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Assessing the Public Health Benefits of Replacing Freight Trucks with Cargo Cycles in Last-Leg Delivery Trips in Urban Centers

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Mineta Transportation Institute

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Report 22-18

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16. Abstract

Increased urbanization, population growth, and demand for time-sensitive deliveries means increased freight movement in cities, which contributes to emissions, noise, and safety concerns. One innovative mode gaining widespread attention for urban deliveries is cargo cycles—bicycles adapted for freight delivery. Despite the recognized potential and possible success of transporting at least 25% of freight via cycle, research remains limited. This research investigates the potential of cargo cycle delivery for last mile freight in Oakland, California, with a focus on the West Oakland neighborhood. The data collection included interviews, focus groups, vehicle field observation and counts, and traffic simulation modeling. The traffic simulation examined scenarios where businesses converted different percentages of current deliveries to cargo cycles using a transfer hub as the starting point for their cargo cycle delivery. The best-case scenario—where the maximum percentage of deliveries were made with cargo cycle instead of motorized vehicles—resulted in reductions of 2600 vehicle miles traveled (VMT) per day. In that case scenario, the vehicle miles traveled (VMT) reduction is equivalent to a reduction in emissions of $PM_{2.5}$, PM_{10}, NOx, and reactive organic gas (ROG) of taking about 1000 Class 4 box trucks off the roads of West Oakland per day. In the worst-case scenario, with a significantly smaller percentage of motorized package deliveries converted to cargo cycles, there is a reduction of 160 VMT, equivalent to the removal of approximately 80 Class 4 box trucks off the roads of West Oakland per day. This potential reduction in air pollution and traffic congestion, as well as job creation, would benefit West Oakland residents.

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CONTENTS

LIST OF FIGURES

List of Tables

Executive Summary

Objective

This study sets out to evaluate the impacts of replacing freight trucks with cargo cycles on mobility and emissions in West Oakland, California, identifying enabling conditions that may facilitate an effective shift and offering policy recommendations to incentivize cargo cycle schemes.

Background & Significance

The burning of fossil fuels from motorized vehicles has far-reaching impacts on the environment, human health, and the economy. Pollution produced by motorized transportation have significant impacts on natural resources and agricultural production. Air pollution is associated with a wide range of human illnesses, including asthma, birth defects, lung injures, brain damage, cancer, and cardiovascular and coronary heart diseases, as well as cognitive functioning. The positive association between diseases caused by poor air quality and mortality has been well documented (Liu et al., 2019). Children, people living in low-income neighborhoods, the elderly, and people with chronic cardiovascular, respiratory, and metabolic diseases and compromised immune systems are at higher risk of adverse health effects from air pollution. Further, noise pollution from motorized trucks increases levels of stress, disrupts sleep, and increases the risk of cardiovascular disease (Hammer et al., 2014). The economic costs of air pollution are estimated at billions of dollars, with transportation being one of four sectors of the US economy causing a disproportionate amount of damage from its generation of air pollution (Tschofen et al., 2019).

Urban planning and urban operations have been shifting away from an economic model that emphasizes economic development, productivity, and efficiency. The new model is one of livable cities, prioritizing quality of life and the physical, mental, and social wellbeing of all city residents. When appropriate and possible, shifts from motorized vehicles to more sustainable and environmentally friendly forms of transportation can be a part of such a livability strategy. Specifically, replacing motorized trucks with cargo cycles for last mile deliveries is consistent with these new priorities. A support of cargo cycle freight delivery would also mark a shift in priorities on how neighborhoods are designed; an infrastructure that supports cargo cycle delivery is also one that increases the use of bicycles for transportation and recreation, lending to improved physical and mental health outcomes, lower levels of air and noise pollution, and lower vehicle miles travelled (VMT).

Empirical evidence to date suggests that cargo cycles can be integrated into last mile deliveries and are often a cost-efficient strategy (Choubassi et al., 2016; Fishman et al., 2015; Koning, 2016). By replacing truck miles, cargo cycle schemes can also reduce air pollution (Conway, 2015; Melo and Baptista, 2017; Ren et al., 2019; Schliwa et al., 2015). On the other hand, cargo cycle use can increase risk of injuries or fatalities of cycle users, though research has shown that the health benefits of cycling far exceed the risk of injuries (Pucher and Buehler, 2008). Cargo cycle operator safety should be at the forefront of decision-making, considering operator injury from collisions with motor vehicles and exposure to air pollution.

Cargo cycle schemes tend to be most successful in areas with a high level of deliveries from mail, courier, or parcel services; a high concentration of retail business and offices; cycle-friendly street design; truck regulations; and the availability of possible transfer hubs. Similarly, pollution and congestion problems in an area serve as a significant motivation for replacing motorized vehicles with cargo cycles.

There are a number of enabling conditions that can facilitate the shift to cargo use in last mile delivery, including the availability of consolidation centers or hubs (Aljohani and Thompson, 2016; Allen et al., 2012) and public acceptance (Gruber and Narayanan, 2019). In addition, municipal, regional, and state policies can accelerate the shift to cargo cycle use (Pucher and Buehler, 2008). These policies include providing separate infrastructure for cycles when appropriate, offering subsidies to cargo cycle operations, establishing cargo cycle facilities, and de-incentivizing motorized travel use by imposing traffic restrictions and managing parking.

West Oakland is a community highly impacted by pollution and its devastating health and environmental consequences. Flanked by highway and port activity, West Oakland has a mixture of land uses—from industrial to commercial and residential—that make it an appropriate focus for a potential shift from motorized truck activity to cargo cycles for last mile deliveries.

Methods

To advance the study objectives, primary data were collected using key stakeholder interviews, focus groups, field observations, and traffic counts. Interviewees included employees of four government agencies, two local nonprofits, five businesses, two residents, two truck drivers, and one mobile air pollution monitoring expert. Focus group participants included local business owners, delivery persons, cyclists and transit advocates, environmental advocates, and residents. Field observations and traffic counts throughout West Oakland were also conducted. There were 10 data collection sites, split into five vehicle count sites and five truck delivery behavior sites. Each of the five pairs of data collectors recorded information from the same two sites each day. Secondary data, data utilized from established databases, included the location of parcels and land uses in the study area were used to identify potential generators and attractors of freight trips. Both primary and secondary data were used to inform a simulation model to examine scenarios where businesses, organized by industrial sector, converted different percentages of current freight deliveries to cargo cycles based on a transfer hub as the starting point for the cargo cycle delivery. We designed seven different scenarios using three possible transfer hub locations and different percentages of freight demand that could be carried by cargo cycles. Emissions savings from estimated VMT decreases were calculated based on emissions factors for Alameda County and the truck fleet observed in the area.

Results

Focus group participants indicated that the benefits of replacing motorized trucks with cargo cycles include lower pollution, less noise, job opportunities for operators, less damage to roads from using lighter weight cargo cycles instead of motorized trucks, and opportunities for local cargo cycle businesses including cargo cycle fabrication and maintenance, as well as a healthy lifestyle for cargo cycle operators. This confirms and validates findings from the literature and provides support for the potential of cargo cycle schemas. Focus group participants provided the following recommendations: (a) establish parking facilities/spaces for cargo cycles to ensure safety and avoid illegal parking; (b) perform outreach to businesses/residents and the local community to activate demand for cargo cycle services; (c) provide cargo cycle operator trainings; (d) create protected cargo bike lanes; (e) use physical traffic management schemas; (f) leverage safe street schemas to incentivize cargo cycles; (g) incentivize business to use cargo cycle services and offset the human cost of running cargo cycle business; (h) limit speed for motorized vehicles and provide improved police enforcement to increase safety for cargo cycles; (i) address safety for cargo cycle operators of color as cyclists of color are known to be in more fatal collisions and may be more likely to be cited by the police (Barajas, 2021). People of color and females are more likely to be concerned with being vulnerable to harassment or being a victim of a crime while bicycling (Hull Grasso et al., 2020; McNeil et al., 2017); and (j) make cargo cycle operator jobs accessible to community members.

Our simulation also suggests that the implementation of cargo cycles could lead to a reduction in emissions. In the best-case scenario, successful implementation of cargo cycles will lead to emissions reduction that is equivalent to the elimination of more than 1,000 Class 4 trucks traveling in West Oakland per day. In our worst-case scenario, we estimated an equivalent to the removal of approximately 80 Class 4 box trucks off the roads of West Oakland per day. In most cases, Clawson, McClymonds, South Prescott, and Acorn are four neighborhoods that may benefit the most in terms of emission savings.

Policy Implications

The following are recommendations for policy implementation that would incentivize cargo cycles and facilitate a shift from motorized trucks:

1. Political and Legal Dimension

    - Restrict access of high-emission, high-noise vehicles in areas where cargo cycles are being prioritized for last mile deliveries through parking management, pricing, motorized trucks temporary/timed bans, speed limits, and pedestrian zones. Consider enforcement via camera monitors.

- Pilot test schemas of cargo cycles and reduce financial risk by offering free trials/e-bikes.

2. Physical and Spatial Dimension

    - Integrate cargo cycle plans into overall transportation strategic and land use plans.
    - Develop cycle infrastructure with cargo cycle specifications.
    - Provide parking spaces for cargo cycles.
    - Flatten curb heights to allow cargo parking.
    - Develop transfer hubs and provide equitable access.

3. Economic Dimension

    - Raise awareness among businesses about the cost-effectiveness of cargo cycles.
    - Model cargo cycle best practices by integrating cargo cycles into municipal fleets. Cargo cycles can contribute to some governmental operations such as street cleaning, waste collection, and the movement of goods and people across government facilities.

4. Social and Cultural Dimension

    - Launch a public awareness campaign to publicize the benefits of cargo cycles' potential for improving quality of life of residents.
    - Hold roundtables with all stakeholders' participation and promote network building and knowledge transfer.

1. Introduction

With increased urbanization, population growth, and changes in goods movement (including patterns favoring just-in-time delivery combined with reduced stock in stores), freight movement in cities has increased (Melo and Baptista, 2017). It is not surprising that freight now makes up a large segment of urban daily traffic, contributing to emissions, noise, and safety concerns. In addition, urban freight logistics and supply chains are often hindered by "last mile" in areas of high population (Choubassi, 2015). Last mile deliveries in urban areas pose a challenge to mobility and may intensify congestion on busy city streets where parking spaces are at a premium. Vehicles often are forced to double park to unload or park illegally when legal parking spaces are not available.

Under such unsustainable conditions, decision makers, engineers, and planners are considering innovative ways of promoting urban sustainability and guaranteeing mobility and quality of life while ensuring an efficient urban goods distribution system (Choubassi, 2015). Similarly, businesses are looking for alternative approaches for the transportation of goods in a timely and cost-effective manner.

One innovative mode gaining widespread attention for urban deliveries is cargo cycles, also known as cargo bikes. As online shopping has increased, leading to concerns about congestion and climate change, cargo bikes have been introduced to several cities, including Paris, London, and Dublin (Haag & Hu, 2019). Despite the recognized potential and possible success of transporting at least 25% of freight via cycle, research in this growing area is limited (Choubassi, 2015).

