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Policies and Strategies for Cargo Bike Goods Movement in California

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A White Paper from the Pacific Southwest Region University Transportation Center

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16. Abstract
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The Pacific Southwest Region UTC conducts an integrated, multidisciplinary program of research, education and technology transfer aimed at improving the mobility of people and goods throughout the region. Our program is organized around four themes: 1) technology to address transportation problems and improve mobility; 2) improving mobility for vulnerable populations; 3) Improving resilience and protecting the environment; and 4) managing mobility in high growth areas.

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Abstract

This white paper presents the synthesis of the literature on the use of cargo bikes for urban goods movement with a particular focus on four barrier and opportunity domains: physical and spatial; economic; political and legal; and social and cultural. It also includes research particularly relevant to California cities, although many of the studies reported were conducted outside California because we found a lack of evidence within California. The barriers to shifting from trucks and vans to cargo bikes for a variety of good movements remain tall in California. They include, among many, a need for a significant shift in the delivery landscape that requires collaboration across different organizations, and support from the local and state level that includes the development of urban consolidation hubs, investment in bike infrastructure, and strict restrictions on larger delivery vehicles. It may also require initial incentives to freight operators to offset the costs of shifting to cargo bike logistics. Although the barriers are large, the need is paramount, given the rise in e-commerce and local goods movement. Motivated by this need, and with targeted efforts to overcome these barriers, synergistic benefits are possible including a safer and more bike-friendly road network supportive of both personal active transportation and cargo-bike goods movement. These outcomes will help achieve wide-ranging goals in transportation planning, including GHG reduction, improvements to public health through physical activity, and emission reductions, among others.

Policies and Strategies for Cargo Bike Goods Movement in California

Executive Summary

The use of cargo bikes for last-mile deliveries has seen renewed interest in some US cities to help meet carbon reduction strategies. Furthermore, cargo-bikes contain possibly the greatest co-benefits of any emission reduction strategies for the freight sector. With the goal of informing state, regional, and local government efforts for transforming local goods movement, this white paper covers a literature review of cargo bikes for goods movement with a specific focus on the challenges facing California.

The findings suggest that a lack of infrastructure such as protected bike lanes and unloading zones are an important barrier for implementing cargo bikes for goods movement. Safe and direct bicycling networks are needed to allow for cargo bike goods movement. Relatedly, traffic signals that prioritize bike traffic and make intersections safer (e.g., protected left turns, no turn on red) are needed to support bicycling of all kinds. In addition, local distribution hubs or micro consolidation centers (MCCs) are needed to make cargo bike last-mile delivery possible. Distribution hubs are challenging to implement because they require a lot of coordination between government and operators.

While e-bikes are seeing greater standardization across the US, flexible regulations on vehicle form (e.g., number of wheels), speed, capacity, and insurance, among others could help to provide structure for the development of standardized vehicles for goods movement.

Evidence suggests that both incentives to operate cargo bikes and disincentives for vans and trucks—including zero-emission vehicle zones, truck-free zones, slow-speed zones, access restrictions—are the most powerful interventions to implement a shift from trucks to bikes for last-mile deliveries. Evidence is less clear on awareness campaigns, although much of that uncertainty may be due to challenges in measurement and evaluation and less to do with the effectiveness of the strategy.

A major shift in the delivery landscape is needed to realize the potential for cargo bikes to reduce the externalities of the current freight sector. That shift includes new collaborations across different organizations, from the leadership to delivery person. In addition, community involvement is paramount to ensure such transitions are effective at achieved benefits for residents and customers.

Cargo bikes can be efficient last-mile delivery vehicles, working as a complement to trucks in the freight landscape. Accelerating the cargo bike adoption requires local and state level intervention that includes the development of urban consolidation hubs, installation of new bike infrastructure, and restrictions on van and truck delivery. In addition, incentives may be needed to support larger deployment of cargo bikes that can achieve economies of scale for last-mile deliveries and drive down the cost of delivery in the long run.

Introduction

The history of cargo bikes began in the 19th century when they were developed from tricycles as a stable alternative to bicycles (Lenz & Riehle, 2013). Although cargo bikes were prevalent in the 1920s and 1930s, automobiles quickly became the primary mode of goods movement and instilled a car/truck/van monoculture for urban goods movement (Möser & Bamberg, 2008; Narayanan & Antoniou, 2022). The recent, renewed interest in bikes for goods movement primarily comes from the problems such as negative externalities caused by truck and van travel including greenhouse gas (GHG) emissions, congestion, local pollutants, noise, separation of communities, traffic injuries, among others (Jaller, Otero-Palencia, et al., 2020; Möser & Bamberg, 2008; Narayanan & Antoniou, 2022). A recent study in London shows that cargo bikes reduce emissions by one-third compared to electric vans and by 90% compared to traditional diesel vehicles (Verlinghieri et al., 2021). On the operational side, the ease of delivery from cargo bikes can be more efficient compared to commercial vans due to parking regulations (Zipper, 2021). On the adoption side, the market for cargo bikes is also rapidly expanding in recent years where 43% of the sales of cargo bikes are projected to be from the business sector in 2021 (Sutton, 2021).

