting goals for electrification of urban freight is difficult if not every company has equal access to electric vehicles, if the vehicles do not meet the requirements of a company's operations, or if most companies have yet to complete piloting or testing of those vehicles. Disaggregation has also led to competition among companies for limited supplies of low-emission vehicles.

The challenges identified by companies are unique to their own experiences, but often overlap with the experiences of other companies. EV affordability, challenges with installing charging infrastructure, the need to test new technology, and the requirement to meet existing customer expectations are common among last-mile delivery companies. As with cities sending market signals to companies, companies are trying to signal public entities such as utilities. By publicly announcing intentions to electrify fleets, they put not just the OEMs on notice, but also utilities and municipal governments that exert some form of control over the electricity provider (e.g., Seattle City Light). They know that they must make permitting and building out of this infrastructure a priority.

Two elements are necessary for cities to pursue effective sustainable urban freight policy: collaboration and additional resources. Collaboration with industry partners can help city departments better understand the freight industry and individual companies' operations, but the lack of collaboration in many cities is also a factor in reducing emissions quickly. Cities must be a willing partner in pilot and testing programs so that companies can identify problems with new technology quickly. We need enough pilots to understand the range of urban conditions. We heard from multiple carriers that electric vehicles have varying ranges based on topography and weather. However, collaboration should not be limited to just corporate partners. Departments must work with other departments to ensure that their goals and policies are aligned so that they are not sending mixed signals

to delivery companies. Additionally, if they are setting goals for electrification, they need to ensure that the utility is prepared to support the new demand and is willing to expedite the installation of new grid infrastructure.

Cities should also dedicate resources to urban freight if they are going to become part of the urban freight system. Governments have long focused on passenger transportation and even active transportation, but the same principles and policies might not apply to freight. Cities also need support from the state and federal governments. This support can come in three forms: direct subsidies, market signaling, and policy modification. Examples of direct investment or subsidies are the federal New Qualified Plug-In Electric Drive Motor Vehicle [tax] Credit (IRC 30D) and California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) [25,26]. Both programs are intended to lower purchasing costs for low- and zero-emission vehicles, but are capped in value and, in total application, accepted. Neither subsidy reduces the cost of current vehicles to that of comparable gasoline and diesel vehicles. IRC 30D originated during the 2008 Recession stimulus program, and future stimulus packages could offer subsidies directly to cities, which, in turn, can focus on distribution to urban freight companies. Cities' agencies have stated that their role in urban freight is to signal the market. Cities can accomplish this by providing public charging or free parking to green vehicles. Federal policies, including the Corporate Average Fuel Economy Standards (CAFE), can further signal to the urban freight market where vehicle technology is heading, only strengthening the effectiveness of city policies [27]. Finally, federal and state policymakers need to be willing to adjust laws that act as a barrier to strategies. The Minneapolis cargo bike example is a case in point. State lawmakers should see the value in enabling cargo bikes to park and charge on city property.

6. Conclusions

This research presents a structured overview of the common challenges faced by cities and companies that seek to reduce CO_2 emissions from last-mile deliveries in the urban environment. The challenges were identified through expert interviews with stakeholders. These stakeholders included city agencies, a municipal utility, a labor union representative, goods carriers, wholesalers, vehicle manufacturers, and commercial real estate developers. The interview question responses were analyzed and categorized by the authors according to their commonalities and applicability to the industry as a whole. By conducting these interviews, we also sought to identify the motivations behind a city's or company's emission reduction goals and the strategies that were actually being pursued by these entities.

The generalizability of this study is limited by the sample size of the interviews. There are many city departments and company specializations that are involved in the urban freight space. Future research can build upon this work by expanding the interviews to include freight dispatchers, owner–operators, tech disruptors entering the industry, and more companies operating in only one or two cities. The type of study can be applied to a more geographically diverse set of stakeholders, such as cities and companies in Europe, Asia, and elsewhere. The results are specific to companies operating in the U.S. and Canada and cities in those two countries. Different challenges may be faced by companies operating in Europe, by comparison. Finally, this research emphasizes the most important challenges to large companies. Further research is required to understand if the challenges faced by small businesses are different from those included here and to measure the degree to which policies such as parking incentives or direct subsidies for new vehicles can be effective for these companies.

The contributions of this research are its focus on challenges and the structure applied to a range of interviewed stakeholders' interview responses. Government-supported roadmaps and similar reports highlight many strategies that cities and companies can pursue to reduce carbon emissions from last-mile movement of goods without explaining the barriers that these stakeholders face before and during implementation. These reports are forward-looking, but the time horizons often do not match up with the steps that

cities and companies are taking now. As sustainable urban freight is an emerging topic, these early steps and strategies are important. The scientific literature, with an emphasis on analyzing pilot programs, is grounded in current strategies. However, challenges are discussed infrequently and typically on a city-by-city or strategy-by-strategy basis. This study extends the body of knowledge on the state of sustainability in urban freight and highlights future research needs—namely, the solutions to the described challenges.

Urban freight companies and municipal policymakers can use this research to identify challenges and ways to address those challenges as they begin their own focus on reductions of emissions from urban freight. Future research should reflect the challenges faced by urban freight stakeholders, but should also close the disconnect between theoretical and practical solutions by focusing on the strategies that cities and companies are actually pursuing.

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