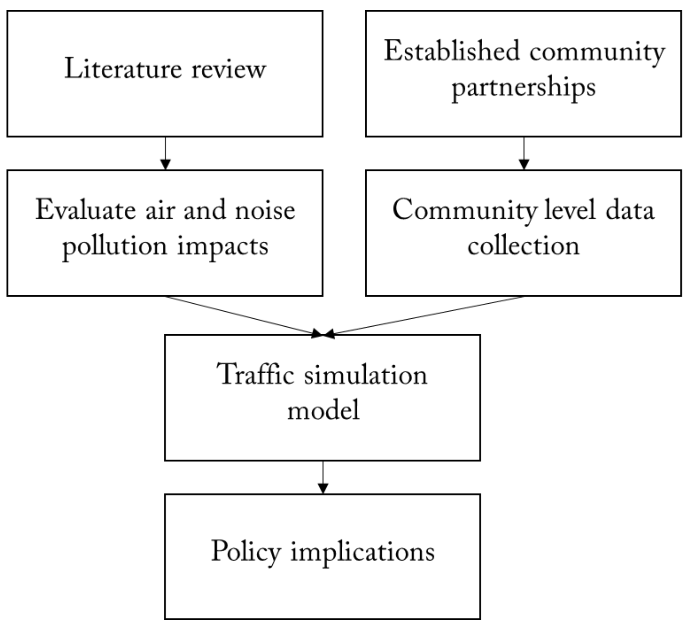
Of note, our research was conducted from February 2020 to September 2021. This time period took place almost entirely during the COVID-19 pandemic. It is important to put our findings in the context of the pandemic. The COVID-19 pandemic changed traffic and freight delivery patterns. As travel restrictions were put in place, there was an overall increase in e-commerce and home deliveries. Truck travel has remained stable overall, but there has been a shift away from deliveries to shopping centers and truck trip generation from major manufacturers and towards home deliveries (Haake, 2020). Average truck trip length has decreased during the pandemic. With decreased passenger traffic, freight trucks have been able to move at higher speeds in areas normally congested by traffic (Murray et al., 2021). The COVID-19 pandemic has had a significant impact on commerce, commuting, and traffic patterns, with the long-term impacts still unknown.

This research study sought to cultivate interest in understanding and examining the use of non-motorized cargo cycles as an innovative strategy to freight-induced congestion, pollution, and noise problems in urban centers, as well as the relevant policy and practice implications.

1.1 Overall Study Methods

Our research investigated the potential of cargo cycles to deliver last mile freight in Oakland, California, with a focus on West Oakland. Our work was organized into several tasks, the first of which was to conduct a literature review on national and international efforts to utilize cargo cycles for freight delivery, including identifying Oakland-specific rules for cargo bicycle use in bike lanes, sidewalks, or regular traffic lanes. In tandem, we developed relationships with members of the Oakland community, including Oakland Caltrans contacts, bicycle and environmental advocates, community leaders, and local business leaders. We examined community-level data about the nature and extent of the problem of noise and pollution produced by freight vehicles in West Oakland, learning from published literature and collecting vehicle count and truck behavior data. In addition, we interviewed key stakeholders and held focus groups to learn more about the community's opinions about cargo cycle deliveries. These research efforts informed our traffic model simulation, a modeling effort that calculated the possible emissions reductions due to the transfer of some motorized truck deliveries to cargo cycles.

Figure 1. Overall Study Tasks



1.2 Research Objectives

Data collected from the interviews, focus groups, field observations and counts, and traffic simulation modeling were utilized to develop cargo cycle policy suggestions for West Oakland, which could inform and encourage the adoption of cargo cycles for other municipalities where congestion, pollution, and other public health impacts from freight delivery are of concern. Study objectives included:

(1) Evaluate the impact of replacing freight trucks with cargo cycles on mobility, traffic efficiency, and emissions.

(2) Determine circumstances in which cargo cycles can replace freight trucks and private commercial businesses can change their packing/delivery practices to achieve the policy goals of sustainability, mobility, and improved environmental and public health outcomes (especially those pertaining to noise, air quality, and road safety).

(3) Provide recommendations to improve the availability of facilities, such as consolidation centers and dedicated bike lanes, to facilitate the adoption of cargo cycle freight delivery.

2. Literature Review

This chapter of the report includes the literature review supporting this research project, first describing the public health, environmental, and economic challenges created by today's motorized transportation. Subsequent sections of the literature review describe sustainable solutions to reduce the impacts of transportation on public health, the environment, and the economy, in a broader sense. This chapter closes with the current literature about cargo cycles, bicycles adapted for freight delivery, as a potential opportunity to reduce the air pollution, noise pollution, and traffic congestion issues society currently faces.

2.1 Intersection of Public Health, Transportation, and the Environment

2.1.1 Public Health Impacts of Air Pollution

Certain human activities, such as the transportation sector's use of fossil fuels, lead to air pollution, which has adverse impacts on human health, the environment, and the economy.

The burning of fossil fuels to power motorized vehicles contributes to the emission of air pollutants including carbon monoxide (CO), particulate matter (PM), lead (Pb), nitrogen oxides (NO_x), and photochemical oxidants (e.g., ozone or O_3). The transportation sector contributes to more than half of the nation's CO and NO_x emissions (EPA, 2021). There is a positive relationship between vehicle miles traveled (VMT), vehicle emissions, and ground-level ozone.

Air pollution produces negative health impacts including irritation of the nose and throat, asthma, cardiovascular disease, lung cancer, birth defects, long-term lung injury, brain and nerve damage, and eye damage (Kampa & Castanas, 2008). In addition, adverse health impacts from air pollution include damage to the respiratory organs as well as increased cardiovascular diseases, lung cancer, skin cancer, leukemia, and mortality (Schwela & Wiele, 2009). Air pollution can also damage the ecosystem and adversely impact crops, wildlife, and bodies of water including their aquatic life (Environmental Protection Agency, 2007).

In urban areas, traffic-related air pollution (TRAP) is a major segment of air pollution and has been linked to many adverse health effects. Additionally, many who live in urban areas live near major roads and are constantly exposed to TRAP (Matz et al., 2019). Studies have shown a causal relationship between TRAP and asthma exacerbation, cardiovascular disease mortality and morbidity, and impaired lung function (Health Effects Institute, 2010). TRAP has also been linked to higher rates of cognitive diseases. A population-based cohort study found that living near major roads is associated with a higher incidence of dementia (Chen et al., 2017). Those most at risk of developing adverse health effects as a result of TRAP exposure are individuals who live less than 500 meters away from major roadways (Health Effects Institute, 2010).

In research by Thurston et al. (2016), the researchers, using a cohort study design, found a link between long-term diesel exhaust exposure and the risk of dying from coronary heart disease. An et al. (2018) looked at the short- and long-term effects of particulate matter on human health and wellbeing. That study found that, in the short term, increased exposure to PM caused an increase in cardiovascular disease morbidity. There was also a positive association between cardiovascular mortality and exposure to PM, and minor exposure to air pollution over a long period ultimately caused cardiovascular deaths in the U.S. (An et al., 2018). Similarly, Liu and colleagues found a positive association between short-term exposure to PM_{10} and $PM_{2.5}$, inhalable particulate matter 10 microns and smaller and 2.5 microns and smaller, respectively, and cardiovascular and respiratory daily mortality (Liu et al., 2019). The smaller particulate matter, $PM_{2.5}$, are considered fine particles, which are of greater concern because of their ability to lodge more deeply in the lungs (California Air Resources Board, 2022; Environmental Protection Agency, 2022).

Young children, the elderly, and those whose immunity is compromised are at greater risk of developing health problems related to exposure to air pollution. Lead exposure from air pollution is related to the use of leaded gasoline in motor vehicles. Adverse health impacts of lead exposure is pronounced in children since their bodies are still developing. Children exposed to lead are known to develop learning disabilities and decrease in intelligence quotients (Simoni et al., 2015). Lead exposure can also lead to other adverse health effects such as anemia, kidney damage, and changes in blood pressure (Agency for Toxic Substances and Disease Registry, 2022).

Air pollution, particularly the emission of greenhouse gases, contributes to global warming and climate change because it affects the amount of solar energy retained by the earth. Climate change, in turn, contributes to air pollution in a vicious cycle. Climate change affects the frequency of heat waves and global wind patterns. Global warming can create longer periods of time when the ozone levels are elevated, intensifying ozone concentrations (Hartmann, 2000).

The transportation system's impact on public health and environmental degradation is undeniable. Evidence shows that, besides the direct consequences of air quality and air pollution on human illnesses, motor vehicle-related incidents are the leading cause of fatality in the United States (Gantz et al., 2003). Motor vehicle accidents disproportionately affect communities of color (Gantz et al., 2003). Younger and older populations are also particularly vulnerable to fatalities and injuries from motor vehicle crashes (Kim et al., 2008).

2.1.2 Public Health Impact of Noise Pollution

Although noise pollution is not recognized as a public health threat to the same degree as other environmental threats such as air pollution or water contamination, many emerging studies show that noise pollution is associated with a higher incidence of many adverse health effects (Hammer et al., 2014). The United States Environmental Protection Agency (US EPA) recommends that 24-hour average noise levels do not exceed 70 dB, as higher levels can lead to hearing loss over a lifetime (Environmental Protection Agency, 2016). The general consensus among researchers is that yearly average decibel levels higher than 55 dB are associated with a significant increase in the incidence of cardiovascular disease (Hammer et al., 2014). In addition, the US EPA has set a standard of 55 dB outdoors and 45 dB indoors as the levels of noise that interfere with daily activities (Environmental Protection Agency, 2016). In 2013, it was estimated that 145 million Americans were exposed to decibel levels over 55 dB, and 72 million Americans were exposed to yearly average decibel levels of over 70 dB that same year (Hammer et al., 2014).

The causal hypothesis linking noise pollution to cardiovascular disease is that sleep disturbances caused by high noise exposure lead to an increase of stress hormones such as cortisol; these stress hormones then increase heart rate and blood pressure (Babisch, 2003; Hammer et al., 2014). Decibel levels higher than 50 dB cause sleep disturbances, leading to sympathetic nervous system activation (Hurtley & World Health Organization, Regional Office for Europe, 2009). The activation of the sympathetic nervous system from sleep disturbances can also lead to an increase of blood lipid levels (Hammer et al., 2014). Chronically elevated heart rate and blood pressure will cause heart strain, and, together with increased blood lipid levels, the risk for developing atheroschlerosis increases (Hammer et al., 2014).

One of the primary contributors to noise pollution is road traffic. After airports, areas that are exposed to the highest levels of noise pollution are areas surrounding highways and urban areas where there is a high amount of road traffic (United States Department of Tranpsortation, 2018). It is logical that an effective way to reduce noise pollution would be to reduce road traffic. There are many ways to reduce road traffic: one of them is to reduce the amount of delivery trucks. Ambient noise levels increase by 4 dB when a truck passes by (Han, 2018). Limiting the amount of delivery trucks on the road would lower the ambient noise levels, reducing noise pollution.