Academic literature has a broad definition for the term “cargo bike”. It can include a wide variety of vehicles including but not limited to bikes, trikes, and quads both with and without electric power. In this article, we broaden the definition of cargo bikes further to include bikes equipped with trailers designed to haul cargo. These bikes can be electric pedal-assisted, or throttle assisted (no pedaling needed) e-bikes. E-cargo bikes vary in electric range, size, speed, and carrying capacity. Today, e-cargo bikes can transport 50–250 kg of cargo (with exceptions up to 500 kg) and have a battery range of up to 30 to 50 miles (Narayanan & Antoniou, 2022), although rapid technological advances suggest the maximum capacity likely exceeds this level even by the time of this writing.

In California, GHG emissions from the transportation sector are around 50% after considering the full life cycle (California Air Resource Board, 2021). The fact that GHG emissions in California are large in absolute terms makes California an important target for innovative transportation interventions. General accounting suggests that around 43.1% of transport GHGs come from freight transport and over 80% of these transport emissions come from trucks (Hollingworth & Sims, 2011). Furthermore, the GHG emissions from freight have been increasing rapidly. These increases have become of great concern as climate targets have become more aggressive (Hofmann et al., 2017). In addition to emission concerns, growing e-commerce and freight volumes have put greater stress on cities including infrastructure wear, congestion, and air pollution (Hofmann et al., 2017; Pahwa & Jaller, 2022).

California has introduced several initiatives previously to curb the emission such as introducing Assembly Bill 32 (AB32) or the Global Warming Solution Act 2006 which requires California to reduce its GHG emissions to 1990 levels by 2020 and Senate Bill 32 or the Global Warming Solution Act 2016 which is expanded upon AB 32 to reduce greenhouse gas emissions (California Air Resources Board, 2018; *California Senate Bill 32*, 2016). The efforts during the development of the California Sustainable Freight Action Plan also coordinated to identify strategies to mitigate various freight system impacts (Jaller, 2016). In addition, the Advanced Clean Truck (ACT) rule sets a timeline for manufacturers to phase out most gas-powered heavy-duty vehicles by 2035 (Kaenel & Guillen, 2023). These, amongst other initiatives, set the landscape for the relevance of commercial cargo bikes to help achieve emission reduction goals from the freight sector in California.

Cargo Bikes for Goods Movement: Current Conditions in the US

California and the US generally have been late to the revival of the cargo bicycle for goods movement relative to the European Union (EU). Some countries in the EU began promoting cargo bikes for last-mile delivery decades ago (e.g., Scandinavian countries and the Paris La Petit Reine projects are most notable) (Holguín-Veras et al., 2015; Interreg Europe, 2021). One study estimated that in European cities, cargo bikes can replace around 51 percent of entire motorized freight traffic (Wrighton & Reiter, 2016). Another study showed that in Paris, it is possible to deliver 91 percent of freight using e-cargo bikes (Robichet et al., 2022). In the US, most cargo bikes for goods movement pilots began very recently. For the same reason, there has been little research on the feasibility of cargo bikes in US cities.

In the US, consumers commonly use cargo bikes to transport kids and goods for personal use. The potential for using cargo bikes for business-to-consumer (B2C) good movement is mainly unknown. In the use cases that only require relatively short delivery distances (i.e., the "last mile" deliveries), a few pilots in US cities showed some promise. Specifically, direct urban distribution schemes (i.e., point-to-point deliveries) may be the most suited to cargo bikes (Hofmann et al., 2017). They demand little cargo, require no transshipment complexity, and are often demanded only for short-distance journeys. Courier services and food delivery services are common examples. Direct distribution can include multiple deliveries or single deliveries depending on the structure of the service.

Several studies using real-world data from different US cities have shown promise for cargo bike deployment for last-mile goods movement. In one study, Sheth et al. (2019) used real-world data and simple cost scenarios without considering delivery points to estimate the competitiveness of cargo bikes in Seattle, Washington. The authors found that short distances combined with large frequencies of close deliveries, and deliveries close to the point of distribution make cargo bikes more competitive (Sheth et al., 2019). Dense urban environments are an important prerequisite for cargo bike deliveries (Fištrek & Rzewnicki, 2016). Beyond dense urban environments, logistics operations have an important role in the support of cargo bike deliveries. Another scenario-based study assessed the potential of cargo bike delivery for last-mile freight using the West Oakland neighborhood of Oakland, California (Hartle et al., 2022). The study used several scenario simulations where businesses converted different percentages of current deliveries into cargo bikes. The best-case scenario that delivered maximum percentages using cargo bikes showed that cargo bikes could considerably reduce vehicle miles traveled (VMT) by motorized vehicles, be cost-efficient, and reduce air pollution. Even the worst-case scenario, where the minimum percentage of deliveries are done by cargo bikes, showed VMT reduction and emission benefits (Hartle et al., 2022).

US Pilots

Several jurisdictions in the US have tested (e.g., New York, B-Line Sustainable Urban Delivery in Portland) or are currently piloting cargo bikes. In Seattle, "Pedaling Relief Project" tested the effectiveness of e-cargo bikes for dense urban deliveries. That project focuses on delivering food bank donations to the residents in need of local groceries. Another study in Seattle is also piloting a micro hub in downtown (Seattle Neighborhood Delivery Hub) that tests different zero-emission deliveries which include cargo bikes. The study put cameras in the e-cargo bikes to test how the drivers are using the infrastructure (e.g., spending time on sidewalks versus streets, use of bike lanes, etc.) (Herbert, 2022).