2.1.3 Public Health Impact of Cycling

The topic of cycling and its effects on public health is a relatively new area of research. After the Paris Agreement was signed in 2015, many of the signatory countries looked at cycling as a way to cut emissions from the transportation sector by reducing passenger vehicle travel (Keall et al., 2018). The main benefits associated with bicycling are increased physical activity for those who bike and reduced greenhouse gas emissions. The main harms associated with cycling are increased exposure to air pollution to the cyclist and increased risk of traffic collision. Local conditions may vary, and transportation planners should be aware of the particular factors that influence a cyclists' overall health in the area they are operating.

Many studies have modeled the health impacts of cycling. The main health benefits from cycling stem from the physical activity. Research based in the Netherlands and Ireland found that the increased level of physical activity from cycling may incur many benefits, including reductions in years of life lost (YLLs) from cardiovascular disease, diabetes, depression, and cancer (De Hartog, 2010; Doorley, 2017). The reduction of YLLs from physical activity outweighs the YLLs gained from increased air pollution exposure and traffic collision risk (De Hartog, 2010; Doorley, 2017).

Models from Spain have shown the number of deaths reduced due to physical activity from cycling outweigh the number of deaths from air pollution and traffic collision (Rojas-Rueda, 2011). In general, the cycling infrastructure, such as dedicated bike lanes, is more developed in Europe. This infrastructure difference between the United States and Europe should be taken into consideration when applying findings from European contexts to a US city.

Another benefit from cycling is a reduction in greenhouse gas emissions. In the U.S., the transportation sector contributes 29% of total greenhouse gas emissions, the most of any sector (Environmental Protection Agency, 2017). In the transportation sector, 59% of greenhouse emissions come from light-duty road vehicles (passenger cars, low-load trucks, buses, etc.). Studies have modeled how cycling reduces greenhouse gas emissions. In models from New Zealand and Spain, the reduction in greenhouse gas emission from cycling has been shown to be up to 1.4% (Keall et al., 2018; Mizdrak et al., 2019).

One of the concerns for advocating the public to switch to cycling is that cycling may increase air pollution exposure for the cyclist. For global urban average $PM_{2.5}$ levels of 22 μg/m^3, the physical activity benefits far outweigh the harms from $PM_{2.5}$ exposures (Tainio et al., 2016). At $PM_{2.5}$ levels of 100 μg/m^3, the harms of air pollution exposure begin to outweigh the benefits from physical activity after 1 hour and 30 minutes of bicycle travel (Tainio et al., 2016). At the time of writing this report, the San Francisco Bay Area air quality exceeds thresholds for State and federal particulate matter air quality standards, and State air quality standards for ozone (San Francisco Planning Department, 2022). Pollution is not uniform throughout the SF Bay Area, with recent research conducted in Oakland using hyperlocal air monitoring showing that variation in air quality exists within a city, and even within a neighborhood (Southerland et al., 2021). More information about air pollution in West Oakland can be found in section 3.1. Local air pollution issues and the potential for harmful exposures to cargo cycle operators needs to be taken into account when weighing the public health benefit of cargo cycling.

There is a perception that cycling is dangerous and exposes the cyclist to risk of injuries and fatalities. Pucher and Buehler (2008) argue that as bike use increases, injuries decrease because infrastructure development that accommodates increased demand enhances safety. Research comparing injury data from California, USA, the Netherlands, and Great Britain showed a "safety in numbers" effect, where a greater number of people walking and cycling decreases the risk of getting in an accident with a motor vehicles (Jacobsen, 2015). In other research, an analysis conducted in the San Francisco Bay Area, CA, USA investigated the factors contributing to the racial/ethnic differences in risk of being in a bike accident. Taking into account traffic levels and bicycle infrastructure, cyclists in communities of color are more likely to be in an accident, with Black cyclists at the most risk on a per-capita and per-distance basis (Barajas, 2018). Studies in the Netherlands examined the rise of bike use by 25% between 1980 and 1996 and tracked the 50% reduction in bike fatalities and injuries in the same period (Fishman et al., 2015). Fishman et al. argue that existence of sufficient bike infrastructure and policies are critical to promoting safety (2015).

Research conducted in the San Francisco Bay Area took into consideration the health impact and the greenhouse gas emissions impact of active transportation modes such as walking and bicycling. With just moderate increases in walking and biking, cardiovascular disease and diabetes rates decreased, greenhouse gas emissions decreased, but traffic injuries increased. The study concluded that an overall improvement in population health could result from increased physical activity from active transport, but measures to minimize pedestrian and bicycle safety would have to be implemented (Maizlish et al., 2013).

2.2 Sustainable Economic, Social, and Environmental Development, and Street Design and Operations

When we consider the adverse health impacts of air pollution, it is clear there are enormous impacts on the economy. Economic impacts are estimated at billions of dollars of increased medical costs, loss of work productivity, illnesses, crop damage, damaged soil, threatened forests, polluted lakes and rivers, and lower agricultural and commercial forest yields (Narain & Sall, 2016).

Urban design has always been shaped by two competing value systems: an economic model and the livable cities model (Lennard, 2019). The economic model prioritizes the city's role in fueling economic growth and wealth. The livable cities model centers the critical concepts of community wellbeing, social life, community connectedness, physical and mental health, civic engagement, and sustainability. The livable cities model emphasizes quality of life and encourages the design of cities that are walkable, bikeable, and accessible through public transportation. Policies and programs that pursue sustainable livable cities include improving the biophysical environment, climate protection and adaptation to reduce air pollution, land use regulations, energy efficiency, bicycle ridership, expandable public transportation access, and open space. Implementation of such policies call for political commitment, partnerships-based approaches, and collaborative governance.

Figure 2. Economic Model Versus Livable Cities Model

Economic Model	**Livable Cities Model**
• Cities are economic engines that fuel economic development • Movement of people, goods and services are of paramount importance • Priorities are given to motorized transportation and development • Programs and policies prioritize the needs of businesses and development	• Cities must provide quality of life to its inhabitants • City design must provide access and opportunities for residents to have physical, emotional, mental and social health • City design must provide safe facilities that reduce risk of injuries and fatalities and provide opportunities for residents to be physically active, connect with other city residents, civically engage with community organization, safely access options of walking, biking, public transportation and recreational activities

The idea of livable cities is simple: quality of life matters. Prioritizing quality of life and residents' wellbeing mandate that city designs take into consideration users' safety, the availability of a range of multimodal transportation options, the ability to access recreational opportunities, employment, and educational institutions, and the ability to acquire goods and services easily. Quality of life is also improved when city dwellers can socialize with their neighbors and engage in community affairs. Such engagement strengthens community organization, guards against social isolation, increases social capital, and makes communities more sustainable and more resilient. Equity is a value rooted in the concept of livable cities. Equity considerations mandate that all people—regardless of age, ability, or mode of transportation—must be able to have the same access to opportunities, goods, and services. Economic activities are expected to flourish as residents have easier access to schools, work, parks, retail shops, and services. People become healthier as they decrease their dependency on private, motorized modes of transportation and use walking, biking, and public transportation, which require higher levels of physical activity. Residents reduce their expenditure on transportation as they rely less on private vehicles and the air becomes cleaner as fewer cars are operating on roadways, reducing emissions. Congestion in the city is alleviated as people walk, bike, or increase the use of high-occupancy transit vehicles.

The concept of complete streets emerged to capture the ideal of the livable city where there is an emphasis on (a) building/modifying the transportation sector's operational and physical infrastructure to make non-motorized and transit travel more accessible, safer, and more convenient than motorized private travel modes, (b) educating the public on the benefits of the modified infrastructure and encouraging its use, (c) enforcing the laws and regulations so that all users are safe using the new or modified infrastructure, and (d) evaluating strategies used to ensure their effectiveness (Mid Ohio Regional Planning Commission, 2012).

Complete streets ushered in a new paradigm that focused on designing infrastructure that meet the needs of all users for accessible, sustainable, and connected communities as well as creating complete streets designed to serve those needs in a holistic manner. The concept of complete streets captures the idea of streets that are designed, used, and operated to enable safe access to streets for all traffic such that pedestrians, bicycles, motorists, and public transportation users of all ages and abilities are able to safely move through the transportation network.

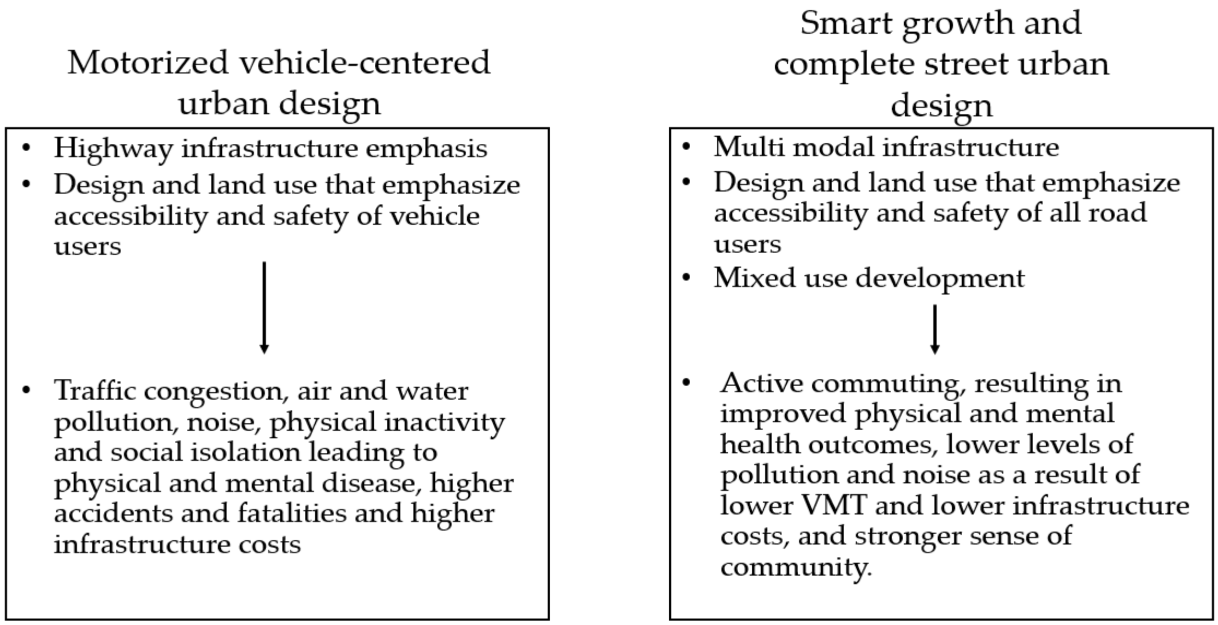
The National Complete Streets Coalition defines complete streets as streets that are designed and operated to enable safe access for all users (Smart Growth America). The American Planning Association's definition of complete streets is to "serve everyone -- pedestrians, bicyclists, transit riders, and drivers -- and consider the needs of people with disabilities, older people, and children. The complete streets approach seeks to change the way transportation agencies and communities approach every street project and ensure safety, convenience, and accessibility for all" (McCann, 2010). The United States Department of Transportation Policy Statement on Bicycle and Pedestrian Transportation Accommodations Regulations and Recommendations (US DOT Policy Statement) supports "fully integrated active transportation networks," including accommodations for bicyclists and pedestrians. The US DOT Policy Statement encourages all transportation agencies and local governments to adopt similar policies to ensure all users of streets, roads, and highways are taken into consideration when developing new or retrofitting existing transportation systems. Pedestrians, bicyclists, motorists, and transit riders of all ages and abilities must be able to safely move along and across a complete street (Federal Highway Administration, 2010).