Apart from understanding the use of infrastructure by cargo bikes, these studies indicate different jurisdictions' motivations for shifting and harnessing the benefits of cargo bikes in their paths toward decarbonizing the freight sector. These pilots can also provide motivation as well as a learning framework for other jurisdictions that are interested in the decarbonization of the freight sector to test such type of innovative initiatives.

In New York, a commercial cargo bike pilot was launched in 2019 with UPS, DHL, and Amazon (increased to 6 participants in 2021) and 100 bikes (increased to 350 bikes in 2021) (New York City DOT, 2021). These bikes can load and unload wherever commercial vehicles are allowed and at designated cargo bike corrals (i.e., designated space on the curbside for parking cargo bikes for loading and unloading). During the pilot program in New York, Amazon initially used cargo bikes for grocery delivery and later expanded their its fleets for standard package delivery (Kinchen, 2021). The cargo bike pilot grew during the pandemic and provided essential contactless service deliveries. Each cargo bike covered an average of 20 service miles per day replacing the vans or box trucks on a 2:1 or sometimes 1:1 basis, which resulted in considerable CO_2 savings and reduced passenger car miles traveled (New York City DOT, 2021). However, it has been argued that one of the limiting factors for the vehicle substitution is the bikes cargo capacity, besides range and the type of commodities that can be transported. Thus, 1:1 to replacement, especially from delivery vans is difficult (Jaller, Otero, et al., 2020). New York city was also one of the first places in the US to evaluate cargo bikes, experiencing issues with local regulations on the electrification of bicycles (Hogan et al., 2019). Other studies in the city have evaluated their potential as a local and last-mile transport option.

Boston plans to launch an 18-month-long electric cargo bike pilot in the Summer of 2023, funded through the Massachusetts Clean Energy Center and the state's Department of Energy Resources. The pilot is a neighborhood delivery service for local businesses that will use electric cargo bikes instead of motor vehicles for package deliveries. Net Zero Logistics company will provide the electric cargo bikes and coordinate delivery logistics. The service is expected to deliver food and small to medium parcels and aims to promote a more environmentally and traffic-friendly way of delivering packages (City of Boston, 2023).

In collaboration with seven other US cities, Miami is also planning an 18-month cargo bike pilot for last-mile freight delivery by replacing trucks with cargo bikes that can carry 500 pounds. The project aims at testing cargo bikes as the primary form for freight curbside delivery. If successful, the project can be scaled up, and there would be learning options for freight trucking industries to adopt cargo bike technologies from the pilot. The project will use a freight model where parcels will be offloaded in warehouses outside the congested areas onto cargo bikes for delivery. A significant data collection initiative is also planned during the project period to understand the traffic flow, VMT reduction, and emission reduction benefits of using cargo bikes for last-mile delivery. Another goal of the project is to share the learnings so that other jurisdictions can replicate if needed (Transport Topics, 2023).

California Specific Pilots

Several jurisdictions in California are exploring zero-emission last-mile delivery options with cargo bikes. The City of Santa Monica launched the first national zero-emission delivery zone in partnership with the Los Angeles Cleantech Incubator (LACI). The program is testing different types of light-duty zero-emission vehicles that include cargo bikes. The program's overarching goal is to provide a blueprint for the cities to implement zero-emission delivery zones, provide learning opportunities for delivery

companies about operating in these zones, provide environmental benefits to the local communities, and provide economic opportunities for small businesses. Later, an e-cargo bike company launched their operation in the City of Santa Monica to pilot zero-emission vehicles (i.e., e-bikes and cargo containers). The plan of this freight delivery operator is to deliver meal kits, e-commerce orders, groceries, and subscription-based boxes regularly (City of Santa Monica, n.d.).

Current Challenges and Supporting Strategies

Several review papers on the topic of cargo bikes for goods delivery demonstrate the complex challenges in transitioning from trucks and vans to bikes (Narayanan & Antoniou, 2022; Patella et al., 2021; Steckler et al., 2020; Vasiutina et al., 2021). In this white paper, we focus on supportive policies and strategies for the deployment of cargo bikes. Unlike Narayanan & Antoniou (2021), which covered a wide variety of topics and literature, we focus specifically on the policy topics and offer a discussion that considers the challenges facing cities in California while referring to other case studies around the world. In our current synthesis, we focus on four basic aspects: physical and spatial; economic; political and legal; and social and cultural.

Physical and Spatial

Infrastructure, Facilities, and Built Environment

Urban logistics is closely tied to infrastructure design with the feasibility of different systems being affected by city transportation networks, land use patterns, and laws and regulations around cars and trucks. Some have noted that the effectiveness of alternative vehicles in US cities compared to EU cities is limited due to inner city infrastructure design (Gruber et al., 2014). While the US and particularly Californian cities are poorly designed for bike travel, cargo bike use may still be viable in dense urban environments where congestion or parking restrictions make truck and van deliveries costly and inefficient (Jaller, Otero, et al., 2020). Uncertainty remains regarding how cargo bikes can be integrated with other road users, where these devices are permitted to load and unload, and what different parking facilities are needed to accommodate these vehicles (Lee, 2019).