Complete streets lead to: a more vibrant local economy since walkers and bikers shop more and spend more in the local economy; safer communities with lower risk of injuries and fatalities from accidents and crashes; more equitable access to physical activities for underserved communities; and a balanced transportation system with varied options for mobility (New York State Department of Transportation, 2022)

Complete streets are policies that promote accessible, safe, and comfortable streets for all users, especially the most vulnerable. These policies strive to provide continuity in designing streets for all users and are integrated within local and state-level plans. Creating complete streets means transportation agencies must change their orientation from building primarily for cars to considering the broad set of street users. Instituting a complete streets policy ensures that transportation agencies routinely design and operate the entire right of way to enable safe access for all users. The key principles of complete streets are: facility connectivity, context sensitivity, comfort, safety, promoting traffic mobility for all users, efficiency, reliability, and the creation of a multi-modal transportation network that considers the needs of all users (New York City Department of Transportation, 2021).

Urban development that does not take into consideration the needs of non-automobile users can discourage active transportation, create safety risks for active transportation users, and possibly lead to longer trips. “Smart growth” is a term coined to convey the need for deliberate planning to facilitate the greater use of active travel modes through providing shorter journeys, greener landscaping, and overall more pleasant, safer, and more attractive and convenient environments for these modes (Smart Growth America).

Figure 3. A Human-Centric Model of Urban Development



The mixing of travel modes, from active transportation to heavy freight trucks, is a key challenge to urban street operations and street design. Differences in vulnerability of users, maneuverability, weight, and visibility create significant difficulties. Planning strategies to address these concerns include separating travel modes (for example, through separated bicycle lanes), prioritizing or prohibiting routes for a given mode (for example, no-truck-traffic streets), and designing facilities with increased visibility and lower speeds.

However, the challenges of street design and operations solutions to address street-level conflicts are magnified by the complexity of freight operations, especially for last mile operations in consolidated parts of cities. Conditions in these locations are usually chaotic because of the lack of streamlining between freight carriers and receivers (Aljohani and Thompson, 2020). In addition, a lack of sufficient parking for loading and unloading often results in double parking, or circulation to find parking, thereby increasing fuel cost, emissions, and congestion.

2.3 Cargo Cycles as Sustainable and Smart Alternatives to Motorized Trucks

Cargo cycle schemes are a sustainable mode of transport in dense urban last miles. Cargo cycles use human- or electric-powered pedals as opposed to fossil-fuel-powered vehicles to transport goods from one point to another. In contrast with large trucks, cargo cycles have a smaller footprint and occupy less space as they operate or park in congested urban areas. They produce zero emissions and therefore do not contribute to air pollution, but instead they advance air quality and sustainability goals. They are consistent with the objectives of making cities healthier and more livable and making streets complete for all users (Orchard and Cluzel, 2018).

Cargo cycles are slower than motorized trucks, which increases the safety of pedestrians and other vulnerable city dwellers. In addition, cargo cycles operate quietly, since they do not have the motorized engines and unloading equipment of freight trucks, thus contributing to quality of life for city residents (Orchard and Cluzel, 2018).

As an active form of transportation, use of cargo cycles has a positive impact on drivers' health. Cargo cycle operators may benefit from a risk reduction for a number of diseases linked to insufficient physical activity such as cardiovascular disease, diabetes, dementia, breast cancer, and colon cancer (Vuori, 2007).

The use of cargo cycles is also associated with decreased journey time and savings of fuel costs and parking fees for business. Cargo cycle use was found to be 2.5-50% faster than vans. Shorter and more reliable journey times can produce desirable efficiencies and flexibility. Cargo cycles are nimbler and can park closer to their destinations because they do not require a large footprint to park. Moreover, there is generally positive public perception of these cycles and approval of their contributions to lowered emissions and improved air quality. This, in turn, reflects well on businesses that are using environmentally friendly modes of transport (Orchard and Cluzel, 2018).

Using cargo cycles as an alternative to motorized freight trucks is an evolving field that holds great promise (Orchard and Cluzel, 2018). For the most part, this field is still in its infancy. Limited wide scale adoption of cargo cycle schemes as an alternative to motorized trucks is attributed to a lack of awareness and recognition of the potential of cargo cycle use.

Despite the benefits of using cargo cycles, there are several challenges that can hinder large-scale uptake and scaling up of these modes of transportation, including the following challenges:

- It is difficult to maintain economies of scale for this mode.
- There is a need to establish a local depot where cargo cycles can load and reload. The existence of such a facility is often a cost-prohibitive option especially in urban areas where space is at a premium. This may add to the overall costs of using cargo cycles for business and/or consumers.

- Operational cost may increase when considering parking and storing facilities for cargo cycles on city streets. On-street secure parking may not be an option in many urban areas.

- The cargo cycle industry is still small which makes contracting at a large scale (locally or nationally) not a feasible option.

- Labor safety is a concern. Mixing bicycles with motorized vehicles poses a high-level of risk for cycle users and pedestrians.

- Complying with often unclear regulations is a challenge that faces cargo cycle use.

- There are limitations to carrying capacity and distance (even with electric assist cycles). Electric assist vehicles, of course, provide for longer distance and larger capacity than human-powered vehicles, and they can allow cargo cycle operators to draw on a large pool of employees regardless of physical fitness. They can also enable drivers to access hilly terrains.

Schliwa et al. (2015) called attention to physical interventions needed to address cargo cycle needs including bike infrastructure, driving and parking restrictions, and consolidation centers. They also called for non-physical interventions such as awareness campaigns and incentive programs including incentivizing private logistics companies

2.4. Cargo Cycle: Empirical Evidence

2.4.1 Cost Savings and Efficiency

Studies in the Netherlands estimated cost savings of $575,000 annually as a result of using cargo cycles in place of motorized vehicles. (BBC Autos, 2014). The study also showed that use of cargo cycles is associated with a decrease of 152 metric tons of CO_2 in one year (BBC Autos, 2014). Cargo cycles were found to be more cost-effective than their motorized counterparts in dense areas of the city and when used for short-distance deliveries (Jorna et al., 2013).

Koning and Conway (2016) estimate savings of 0.8-1.69 million Euros (approximately 0.94-1.99 million USD) from 2001-2014 in CO_2 emissions at the local level from a shift to cargo cycle in the last mile. Similarly, Melo and Baptista (2017) suggest that cargo cycles can be integrated into local last mile solutions as a cost-efficient strategy. Examining the context of Porto, Portugal, they found that replacing 10% of trips that are 2 km and that occur between 8:30-9:30 am would result in reduction in delays, savings in energy consumption, and decrease in CO_2 emissions of 250 kg in a 10% replacement scenario and 746 kg in a 100% replacement scenario. Simulation studies in Portland, Oregon, show that cycle logistical schemes by the company B-Line, which uses micro depots in the city center and replaces vans with cargo cycles, can be viable and cost-effective (BBC Autos, 2014). Similarly, simulation studies in Central Grenoble, France, of cargo bikes that used consolidation centers located outside the city were associated with 55% saving in motorized miles travelled and faster deliveries when sufficient storage at the consolidation center was available.

Choubassi et al. (2016) conducted an economic feasibility study in Austin, Texas, and discovered that electric cargo cycles are more effective than other modes of urban mail delivery in dense urban areas. Fishman et al. (2015) quantified the economic health benefits of cycling and estimated such benefits to be 19 billion Euros per year (approximately 20.5 billion US dollars), 3% of the Dutch domestic product between 2010 and 2013. Fishman et al. (2015) estimated that cycling saves 6,500 deaths annually and adds half a year to human life in the Netherlands. They posit that there is a high-cost benefit return on investing in bike infrastructure in the Netherlands and promoting cycling. This finding implies that under certain conditions and in specific enabling contexts, cargo cycles can help municipalities reap similar benefits.

2.4.2 Reduction of Air Pollution

Schliwa et al. (2015) posit that cargo cycles provide a sustainable alternative to trucks in urban areas. Human-powered cycles have zero emission and can transport lighter goods in urban centers. Conway et al. (2011) note that the use of cargo cycles reduces social externalities and can replace freight in an attempt to decrease traffic congestion and reap environmental benefits.

In 2020, DOT piloted a cargo cycle initiative in New York City which, in January 2021, recorded a 109% increase in deliveries -approximately 45,000 cargo cycle deliveries - and a doubling of commercial participants as well as an expansion in geographic coverage. Cargo cycles replaced motorized trucks and led to a reduction of 7 tons of CO_2 per year per bike or 100 planted trees and 15,436 passenger car miles (New York City Department of Transportation, 2021).

Melo and Baptista (2017) posit that electric cargo bikes can yield environmental and social benefits and positively affect traffic performance; however, key stakeholders' buy-in is critical to implementation feasibility.

Use of micro distribution depots was found to be associated with various benefits and positive impacts. Gnewt Cargo in London, England, is a company that conducts local deliveries for Hermes and other large companies. Data show that there was a reduction of 81% of diesel mileage, 88% of fuel use, and 52% of distance travelled per parcel by replacing Hermes' vans with Gnewt vehicles (Cairns and Sloman, 2019). A reduction of 45 tons of CO_2 was estimated when electric vehicles were used for last mile deliveries from a micro depot operated by DPD company in London (Cairns and Sloman, 2019). DHL's pilot in Frankfurt, Germany, and Utrecht, Netherlands, replaced traditional vehicles for last mile deliveries with an estimated savings of 16 tons of CO_2 (Cairns and Sloman, 2019) In Hamburg, Germany, UPS vehicles cover 70% of the city center and carry 500-600 packages per day in last mile deliveries from micro depots, with cargo cycle delivery resulting in reduced fuel costs (Cairns and Sloman, 2019). Savings of 65 kg NO_x, 8 kg PM_{10}, and 56 tons CO_2 were reported by DPD/GLS, a delivery service company, use of bikes in a pilot conducted in Nuremburg, Germany, in 2016 (Cairns and Sloman, 2019).