The primary supportive infrastructures for cargo bikes are bike infrastructure and bike-friendly road design, parking infrastructure, and transshipment points (Narayanan & Antoniou, 2022). A safe, efficient dedicated bicycling network (requires minimal detours), and compatible with the often-wider designs of cargo bikes and trikes is ideal. Evidence also suggests bike infrastructure has numerous co-benefits for population-level health (Lusk & Li, 2012). Road design principles that are supportive of bicycling include dedicated bike infrastructure and reducing the volume and speed of cars. Current infrastructure in most US cities makes cargo bike delivery difficult or of limited effectiveness because of safety concerns and the lack of effective designs for bikes for goods movement (Gruber et al., 2014). However, a lot has changed in recent years in terms of bicycle infrastructure development in several cities in California. In California, many cities have been investing in bicycling infrastructure and have made improvements in road design to increase bike safety (Curry, 2018), yet bicycling remains an infrequent travel mode likely due to barriers of distance and safety. In addition, cargo bikes can be especially helpful in delivering packages in cities where century-old streets were not designed to accommodate large delivery vehicles.

General bicycling barriers also prevent goods movement by cargo bikes. Even in densely populated areas with close proximity between pick-up and drop-off points, the lack of safe infrastructure makes these

networks risky for commercial use. Road design is an effective tool to encourage less and slower driving (Geurs, 2000). Traffic signals that prioritize public transport and adjust in real-time to prioritize bike traffic may also help increase its convenience in a system that has historically favored car travel. In addition, many safety interventions such as removing right turns on red and unprotected left turns are likely to benefit pedestrians and bicyclists of all kinds including those moving goods (Geurs, 2000). In addition, Idaho Stop rules (i.e., allows bicyclist not having to come to a complete stop at a stop sign and need to be going to slow enough to stop if a vehicle is approaching) that other places are starting to adopt (Halter, 2023) would be particularly beneficial to cargo bikes carrying heavy loads.

Infrastructure for goods movement is essential for safety, but perhaps just as important for goods movement is the availability and type of parking infrastructure. Many cities have been experimenting with curb lane management strategies for deliveries (League of California Cities, 2021). However, most have focused on truck and van deliveries. Replacing some on-street car parking with bike loading and unloading zones could be an effective way of both supporting cargo bike deliveries and reducing the convenience of driving. New York City is already experimenting with this type of approach by introducing cargo bike corrals that would provide increased parking capacity on curbside lanes and loading and unloading options for cargo bikes where demand exceeds available sidewalk space. This has proven to be a strong incentive for commercial cargo bike operators during the cargo bike pilots in New York City. The provision of cargo bike corrals in addition to other initiatives in the New York cargo bike pilot saw an increase in cargo bike deliveries during the pilot period (New York City DOT, 2021).

For parcel delivery use cases, transshipment points are needed to consolidate and redistribute parcels for delivery by cargo bike. Their designation and cost are large barriers to cargo bike deliveries as they are most efficiently placed in dense mixed land-use environments where land prices are at a premium. Transshipment points include space for vans and trucks to park, unload, and distribute cargo bikes for local delivery. Provision or permission to use public parking lots is an effective strategy in many US cities. Repurposing existing parking spaces for other purposes requires minimal cost (Katsela et al., 2022). Hofmann et al. (2017) provide a useful topology of transshipment points and their derivatives like urban consolidation centers (UCCs) and micro consolidation centers (MCCs) (also called local distribution hubs), which consolidate goods from many providers. Because cargo bikes have limited range and cargo capacity, they are not generally applicable for use with UCCs that are generally located on city perimeters. They are much more likely to work with MCCs located within the city, closer to ultimate delivery locations. Consolidation from multiple providers is another added complexity, perhaps not best suited for redistribution by cargo bikes. One of the big challenges of cargo bike deployment is associated with the lack of micro hubs in the US contexts where shippers can consolidate the bikes and the packages (Zipper, 2021).

Local distribution hubs are key for achieving emission reductions and safety benefits, although in only some use cases and contexts they are better than revenue neutral for companies. In a recent study, Pahwa and Jaller (2022) modeled the use of cargo bikes and micro-hubs to serve the Los Angeles region. While finding significant benefits regarding emissions and health issues, the option generates larger costs than other last-mile delivery options, with added facility and labor costs compared to the other modes (Pahwa & Jaller, 2022) (see Figure 1). In fact, initial trials in Europe for consolidation facilities, whether using cargo bikes or other vehicles for the last-mile distribution, found that the cost of the transshipment facility was a significant barrier to overcome and, in some cases, made the business model unfeasible, especially after the pilot incentives are gone (Holguín-Veras et al., 2015).