2.4.3 Comparison of Human, Electric, and Fossil-Fuel-Powered Vehicles

Studies have examined the sole use of e-cargo bikes with no access to micro consolidation centers. In London, England, in 2018, a study of Sainsburys and e-cargobikes.com found that e-cargo bikes were able to fulfill 97% of online orders from one store, delivering 100 orders a day, and the study reported reductions in route length, travel time, and parking time. Cargo bikes were proven to be faster and found to reduce emissions by 75% (2,171 kg) in a study of a local butcher store in Greenwich that substituted 95% of local deliveries under 5 km with cargo bikes. Cargo cycle operators have reported feeling more physically fit from riding bicycles for work, and studies of operators have recorded them burning excess calories from their active workday (Cairns and Sloman, 2019).

Choubassi et al. (2016) conducted a case study of U.S. postal offices that compared the costs of electric assist pedaled bikes, which is a pedal bike with an electric motor, with e-bikes, and e-trikes in three locations in Austin, Texas. They concluded that electric assist pedal bicycles provide the most cost-effective mode of last mile delivery in congested central business districts (CBDs). E-bikes were found to be most cost-effective in areas where there is highest population density and where a distribution depot is present within the delivery area. They also found that as deliveries increase, cost decreases. Melo and Baptista (2017) argue that cargo cycles schemes are appropriate for use in specific areas of the city with distances close to 2 km. Ren et al. (2019) report that electric vehicles show significant benefits in reducing carbon emissions.

Sheth et al. (2019) compared electric assist cargo bicycles with delivery trucks that have the same delivery route and delivery characteristics in Seattle to determine the conditions under which electric assist cargo bicycles would be more cost-effective than delivery trucks (Sheth et al., 2019). The chosen routes were observed and modelled using electric assist cargo bicycles. The study shows that electric assist cargo bicycles are more cost-effective under the following conditions: in the business district center; with a high density of residential and non-residential units; and under conditions of low delivery volumes for each stop. Trucks are more cost-effective when deliveries are far from the business district and require large-volume deliveries for each stop.

A study examined the possibility of shifting to cargo cycles in German cities by providing courier companies with a fleet of 40 electric cargo bicycles (E-CB). Findings show that 42% of deliveries carried out by courier companies, or 19% of mileage in Berlin, can be conducted with cargo cycles instead of motorized freight vehicles (Gruber and Kihm, 2015). The study also found that 72% of bike couriers were not fully informed about E-CBs but were willing to use them. Research indicates that cargo cycles with electric assist can replace up to 85% of car trips made by courier services (De Decker, 2012).

Using an agent-based simulation, Fikar et al. (2018) conclude that a mixed-mode fleet with different types of vehicles and different technologic (diesel and electric) can lead to cost-effective deliveries in the last mile. Similarly, Aljohani and Thompson (2018) reveal that when consolidated deliveries are carried out using electric bikes, delivery vans, and cargo bikes, they have the best chance of receiving the approval of all stakeholders as well as delivering the most contribution in noise, emissions, and traffic congestion reductions.

Conway (2015) studied the use of cargo cycles instead of motorized trucks in New York City. She posits that bike speed was similar to motor vehicle speeds in areas of high density, but speed is affected by trip distance, load, and urgency. Cycles were associated with travel time reliability and low levels of delays due to frequent stops. Reduction in emissions and space needs were variable and shaped by logistics. They were highest in severely congested conditions. Gruber and Narayanan (2019) compared real-life trip data to examine cargo cycles' travel time as compared to conventional vehicles introduced in commercial trips. They conclude that cargo cycles have lower travel times that ranged from 5-40 minutes, an average of 6 minutes faster.

2.4.4 Incentivizing Cargo Cycles

Choubassi et al. (2016) suggest that policies that incentivize cargo cycles and improve its infrastructure as well as discouraging the use of motorized trucks would help leverage the benefits of cargo cycles including quality of life, livability, safety, congestion alleviation, and reduction in noise and emissions. Shifts to cargo cycles urban deliveries provide mutual benefits for both public and private sectors. Effective implementation of cargo cycle schemes is dependent on the public provision of dedicated bike lanes and consolidation centers in urban areas (Choubassi et al., 2016).

2.4.5 Need for Transfer Hubs

First and last mile services require that cargo cycles have a transfer hub. The main function of a transfer hub is to unload cargo from trucks and load items onto cargo cycles. The transfer hubs are different from, but often operated within, distribution centers or consolidation centers. Distribution centers and micro-distribution centers are usually operated by large businesses as key nodes in their distribution chains, serving the purpose of temporary storage and inventory management. The consolidation center can be a permanent or temporary facility and is usually operated by third-party companies that function under contract from multiple businesses. An urban consolidation center is a facility that groups deliveries to receivers to advance the efficiency goals of reducing the numbers of freight vehicles and increasing reliability. In Belgium, large-scale urban consolidation centers achieved a 22% reduction in VMT and 36% decrease in consumption of fuel (Aljohani and Thompson, 2016). In Britain, consolidation centers achieved reductions of 75% of VMT, 89 tons of CO_2, and 1,000 kg of NO_x emissions (Aljohani and Thompson, 2016). The success of these consolidation centers, however, is not always guaranteed. Their success is closely tied to the ability to select the most appropriate consolidated delivery fleet in terms of types, mix, and technology as well as assessment of location (Schliwa et al., 2015).

The implementation of cargo cycles does not necessarily need distribution or consolidation centers if it is limited to local point to point cycle services. Examples of local point to point services include delivery of groceries, mail, small business logistics, retail, and public sector organizations delivering internal mail in the United Kingdom. However, for study areas reliant on trucks for last-leg deliveries, integrating mode transferring into the operation of distribution or consolidation center can provide effective synergy. Studies find that creating a consolidation center at the edge of the service area is a critical best practice for the growth of cargo bike logistics (Schliwa et al., 2015). Investigations of the impact of cargo cycles urban consolidation and delivery times underscore the importance of consolidation strategies to ensure reliable and timely delivery and emphasize the need for sufficient numbers of cycles (Fikar, 2018).

This study uses the term "transfer hub" to highlight the mode transfer from trucks to cargo cycles at the designated facilities. Distribution and consolidation are not required, but they will obviously improve the operation efficiency if implemented.

In summary, empirical evidence suggests that cargo cycle urban deliveries can result in cost savings, cost-effectiveness, and reductions in air pollution. Evidence also points to the fact that cargo cycle urban delivery schemes can be successful when favorable policies incentivize their operations, when consolidation centers are available, and when there is sufficient bike infrastructure that provides increased safety and prevents injuries and fatalities.

2.5 Cargo Cycle Policies, Regulations, and Standards

Cargo cycles are consistent with and support the sustainable development, smart growth, and complete streets concepts that have dominated public policy. They are also supportive of community wellbeing and environmentally friendly practices. Cargo cycle use falls under such policies and constitutes one of the tools in the toolbox of city planners to advance goals that are at the center of these discourses. Some cities have adopted cargo-cycle-specific standards that would guarantee that cargo cycles fulfill their promise and would also minimize the challenges they face. In other cases, cargo cycles fall under the broad umbrella of bicycle transportation and are subject to its regulations.

In New York City, all cargo cycles are expected to comply with New York State laws and New York City laws. The New York City codes and rules mandate the following:

- Commercial bike users complete a commercial safety course that provides information on equipment needed, safety rules, and biking rules in the city.

- Businesses post commercial bike safety rules in a visible area in multiple languages.

- Businesses keep a roster of all employed bikers with their name, address, date of employment, and date of course completion.

- Businesses equip all employees who are hired as commercial bikers with proper gear including helmet, business identification card, and reflective apparel with business name and number.

- Businesses equip cycles with an audible device, headlight, functional brakes, wheel reflectors, and business signs.

Rules also mandate that cargo bikes stay in designated bike lanes and refrain from traveling on sidewalks or other non-designated biking areas. Failing to comply with city ordinances incurs fines by the City Department of Transportation (New York City Department of Transportation).

2.6 Cargo Cycle Enabling Conditions

2.6.1 Stakeholder Engagement

A comparative analysis between motorized trucks is warranted when considering a cargo freight scheme. An effective scheme requires engagement with stakeholders to select the most appropriate option. Aljohani and Thompson (2018) emphasizes the importance of integrating multiple stakeholders' perspectives in planning and implementing urban freight policies. Aljohani and Thompson (2018) point out that it is critical, when selecting delivery configuration, to address the objectives of all stakeholders who are engaged in last mile delivery. They propose a multi-stakeholder participatory decision support framework to implement a balanced approach to addressing varied economic, social, and environmental requirements of stakeholders.

Applying the analysis framework revealed clashing objectives of different stakeholders and offered insights into the interests of each stakeholder group. The authors conclude that there is no single solution that could address or satisfy all the objectives of various stakeholders.

Another proposed framework is The Multi Actor Multi Criteria Analysis (MAMCA) framework by Aljohani and Thompson (Aljohani & Thompson, 2018). They point to the need for the following staged process phases:

Phase 1: Acquire information on stakeholders' objectives

Step 1: Define the problem and the different possible alternatives for delivery configuration.

Step 2: Identify all stakeholders engaged in last mile delivery.

Step 3: Convert stakeholders' objectives to criteria and assign a weight to each criterion to determine worth based on stakeholders' objectives.

Phase 2: Conduct multifactor analysis of alternatives based on stakeholders' objectives

Step 4: Establish measurable or qualitative indicators to determine scope and measurement scale for each criterion.

Step 5: Apply multi-criteria analysis to evaluate alternatives against decision criteria.

Step 6: Rank each alternative based on strength and weakness and performance against stakeholders' criteria.

Step 7: Identify policy recommendations and implementation plan for best alternative.

Stakeholders identified by Aljohani and Thompson (2018) included logistics service providers, receivers, shippers, local authorities, citizens, and logistics property providers. Stakeholders' objectives were varied and included quality of services, cost, reliability, traffic safety, receivers' satisfaction, profitability, product availability, livability, urban accessibility, quality of life, system integration, delivery security, multi-modality, delivery load time, traffic safety, and repair and maintenance cost (Aljohani & Thompson, 2018) .

2.6.2 Public Acceptance

Widespread acceptance of the shift from motorized vehicles to cargo cycles is an enabling factor in the diffusion and scaling of cargo cycle use. In the 2015 study of German use of electric cargo bikes, Gruber and Narayanan (2019) found that there was widespread willingness among carriers to use electric bikes. Others, including Lenz and Riehle (2013) and Schliwa et al. (2015), posit that there is a perception that cargo cycles are not a viable mode of transport and there is lack of knowledge that the conditions where cargo cycles are not only feasible but also a source of benefits to customers and logistic companies.

Community advocacy plays a role in changing public opinion and bringing about greater awareness of cargo cycle benefits. For example, the European Cycle Logistics Federation is a body that advances the use of cargo cycles and their use as an alternative to motorized trucks. The association supports businesses or social enterprises that use cycles to deliver services. They share knowledge on best practices and lobby for more favorable conditions for cycles across the European Union. In the United States, there are a number of advocacy and education groups such as Disaster Relief Trials, an annual competition where simulations of the role of cargo bikes in disaster and emergency scenarios are held. These groups can play an instrumental role in advancing awareness and scale-ups of cargo cycle use.