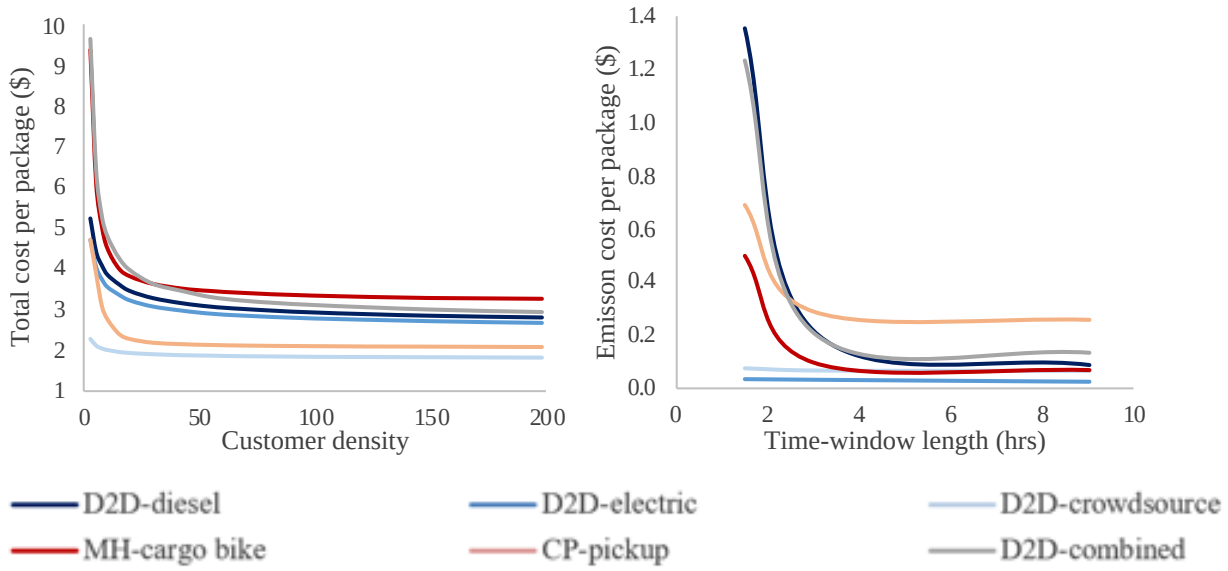

Figure 1. Modeled costs for alternative last-mile e-commerce strategies from Pahwa and Jaller (2022)

Design and Vehicle Form Factors

The design of the bikes and the regulations regarding the bike design poses a lesser, yet important barrier to cargo bike adoption for good deliveries. Manufacturers of cargo bikes have produced devices with various dimensions, sizes, and technology. Given this variability, it is difficult for regulators to develop consistent regulations across jurisdictions. A similar challenge existed for the regulation of e-bikes more broadly. Over several years, through advocacy efforts and government desire for electric bike-related regulations, more US states adopted laws regarding vehicle size, design, form factor, and speed limits. However, there are some inconsistencies from jurisdiction to jurisdiction. PeopleforBikes, a bicycle advocacy group, has listed different state laws and regulations associated with e-bikes and provided a broader classification of electric bikes that can be classed into three classes (Class 1, Class 2, and Class 3) (People For Bikes, n.d.). In addition, in the US, there is federal law HB727 that defines a "low-speed electric bicycle" as a two or three-wheeled vehicle, with a maximum motor output of 750 watts and assistance limited to 20 mph (*Consumer Product Safety Act*, 2003). An e-bike that complies with that law is treated in the same way as a non-electric bicycle. However, the rule varies from state to state. According to the California Vehicle Code, electric bicycles are classified as conventional bicycles that must not exceed an output of 750 watts and a speed of 28 mph at the ground level. California law AB-1096 specifies three classes of e-bikes (People For Bikes, n.d.). However, this is a default framework, and local jurisdictions may enact an ordinance to allow or restrict electric bike use in their areas that may differ from the state default. A bike over 750 watts would be considered a "motor-driven-cycle" and require state approval (e.g., license). However, some e-bikes can reach speeds of over 45 mph, although regulations in most states cap speeds at 20 mph for throttle and 28 mph for pedal assist. In California, class 3 e-bikes that can go up to a speed of 28 miles per hour are prohibited from using bike paths and protected bike lanes with some exceptions (People For Bikes, n.d.). This may restrict the operation of some cargo bikes in several jurisdictions in California. These are important considerations for urban logistics as some of the benefits of e-cargo bikes for reducing externalities are decreased as the bikes become more truck-like in terms of speed, size, and weight (e.g., safety, and maneuverability). At the same time, their benefits as goods movers can increase with growing truck characteristics (e.g.,

increased capacity and operational efficiency). Additionally, under federal law, four-wheeler bikes common in Europe (Erlandsson, 2018) are not allowed on bicycle lanes, limiting the potential for some cargo bikes in the US.

From a design perspective, e-cargo bikes generally have three different wheelbases: two wheels, three wheels, and four wheels. In two-wheeled bikes, cargo area can be mounted to the front and back of the bike and these vehicles tend to be lighter in weight. Three-wheelers tend to be more stable and can hold heavier loads. Even more recent is the development of four-wheelers that are generally used by businesses to carry larger loads (VOK Bikes, 2023). Lastly, specifically designed cargo trailers are being introduced that connect to standard e-bikes as another option for moving goods (City of Santa Monica, n.d.).

Currently, there are no regulations or laws addressing the permitted size of a cargo bike and the carrying capacity in California. For instance, New York state has a maximum width requirement of 36 inches for electric bikes. However, Senate Bill 1975 proposes to create a 4th class of e-bikes for cargo bikes that will be allowed to be 48 inches wide, which is supported by the Department of Transportation (New York City DOT, 2021). Some local governments have enacted their own standards given the lack of regulation at the state level. For example, the city of Chicago has a requirement for bicycles to not exceed 4 feet in width. No such width requirement is found for the State of California for e-bikes.