2.6.3 Public Policies

Pucher and Buehler (2008) show that policies that incentivize the use of non-motorized transport have led to an increase in the share of these transport modes. When cycle policies within the area are aligned with local policies, conditions are deemed cycle-friendly. Cairns and Sloman (2019) call on the government to set up sustainable freight demonstration towns to show the possibility of shifting from vans and motorized trucks to cargo cycles in certain city conditions. They suggest that policies could advance the use of micro depots in urban areas that would serve as distribution hubs, setting up information networks for cycle operations, providing dedicated parking for cargo bike operations, improving cycle infrastructure, disincentivizing and restricting use of motorized trucks in certain areas that could be better served by cargo cycles, and incentivizing cargo cycle use by providing resources.

Incentivizing cargo cycle use has been a common policy utilized by some European countries. Subsidies are offered to cargo cycle operators at 200 Euros in France, 1,200 in Oslo, Norway, and up to 1,000 Euros in Sweden (Markham, 2017). In the U.S., a program in Portland, Oregon, provides electric freight vehicle subsidies, but not for electric bikes (Maus, 2013).

Parking pricing is another enabling strategy for cargo cycles. When parking pricing for trucks and automobiles in the city center is prohibitive, this provides incentives to cycle freight and make it more marketable (Lenz and Riehle, 2013). Urban planners should therefore take into consideration the potential for cargo bikes to replace trucks and automobiles in the city center by addressing the specific demands of this mode of freight delivery (Lenz and Riehle, 2013).

Examples of traffic restrictions in the city center exist in Cambridge, United Kingdom, where motorized traffic is restricted in the city center from 9:00 am to 4:00 pm daily. Similar schemes are implemented in a number of other European cities where traffic restrictions are used as a road demand management tool. Examples exist in Berlin, Germany; Malmo, Sweden; Stockholm Sweden; Paris, France; Milan, Italy, and Mexico City, Mexico. Those schemes include restriction criteria such as even and odd number license plate space rationing or congestion pricing (Cyclelogistics Federation, 2014; De Buen Kalman, 2021). These policies serve as enabling factors since they create a market for cargo cycles.

Pucher and Buehler posit posit that there is a need for a comprehensive and integrated combination of policies and programs to enable cargo cycle use (2008). Cargo-bike-specific parking facilities exist in a number of European cities such as Malmo, Sweden. These cargo bike stalls provide safe, convenient, affordable, and covered spaces (Copenhagenize Design Co). Bike infrastructure in many European countries allow for the sharing of bike lanes by cargo cycles as the lanes provide sufficient room for all types of bikes (Pucher and Buehler, 2008).

2.6.4 Area Characteristics

Cargo cycles are an alternative to freight trucks under specific circumstances including first- and last mile service in dense urban areas and point-to-point services for short-distance deliveries (Orchard and Cluzel, 2018). When considering a cycle freight strategy, a freight management plan is a critical first step. The first step of the plan should include identifying areas of prime potential such as ones where the following conditions exist:

- High level of deliveries from mail, courier, or parcels.

- High concentration of retail business and offices within a 2-3-mile radius.
- Cargo-friendly mobility issues, street width, and parking availability which provide a favorable climate for cargo cycles.
- Cargo-friendly local rules and regulations that do not restrict use of cargo cycles.
- At least one transfer hub in the area.

These favorable conditions for replacement of motorized trucks with cargo cycles can be identified through data on land use motor vehicles traffic restrictions, loading restrictions, and other challenges facing motorized trucks in parking and unloading, and traffic conditions. Additionally, air quality conditions can provide favorable climate for cargo cycles if there are higher levels of pollution in the area. Therefore, cargo friendly locations are those where there is a customer base, transfer hub, quality of cycle infrastructure and local policies favor cargo cycles over motorized trucks.

Puncher et al. (2008) argues that to enable cargo cycle use, there is a need for bike lanes and paths; intersection crossing, traffic education, traffic regulations enforcement, reduction of motor vehicle speed limit, traffic calming interventions, land use policies that facilitate compact, mixed development, secure bike parking and integration of bike infrastructure with public transit.

2.7 Decision-Making Framework

Factors affecting urban logistics include finances, service quality, customer satisfaction, reductions in emissions as well as congestion and pollution. Social and environmental objectives often are deemed of higher priority than economic objectives.

Since cargo cycles are not suitable for every situation, planners and policy makers need a decision-making aid to help determine whether a cargo cycle scheme that would replace motorized vehicles is an optimal approach. Orchard et al. (2018) developed a scoring methodology that would help planners assess the feasibility of cargo cycle freight schemes and suggest criteria for selecting cycle freight based on the following factors:

- Employment, retail diversity.
- Micro consolidation potential.
- Cycle vs. vehicle favorability.
- Congestion.
- Presence of business districts and suitable businesses.

- Cycle-friendly environment and mode share.
- Presence of supportive local policies.

Areas considered for cargo cycle schemes would be scored based on those factors. Highest scores are provided to:

- Areas that are dominated by retail and offices.
- Spaces that can be used as consolidation centers that exist in the business center.
- Restrictions on motor vehicles.
- Cycle routes.
- High levels of traffic congestion and delays of more than half a minute per mile.
- Mix of business-cycle networks.
- Local policies mandating low emissions and sustainability.

Metrics of success that can be used to assess effectiveness of a cargo cycle freight scheme include:

- Number of businesses using cargo cycles instead of motorized trucks.
- Number of motorized vehicles trips replaced by cargo cycles.
- Cost saving from replacing motorized trucks with cargo cycles.
- Effects on congestion and traffic flows in the post-replacement scenario compared to the pre-replacement scenario.
- Extent of emissions and pollutants that were avoided.

Criteria for the assessment of cargo cycle schemes help planners and policy makers make informed decisions that take into consideration the favorable conditions that lend themselves to making the cargo shift.

2.8 Use of Cargo Cycles

Several case studies of cargo cycle use have been documented around the world, initiated by the government, the private sector, and public-private partnerships. While use outside of Europe is limited, several U.S. cities have implemented cargo cycles, mostly through private initiatives, either as first or last mile alternatives to trucks. In New York City, for example, Revolution Rickshaw uses 10 cycles to make 50-60 deliveries per day for green businesses and organic restaurants. Zipments is another cargo cycle company that serves as a broker, coordinating activity for independent cycle couriers. The New York City government, in partnership with the economic development corporation and private funding sources, provided Zipments with a grant to facilitate its operations. Cargo cycle operations exist in a number of cities including Berkeley, Portland, Philadelphia, Boston, and Alexandria (Conway, 2011). Initiatives also exist in Denver, Chicago, and Austin (BBC Autos, 2014).

In Europe, there are numerous examples of cargo cycle projects. Cyclelogistics (2011) reports that Germany and the Netherlands are leaders in the field of cargo cycle use. The city of Bremen offered cargo cycles to firms for free for a period of four weeks to encourage the use of this mode in the hopes of reducing emissions and meeting pollution reduction goals. The city invested 100,000 Euros in the campaign and rented out 38 bikes free of charge. DHL conducted a pilot study of cargo cycles in Germany and the Netherlands. They studied the replacement of motorized delivery vehicles with cargo cycles in inner-city deliveries to advance the goal of carbon-neutral operations. The pilot led to the replacement of 60% of inner-city vehicles with cargo cycles in more than 80 European countries.

In the city of Cambridge, United Kingdom, Outspoken operates a fleet of cargo delivery cycles that carry 300 items every day from a consolidation center outside the city to areas where motorized vehicles are prohibited from entering (European Cycle Logistics Federation, 2015). Trains often replace consolidation centers in carrying goods to the city, where they are transported to their destinations using cargo cycles. Municipalities in Copenhagen utilize cargo cycles to transfer documents, collect public waste, clean streets, landscape, and remove graffiti. Twenty bikes are used to conduct street cleaning and maintenance, making the contributions to reducing noise, providing awareness about the use of this alternative mode of cargo transport, and alleviating emissions from motorized vehicles (European Cycle Logistics Federation, 2015).

In France, cargo cycles transport up to 180 kg of goods per bike and travel 10-15 km per day, serving a number of retail and grocery stores (Fondation Solidarite, 2015). In Spain, cargo cycles are used by the taxi industry and in freight transport. A natural advantage exists for these modes of transport in historical areas where narrow streets make it difficult for large vehicles to travel (Cyclelogistics Federation, 2014). Marketing and advertisements on the sides of the cargo cycles provide added revenues to cyclists (E-Commerce News Europe, 2017).

Several European cities in Austria, Belgium, France, Germany, the Netherlands, Switzerland, and the United Kingdom have bike share programs (McCartney, 2016). The programs encourage the public to use cycles for several trips by allowing people to rent or borrow the bikes when needed. The bikes are conveniently accessed and affordable. For example, consider the Transportrad Initiative Nachhaltiger Kommunen. The project tested the provision of 60 cargo cycles for rent in two German towns to assess cost and accessibility. Some programs provide bike shares based on voluntary contributions and not fixed fees such as the Lastenradkollektif in Vienna, Austria, and

Kasimir in Cologne, Germany. In Ghent, Belgium, cargo cycle programs are provided as part of a multimodal strategy. A fixed monthly fee and hourly rates are used to fund the program. The objective of these programs is to provide accessible, conveniently located, and affordable alternatives to motorized vehicles. Several businesses such as Domino's Pizza in the Netherlands, Whole Foods in the United States, IKEA in Denmark and Sweden, and United Parcel Service (UPS) worldwide, have been using cargo cycles for marketing and transport (My Amsterdam Bike, 2016).

There are numerous examples of cargo cycles in many other countries. Cargo cycles are used as a mode of transportation for freight and passengers. Morris (2008) studied the use of cargo cycles in Kampala, Uganda, as a form of transportation for goods and people. Utz and Currie (2008) showed that the use of cargo cycle in Rwanda improved quality of life, speed, safety and efficiency (Utz and Currie, 2008). Quijano (2011) documented the widespread use of cargo cycles in China for transporting goods, garbage, and people (Quijano, 2011). Similarly, in Nepal, cargo cycles are used for delivering packages and gasoline, selling goods such as food and snacks, and transporting people (Bikes, 2022). Sadhu, Tiwari, and Jain (2014) also documented the use of cargo cycles in India, where use extends to transporting construction materials, retail business delivery, and industrial activities. Also, in Lebanon, cargo cycles are used by food vendors and for delivery of various kinds of goods and services (Deghri, 2015). In Chile and Bolivia, Lipigas (2015) and Rough Guides Ltd. (2015) recorded the use of cargo cycles for transporting goods and people (Lipigas, 2015; Rough Guides Ltd, 2015).

In summary, prior research on cargo bicycles has shown it is a promising technology for last mile freight delivery in particular urban contexts. Cargo cycles can create environmental, health, and transportation benefits for the user and the community. Critical success factors include local support policies, a freight demand mix suitable for cargo bikes, a cycle-friendly environment, local community support and participation, and freight consolidation centers that enable the transfer of freight to and from cargo cycles. In addition, pedal-assisted cargo bicycles and e-cargo bicycles are becoming increasingly popular as a way to manage situations where additional power might be needed (e.g., slight grades, a heavier-than-usual load).

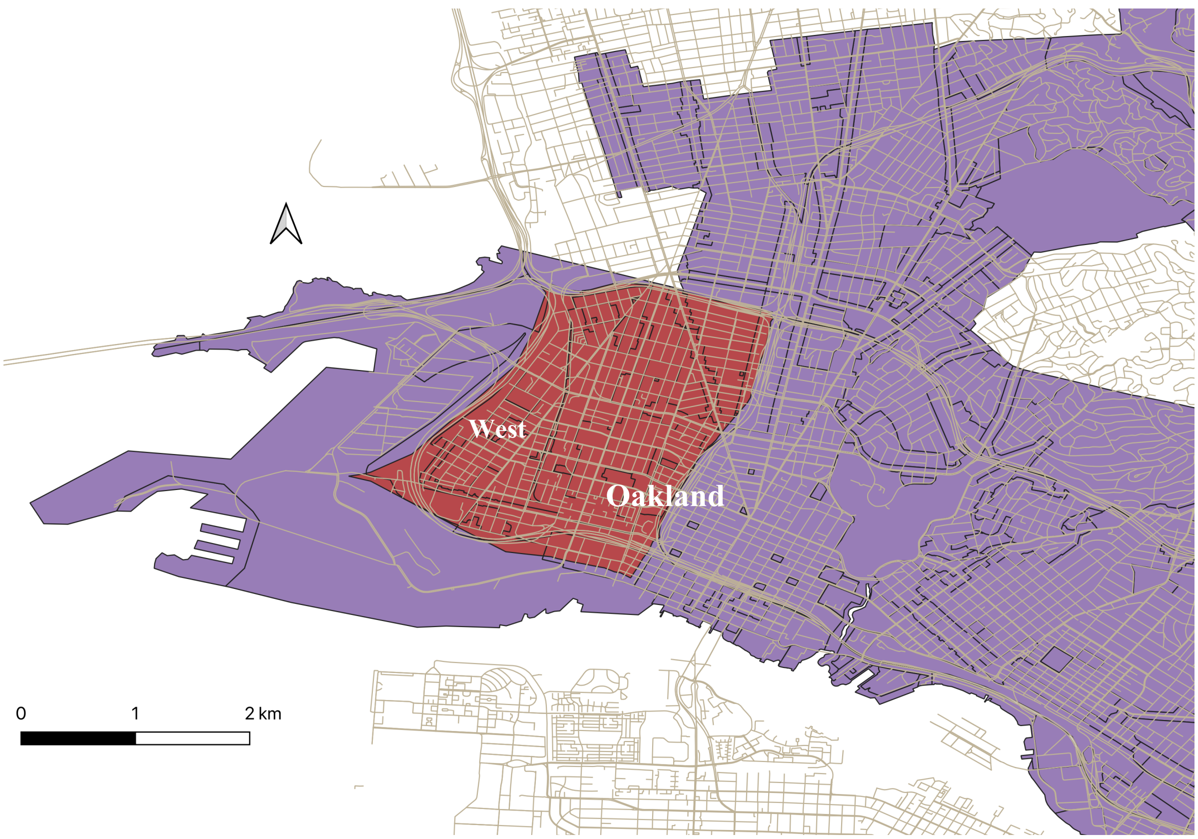
Despite the promise of cargo bicycles, our review revealed that stakeholders' engagement is critical to harnessing the potential of cargo cycle in last mile delivery. Enabling conditions and favorable policies are also needed to successfully shift operations from motorized trucks to cargo cycles. However, local context also matters. Hence, a study of cargo cycles requires centering one's focus on the local context, understanding both the opportunities and the barriers that may exist for cargo bicycles.

3. The Environmental Burden Faced by the West Oakland Community

Chapter 3 provides a brief overview of the disproportionate environmental burdens faced by the West Oakland community as a result of transportation related air pollution and noise pollution. Information included are West Oakland's community efforts to reduce diesel pollution through the AB617 legislation, local air pollution monitoring efforts and their potential to aid harm reduction activities, and the challenges in trying to mitigate past transportation planning decisions.

3.1 Air Pollution in West Oakland

Figure 4. Map of West Oakland



West Oakland, one of the communities most impacted by air pollution in California, is bounded by the I-580, I-880, and I-980 freeways, the Maritime Port of Oakland, and the Union Pacific Railroad Yard. It is 6.5 square miles, with a population of 45,000 residents (City Data, 2019). This neighborhood faces high rates of asthma and other cardiovascular health issues due to diesel exhaust from trucks and the high traffic that passes through this neighborhood. The West Oakland community is disproportionately affected by air pollution, leading residents of this community to have worse health outcomes than residents of other nearby municipalities. This disproportionate burden of environmental hazards experienced by West Oakland residents is evidence of environmental racism, whereby development decisions about freeway placement, industrialization, and preservation of greenspace, are grounded in racial bias. Communities of color, such as West Oakland, are disproportionately affected by environmental justice issues.

The importance of improving air quality in West Oakland is recognized by the selection of West Oakland as a first-year priority community for AB617. AB617 is a California state bill that requires the California Air Resources Board (CARB) and local air districts develop plans on how to mitigate air emissions in disproportionately affected communities. From this legislation grew the Community Air Protection Program, a program with the goal of reducing emissions through community-based efforts. In West Oakland, the Bay Area Air Quality Management District (BAAQMD), the local air district of the San Francisco Bay Area, worked with the West Oakland Environmental Indicators Project (WOEIP) and a community-based steering committee to develop the West Oakland Community Action Plan (WOCAP) entitled "Owning Our Air."(BAAQMD and WOEIP, 2019) The WOCAP identifies ways to improve local air quality by reducing toxic air contaminants and criteria pollutants by developing Community Air Monitoring Plans (CAMPs) and Community Emissions Reduction Programs (CERPs) (MacIver, 2019). The main goal of the WOCAP plan is to "protect and improve community health by reducing disparities in exposure to local air pollution (BAAQMD and WOEIP, 2019)." The AB617 legislation and the WOCAP also serve as an institutionalized model of putting planning and decision-making power into the hands of both community members and governmental agencies (MacIver et al., 2022). The WOCAP was adopted by the BAAQMD in October 2019, and the CARB adopted it in December 2019. Details of the WOCAP and committee proceedings are publicly available (BAAQMD and WOEIP, 2019).

The selection of West Oakland as an AB617 community is based upon research about the disproportionate air pollution and health effects experienced in this neighborhood. Exposure to poor air quality from tailpipe pollution—more specifically, diesel exhaust from trucks—is related to the high rates of asthma prevalent in East and West Oakland (Gonzalez et al., 2011). Diesel exhaust has also been attributed to causing 1,200 excess cancer deaths per million in West Oakland residents (California Air Resources Board, 2008). Diesel exhaust contains "ultrafine particles," which are nanosize particles that are smaller than other PM such as $PM_{2.5}$ and PM_{10} that are regulated. This particle size makes diesel exhaust dangerous for human health because particles this small are not naturally cleared by the body's defense systems, allowing these ultrafine particles to deposit deeply in the lungs and even enter circulation (Gonzalez et al., 2011). When communities are exposed to this diesel exhaust, their chance of developing asthma and being hospitalized also increases. This was observed through the high rates of asthma hospitalizations in Oakland, higher than any other city in Alameda County (Alameda County Department of Public Health, 2014), and in East and part of West Oakland neighborhoods, in particular (Alameda County, 2016). Also, Alameda County data show that asthma hospitalization for African Americans (all ages) is four to six times higher than for any other racial/ethnic group, and childhood asthma rates for African Americans is three to five times higher than for other racial/ethnic groups (Alameda County Department of Public Health, 2014).

The impacts of exposure to TRAP on mortality rates in West Oakland has been examined before. The increase in cancer-related mortality from exposure to $PM_{2.5}$ was projected by the Waterfront Ballpark District at Howard Terminal Draft Environmental Impact Report, a report required for a re-development project in West Oakland, using a WOCAP modeling approach for different pollution sources. This report shows that the number of excess deaths from the cumulative contributions of highway sources (trucks and vehicles driving on highways), other sources (ferry and truck-related businesses), and streets (trucks and vehicles on driving local roadways) would be 26.1 excess lifetime cancer risks per million (City of Oakland, 2021). Excess lifetime cancer risks are the risk of dying of cancer above the background risk.

Research has shown that exposure to tailpipe air pollution can vary between neighborhoods in the same city, and, furthermore, block-by-block within a neighborhood. Looking at air pollution in this smaller scale, at the neighborhood level, is considered “hyperlocal.” Methods to develop hyperlocal mobile air monitoring and evaluate its utility have been explored in West Oakland. Caubel et al. utilized a dense network of black carbon (BC) sensors and showed spatio-temporal variation in pollution levels within the community (Caubel et al., 2019). Other researchers used data collected by Google Street View cars to measure NO, NO_2, and BC. Apte et al. discovered that although air pollution patterns are stable, the spatial variation of the pollution patterns can be starkly different from area to area (Apte et al., 2017). Messier et al.’s research study concluded that using Street View car mobile monitoring with multiple recordings of street segments can more accurately measure air pollution at a hyperlocal level vs. using a technique called land used regression modeling (LUR) that predicts air pollution concentrations from a statistical model that utilizes just a sub-sample of this data (Messier et al., 2018). Adding additional data points to a LUR model can improve the power to predict local-level air pollution. Collecting street-level pollution data with Street View Cars may not always be feasible, is time-intensive, and resource-intensive. When only minimal data are available, a LUR model could create a general map of air pollution in a neighborhood (Messier et al., 2018).

In terms of health effects, a recent study that mapped tailpipe air pollution with Google Street View cars in the East, West, and Downtown Oakland neighborhoods found that localized differences in exposure to traffic related air pollutants (TRAP) (Alexeef et al., 2018). Long-term exposure to elevated concentrations of TRAP is correlated with a higher risk of a cardiovascular event in older adults (Alexeef et al., 2018).

Recent research from Southerland et al. also investigated air pollution and the associated health effects at a hyperlocal level (2021). This research effort employed two different air pollution measurement tools: (1) mobile monitoring data of NO_2 and BC measured by Google Street View cars, and (2) land-use variable and satellite imagery to create maps of the air pollution status. They compared the air pollution distribution information to health information at the census-block-group level and the county level. They discovered a substantial variation in health effects attributable to air pollution (namely, cardiovascular mortality and hospitalizations, asthma ER visits, and all-cause mortality) within a neighborhood. An understanding of the variation in baseline health at a local level is necessary to fully interpret this data (Southerland et al., 2021). Communities affected by air pollution over multiple generations, as in West Oakland, may have a baseline health that is compromised in comparison the rest of the city or county.