For sustainable goods movement, new regulations on vehicle form, speed, capacity, and insurance, among others are needed to provide structure for the development of standardized vehicles (Lee, 2019). Throughout the world, freight delivery companies use cargo bikes for different purposes. Providing flexible constraints in using different forms of cargo bikes can be an important driver for cargo bike adoption. Regulations that balance the goals of safety and efficiency are more likely to support cargo bikes for goods movement.

Charging Facilities

Charging facilities can be another key determinant for the adoption of cargo bikes for goods movement. For greater adoption, cities need to incorporate electric bicycle charging into their existing electric vehicle charging program and look for opportunities to retrofit. In 2019, Boston adopted an electric vehicle policy that included guidelines for electric bicycle charging in new infrastructure and developments (Kinchen, 2021). This policy allows flexibility in fulfilling the requirement of electric vehicle charging facilities in new development to accommodate electric carshare and electric bike parking amenities (City of Boston, 2019). Such types of policies along with other policies specifically targeting electric cargo bike charging may help with encouraging the adoption of cargo bikes for goods delivery.

Economic

Costs and Incentives

As companies try to adopt cargo bikes into their commercial delivery system, it is important to understand the challenges associated with the cost of operation of such types of vehicles. Although some studies shows that cargo bikes have an advantage in cost compared to small delivery vehicles (Rudolph & Gruber, 2017), there is a lot of variability and uncertainty associated with cargo bike economic evaluations. Methods must be developed that consider not only the purchase price of these

devices but consider the Total Cost of Ownership (TCO) of cargo bikes over their entire life cycle. TCO components include costs such as the cost of insurance and registration of cargo bikes for commercial goods delivery apart from other operational and capital costs (if applicable). Electric cargo bikes may not have a well-defined risk profile, hence it is uncertain how insurance companies define liability policies for such vehicles (Kinchen, 2021).

Addressing operational challenges for the business community and other stakeholders in dealing with cargo bikes is also important. There are some major operational challenges associated with managing cargo bike deliveries. An upfront investment is needed for purchasing bikes, maintaining them, and storing them. In addition, larger companies must adapt their current delivery software packages to generate the routes for cargo bike deliveries that can be considerably different than the current delivery routes taken by vans and trucks (as these vehicles can use different types of bike infrastructure, can park on bike parking locations and cargo bike corrals, etc.). As cargo bikes are heavier than conventional bikes and need wider turning circles, companies also must train a new delivery labor force who must bike around the city rather than drive (Ralston, 2022). These challenges will add cost to the overall TCO of cargo bikes. However, delivery with cargo bikes can create jobs using a bicycle that does not require a commercial driver's license, opening delivery driver positions to a wider pool of the labor market (Merwin, 2022).

Currently, there are several incentive programs available for e-bikes in different jurisdictions across the USA (MacArthur & Bennett, 2023). Some of these incentive programs also cover cargo bikes. For example, the state of California has a soon to launch e-bike incentive program. Administered by the California Air Resource Board (CARB), that program has a maximum incentive of $1750 for cargo bike purchases (MacArthur & Bennett, 2023). However, these incentives only cover the individual-level purchase of e-bikes, not commercial purchase and use. The use of these or other incentives to directly encourage freight delivery companies to purchase cargo bikes remains an open opportunity.

In California cities, where real estate values are high, yet parking lots are plentiful, government support for cargo bikes might best be gained from designating public car parking for cargo bike operations. Further, incentives to operate cargo bike fleets may be needed to entice companies to invest in cargo bikes and change operational strategies. This is in addition to satisfying the necessary factors for supporting cargo bikes for goods movement outlined in Narayanan & Antoniou (2021). Many California cities' ability to support cargo bikes is challenging due to the general sprawling land use (lack of density and land use mix), and the rise in residential goods deliveries (and delivery expectation).

A separate and common concern of businesses for converting to bike delivery is the theft of bikes and packages. However, while evidence suggests that the quick drop times of urban freight delivery, these concerns are mostly unfounded (Transport for London, 2009), the psychological barrier remains.

For the successful deployment of cargo bikes, a state-level initiative and pilot programs are important. As several cities are experimenting with cargo bikes and/or zero-emission vehicle pilots with State-provided grants, the biggest challenges can emerge when the grant money runs out. Thus, cities, private operators, and businesses should collaborate to explore the opportunities for making the program sustainable beyond the grant period. The learnings from the commercial cargo bike pilot that was done in participation of the major vendors of the commercial deliveries in New York City can provide a good model. These types of large-scale pilots can be a powerful incentive for freight delivery companies. At the current level, from an operational point of view, last-mile delivery with cargo bikes may not be

economically beneficial compared to the current delivery model in jurisdictions that are not dense. However, suppose cities consider the savings from the reduced emission and vehicle miles traveled in the cost structure. Further suppose state-level regulation required those costs to be included in the shipment of goods. In that case, cargo bike deliveries are likely to reduce the cost per parcel delivery from the current model with vans and trucks. Though, as mentioned before, the added cost and collaboration required for local transshipment facilities (e.g., micro-hubs) may still need additional government incentives.

Political

Regulations

Regulations can be an effective strategy to support a transition towards cargo bikes for goods movement. Cities that already embraced cargo bike regulations such as New York and Chicago may be better positioned to embrace those as lawmakers may have a better understanding of how to deal with these vehicles compared to Californian cities. For California, while developing regulations, a state-level collaboration is needed as varying regulations regarding speed caps, permitted width, and power limit may put a burden on freight operators and discourage adoption. In fact, during the recent development of policies to decarbonize urban freight, such as the advanced clean truck and advanced clean fleet rules, CARB discussed providing allowances for companies using cargo bikes as an option to comply. Although this was not ~~necessarily~~ included in the final policy, agencies should consider operational changes and the transition to alternative delivery vehicles as real and effective options. The current unclear regulatory status of cargo bikes makes these considerations challenging for this sector.

By far the most compelling effect of regulations on cargo bike goods movement can be the restriction on truck and van traffic in city centers (Choubassi et al., 2016b; Rudolph & Gruber, 2017; Sheth et al., 2019). These are growing in the EU cities where cities have clearly defined centers of commercial activity and political support is more widespread. These types of approaches include zero-emission zones, truck-free zones, access restrictions (time, weight), and slow-speed zones. This is also happening in the US which can be seen from several case studies of pilot zero-emission delivery operations across different cities in the US. In California, truck, and van traffic restrictions along with general car-free zones could prove to be an effective strategy to help initiate cargo bike deliveries in central business districts (CBDs) and other large commercial centers. This can be validated by the study in London that shows an increase in cargo bikes trip after the implementation of a low-traffic neighborhood approach (Goodman et al., 2021).

Safety can be an important aspect while developing regulations for cargo bikes. Concern for safety is also closely linked with the cargo bike design and form factors discussed earlier. The US National Highway Safety Administration has published safety guidelines that apply to vehicles operating between 20 to 25 mile per hour speed range (i.e., Low-speed vehicles (LSV) or Neighborhood Electric Vehicles (NEVs). NEVs need to fulfill several safety requirements. Possibilities should be explored to consider cargo bikes within the category of NEVs in the future.

Newer regulations regarding cargo bikes need to be introduced that are different from the current ones for accommodating different form factors for cargo bikes of small to medium sizes. These regulations should specify the speed limits, different allowable form factors (e.g., number of wheels), carrying capacity, powertrains, and other related design aspects of cargo bikes. The safety aspect is also

intertwined with safe bicycle infrastructure as local authorities tend to invest in bike infrastructures for ensuring the safety of vulnerable road users. A result of the Seattle cargo bike pilot shows that delivery cyclists rode on sidewalks approximately 40 percent of the time, a finding that may have a major safety implication for pedestrians (Dalla Chiara et al., 2023; Zipper, 2021). Specific regulations that outline the penalties for violation may be necessary for the use of cargo bikes on pedestrian infrastructures, although improved road and off-street facility design for wider cargo bikes, and including specific loading and unloading zones is more likely to success than using enforcement strategies.

Parking regulation is another important factor that can make cargo bikes competitive with respect to other delivery options. In most cases, it is unclear whether cargo bikes can use the commercial parking vehicle loading zones, and if so, whether they are exempt from parking meter payments (Lee, 2019). For instance, regulations for such cases are different in New York City and in the City of Chicago, which may confuse policymakers who want to follow those for developing parking regulations in their jurisdictions. Clear regulations are needed for the effective operation of cargo bikes for good movements at the local level. However, for encouraging the operation of the vehicles, it is important that cargo bikes are supported and incentivized, not over-regulated.

Clear regulations are necessary with respect to the requirement of bike licensing and/or permits, driver training and licensing, and insurance requirements for cargo bikes that are widely varied from city to city in the US. Several less direct regulations that can also support cargo bikes are congestion pricing, greater parking fines for delivery vans, and reduced speed limits (Narayanan & Antoniou, 2022; Tipagornwong & Figliozzi, 2014).

Additionally, freight efficient land-use strategies could provide an environment that fosters the use of cargo bikes or other zero-emission last-mile distribution options. Jaller et al. (2022) studied new trends in California where freight distribution is using more numerous smaller facilities closer to customers, possibly to allow the speedier distribution of goods to customers. And while this trend has been happening for the last few years, there are currently no land use plans that fully incorporate these trends to manage the potential impacts on roads and nearby communities. Therefore, freight-oriented land use planning will be able to address some of these issues, and considering that cargo bikes can be an important tool to decarbonize, these plans can help overcome some of its infrastructure-related barriers.

Social and Cultural

Public Awareness and Stakeholder Engagement

Public awareness and stakeholder participation can be key factors for the local-level adoption of cargo bikes. It is important that policymakers are aware of the disruption different types of cargo bikes can bring at the neighborhood level. As bicycling is still not an established culture across many communities in California, the introduction of cargo bikes for goods movement instead of vans may not be welcomed at the community level in certain jurisdictions. In addition, the use of the sidewalks by cargo bikes for commercial delivery purposes can be a concern at the community level.

While monetary and land (for storage and consolidation) incentives have proven effective to aid cargo bike use (Choubassi et al., 2016a; Narayanan & Antoniou, 2022), the evidence for educational policies is more limited and inconclusive with regard to transitioning to cargo bikes (Möser & Bamberg, 2008). The difficulty in finding conclusive evidence for soft policies appears to be twofold: (1) the effects may be

small in general, and (2) the wide variety of types of policies and the intertwined nature with monetary incentives, makes the evaluation of informational policies difficult (Möser & Bamberg, 2008). Local government support can come in other ways besides direct incentives including negotiation with other landowners and planning the deployment of cargo bike operations. Disincentives for van and truck use also go hand in hand with these incentives (see the section on Regulations above). Just because awareness and engagement campaigns are more inconclusive in their effects does not mean they should not supplement other strategies. Public awareness building at the local level can be a key strategy to cope with many challenges. Public awareness and information campaigns can be done with the participation of the local communities, local government staff, and cargo bike freight operators. Such types of engagement can assist in improving communities' perception towards cargo bikes and that can lead to greater adoption of the service. While more research is needed, recent research suggests awareness campaigns are important to provide sufficient information, as well as get people interested in cargo bike technology (Gruber et al., 2014). Other forms of awareness creation through networking and knowledge transfer, and municipal use and trial schemes become the primary means of awareness creation (Narayanan & Antoniou, 2022).

Conclusion

Cargo bikes have great potential for goods movement in the US. Europe has already moved towards using different forms of cargo bikes for goods movement, and many areas of US and California cities could follow it. The introduction of cargo bikes can bring a major shift in the delivery landscape that requires collaboration across different organizations, from the leadership level to the cargo bike deliverer level, as well as integration of the communities who would be primary service beneficiaries in this process.

Cargo bikes are likely to act as a replacement for trucks in the last-mile delivery system, however, they would still complement trucks in the overall freight delivery landscape. In this way, cargo bikes can be easily integrated with zero-emission delivery trucks and assist in building a zero-emission freight delivery system. Within this system, cargo bikes can deliver small to medium size parcels with a small footprint compared to a commercial van (both diesel and electric) and can efficiently navigate around congestion. As discussed by Pahwa and Jaller (2022), using local distribution hubs (micro-hubs, MCCs), cargo bikes can allow for minimal delivery emissions, and are best suited for light-weight deliveries under dense and congested urban environments where their lower volume capacity and lower service speeds are not a limiting factor compared with delivery trucks and vans.

Accelerating cargo bike adoption requires support from the local and state level that likely includes the development of transshipment points, investment in bike infrastructure, and strict restrictions on diesel vans. In addition, providing incentives to the freight operators can encourage them for the larger deployment of cargo bikes that in turn can achieve economies of scale and drive down the cost of delivery in the long run with cargo bikes.

To complete this review, in Table 1 we draw on the case studies and evidence to describe some key areas of intervention to allow for the spread of cargo-bike for urban goods movement. This synthesis is an intuitive selection of key elements, each of which is likely to provide synergistic benefits and guidelines for communities and freight operators for cargo bike adoption. However, because estimates

of their expected effects are limited, we only provide these strategies as a framework for future testing through a variety of methods including modeling, pilots, and full-scale implementations.

Table 1. Synthesis of policies and strategies to support cargo bikes for goods movement

Category	Policy/Strategy	Stakeholders	Land Use Context
Funding / Incentives	Direct incentives to delivery companies for capacity building	Food and parcel delivery companies	Dense mixed-use
	State-level funding for running pilot projects	• Food and parcel delivery companies • Local government • Local businesses	Dense Mixed, Residential, Commercial
	Incentives in the form of free parking for delivery	• Food and parcel delivery companies • Local parking management authority	Dense Mixed, Residential, Commercial
Bike Infrastructure	Providing community-level safe bike infrastructures	• Food and parcel delivery companies • Individuals living in communities	Dense Mixed, Residential, Commercial
Parking infrastructure	Providing cargo bike corrals along the curbside of the road for loading unloading and parking while delivery	• Food and parcel delivery companies • Local parking management authority	Dense Mixed, Residential, Commercial
Urban consolidation centers (UCCs) and Micro Consolidation centers (MCCs)	Provide UCCs and MCCs at appropriate locations that serve the integration of truck deliveries to last-mile cargo bike deliveries	• Local businesses • Local government	Dense Mixed, Mixed, Single, and Multi-family Residential, Commercial

Category	Policy/Strategy	Stakeholders	Land Use Context
Charging Facilities	Provide charging facilities for cargo bikes with electric vehicles	Local government	Dense Mixed, Mixed, Single, and Multi-family Residential, Commercial
Truck/ Van restrictions	Restriction of trucks/vans on certain types of streets in the neighborhood	• Local businesses • Food and parcel delivery companies • Local government	Dense Mixed, Residential, Commercial
Design regulations	Produce homogenous cargo bike design regulations that can accommodate a variety of designs and vehicle forms	• Food and parcel delivery companies • Local government • Cargo bike manufacturer	
Cargo bike movement guidelines on roads	Consistent and clear guidelines for allowing the movement of different types of cargo bikes on different types of roads and bike infrastructures across communities	• Food and parcel delivery companies • Local government	Dense Mixed, Residential, Commercial
Parking Citation	Provide a clear guideline regarding how the commercial cargo bikes will be cited when violate parking regulations	• Food and parcel delivery companies • local parking management authority	Dense Mixed, Residential, Commercial
Awareness and Outreach	Community-level awareness building for accommodating the disruptive change in the delivery landscape	• Food and parcel delivery companies • Individuals living in communities • Local government • Local businesses	Dense Mixed, Mixed, Single, and Multi-family Residential, Commercial

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