Hyperlocal air pollution monitoring could be utilized for planning cargo cycle routes and evaluating the success of cargo cycle implementation programs. Optimal cargo cycle routes could be developed to utilize roads with less pollution and less traffic in order to maximize cargo cycle operator safety in regards to air pollution health effects and potential accidents with vehicles. The routes could be developed using the publicly available air pollution monitoring data provided by Aclima (Aclima, 2022). The data at their web-site (https://insights.aclima.io/west-oakland) provides historic, block-by-block data from their mobile monitoring systems. In addition, there is real-time information from stationary air monitoring. Another way that the hyperlocal air pollution monitoring could be useful is as a tool for comparing air pollution patterns before and after the implementation of cargo cycle delivery operations could help evaluate the success of programs and areas of improvement.

3.2 Impact of Transportation Efforts on West Oakland

While it is essential to keep in mind the above air pollution factors, it is also critical to acknowledge the various unintended consequences that come with measures that aim to reduce it, including transportation projects. An article by Patterson and Harley investigated how freeway rerouting and rebuilding affect exposure to traffic-related air pollution and examined how it could have negative socioeconomic and demographic changes, known as environmental gentrification, in West Oakland (Patterson & Harley, 2019). On the positive side, the rerouting of the Cypress freeway to an alternative location and the transition of the original freeway site to a street-level, landscaped boulevard (Mandela Parkway) was an example of how the community was able to influence a major transportation project. The rerouting of the Cypress freeway that originally bisected West Oakland resulted in a reduction in the annual concentrations of NO_x and BC along Mandela Parkway (Patterson & Harley, 2019). However, the effort to revitalize communities appears to have caused environmental gentrification (Patterson & Harley, 2019). This is because these efforts often excluded the very community they were intended to help (Patterson & Harley, 2019). Environmental gentrification was observed in the form of an increase in property value (180%), but a decrease in the Black population in West Oakland (-28%) (Patterson & Harley, 2019). The main reason Black residents leave this area is because of the high cost of housing (Patterson & Harley, 2019). In order to alleviate this issue, the authors suggest increasing the supply of affordable housing (Patterson & Harley, 2019).

3.3 Impact of Noise Pollution in West Oakland

Noise pollution is a hazard to the population of West Oakland. According to the US EPA standards, outdoor noise levels should be below 55 dB and indoor noise levels at 45 dB to avoid annoyance and activity interference (Environmental Protection Agency, 2016). Reflecting these standards, the City of Oakland has a noise standard of 45 dB for indoor settings (City of Oakland, 2021). Despite this, a majority of West Oakland residents are exposed to noise levels higher than 60 dB, which increases their risk for cardiovascular disease (City of Oakland, 2018). The main sources of ambient noise are vehicle traffic on major roadways, operations at Oakland International Airport, and BART. The main sources of traffic noise are the I-880, I-980, and I-580 freeways, as well as Mandela Parkway, West Grand Avenue, Market St., 7th St., and 14th St. (City of Oakland, 2018). Ambient noise levels along the freeways in West Oakland can reach 80 dB, and noise levels along major arterial roads in West Oakland reach 70 dB (City of Oakland, 2021). The noise standards in place in the City of Oakland mainly regulate transient noise, such as construction noise (City of Oakland, 2018). Possible solutions to mitigate ambient noise from traffic include creating barriers or buffers between roadways and residential areas, re-routing traffic away from residential areas, and installing sound insulation in homes (City of Oakland, 2005).

This chapter's aim was to give a brief overview to the reader about the historic and ongoing environmental health challenges that West Oakland specifically faces. Decades of planning choices have created a community that has significant air pollution and noise pollution sources, most of which are transportation related. The AB617 legislation is an historic opportunity for West Oakland community members to work in partnership with government agencies to reduce the environmental health burden that residents have faced for generations and to create a more liveable neighborhood. New hyperlocal air monitoring strategies tested in West Oakland could be a promising way to document progress in pollution reduction on a block-by-block basis. It could also provide an opportunity to find the safest routes for cargo cyclists to ride so that they are exposed to the lowest levels of air pollution.

4. Community Data Collection Methods and Results

This chapter provides information about the efforts to collect community level data from people who live and work in the neighborhood of West Oakland or the city of Oakland and from observations of traffic patterns and truck behaviors in West Oakland. The results from the interviews, focus groups, and field data collection are presented below.

4.1 Community Data Collection Overview

To inform our traffic model simulation and policy recommendations, the research team collected West Oakland community-level freight activity information and stakeholder perceptions. Data were collected using two main methods: interviews (both individual and group) and field observations. In addition, community-level data were collected through regular attendance to the WOCAP Transit/Walk/Bike subcommittee and WOCAP Steering Committee meetings, and through informal email and phone communications. The main goal of the data collection was to learn more about the West Oakland freight delivery issues, community priorities regarding freight delivery, knowledge of cargo cycles, challenges/barriers to implementing cargo cycle delivery, and interest in cargo cycle delivery in the community. The following sections describe the methods employed.

4.1.1 Community-Level Interviews

The research team collected community-level information through individual interviews and group interviews. Before research commenced, the research plan was reviewed and approved by the San José State University Human Subjects Institutional Review Board (IRB Protocol Tracking Number: 20119).

4.1.2 Key Stakeholder Interviews

The first stage of community-level data collection took place through key stakeholder interviews. The research team sought key stakeholders with knowledge from their work in non-profit agencies and government agencies supporting West Oakland, local bicycle advocates, business owners, delivery persons, and West Oakland residents. All interviews were semi-structured, proceeding with a set of questions adapted to the particular interviewee. Interviews were conducted through the web conferencing tool Zoom, recorded, and transcribed. Key themes were developed from the transcriptions.

The research team collected data from nineteen community members. Descriptions of the interviewees' roles in the community are presented in Table 1.

Table 1. Key Stakeholder Interview Descriptions

Category	Descriptions of Interviewees
Local government agencies	Four government agency employees were interviewed, representing city, county, and state agencies. Interviewees were from transportation agencies, air districts, and public health departments.
Local non-profits	Two local non-profit employees were interviewed, representing West Oakland and Alameda County environmental health interests
Bicycle shops/education/advocacy groups	Five people were interviewed, representing local bicycle shop owners, bicycle educators, and bicycle advocacy groups
Oakland business districts/Community Benefits Districts	Three people were interviewed, representing the Central CBD, Uptown & Downtown, Temescal, Koreatown and Northgate CBD of Oakland
West Oakland/Oakland residents	Two people were interviewed, representing West Oakland and Downtown Oakland, from the youth and senior perspectives
Truck drivers/Trucking business owners	Two people were interviewed, representing truck drivers and trucking business owners in the Oakland area
Mobile air pollution monitoring	One person was interviewed regarding the data collection methods and data available for air pollution in West Oakland

4.1.3 Focus Group Interviews

Our focus group recruitment aimed to target the following community members to contribute to the study: West Oakland business owners, delivery persons, bicycle/transit/environmental advocates, and residents. Focus group participants were recruited through the assistance of many community members and organizations. Recruitment efforts included announcements in the WOCAP Transit/Walk/Bike subcommittee meeting, using the WOEIP email distribution list, online posting (to the West Oakland neighborhood watch groups, a Facebook group, Nextdoor, and Twitter), as well as email outreach to key stakeholders. All interested parties were directed to enter their information at our research website. The website provided additional information about the research study, a consent form to review, and information about the research study. Participants under the age of 18 had their parent/guardian review and sign the consent form. Participants of the focus groups were provided a gift card of a nominal amount as a gesture of thanks for their time.

Focus group interviews were conducted using structured interview methods and the web conferencing service Zoom. The focus group questions were designed to collect information about bicycle use behavior, barriers to bicycle usage, knowledge of cargo cycles, benefits of cargo cycle use, challenges of cargo cycle implementation, and the best placement of transfer hub locations in West Oakland. Focus groups interviews also included written data collection using the real-time collaborative web platform padlet and visual data collection using Zoom whiteboards to allow participants to add data to West Oakland maps. Audio and video of all focus groups were recorded and audio portions were transcribed.

4.1.4 Field Observations and Counts

To inform our traffic model simulation, West Oakland vehicle count data and traffic behavior data were collected on March 30 and March 31, 2021. Research assistants were trained on data collection methods on Saturday, March 27, or Monday, March 29. The training consisted of an overview of the cargo cycle study, overview of vehicle count data collection tasks, specifics about data collection sites, methods, and staff expectations. The research team also needed to adhere to strict COVID-19 safety guidelines. These guidelines were developed by Dr. Hartle and Brandon Nguyen (SJSU MPH program Graduate Research Assistant), and they were reviewed and approved by SJSU VP of Innovation & Research, the College Dean, and the Environmental Health & Safety department before research commenced. Dr. Hartle consulted the SJSU IRB, and no changes needed to be made to the study's existing IRB for this study as this portion of the research was not considered to include human subjects.

The data collection site selection was informed by knowledge from previous vehicle count data collection efforts including the West Oakland Truck Survey Report (WOTSR) (Lau et al., 2009) from 2009 and from personal communications with Brian Beveridge, the co-director of the West Oakland Environmental Indicators Project (WOEIP). We selected data collection sites where we thought would capture the most lighter-duty truck traffic, which is the type of traffic that could potentially be replaced by cargo cycle delivery. Our initial sites were listed in the WOTSR Table 3 as: considered a major intersection, had significant truck traffic, near the post office (with high daily volume of delivery activities), a high-activity street, or proximity to a school that would presumably receive numerous daily deliveries. Another factor that was considered was if the traffic was considered port or non-port traffic. Port traffic would include heavy duty trucks carrying freight, such as shipping containers, to and from the Port of Oakland. Data collection was not placed in locations with majority port traffic as this heavy freight cannot be delivered with cargo cycles. Based on the WOTSR, the initial locations were cross-referenced with the sites with a high volume of non-port traffic vehicles, according to the report's Table 7.

For the truck delivery behavior sites, where the goal was to collect information about the number of deliveries, length of deliveries, truck parking status (legally or illegally parked), and truck operational status (idling or parked), data collection sites were selected that were a mix of industrial and residential locations. Data collection sheets were developed for truck counts: these were based on the WOTSR log sheets in Appendix A and adapted to collect data for each class of trucks (Class 1-8). Truck count delivery behavior data collection sheets were developed separately.

Data were collected on Tuesday, March 30, and Wednesday, March 31, 2021. There were 10 collection sites, 5 vehicle count sites, 5 truck delivery behavior sites, and 5 pairs of data collectors (10 total data collectors).

Data collection occurred at each location in the morning on one day and afternoon on the second day, or vice-versa.

Table 2. Field Data Collection Sites, Original

Intersection or Block Designation for Truck Delivery Behavior	Type of Survey	Tues AM / Wed PM	Tues PM / Wed AM
7th St. and Adeline St.	Vehicle count	X	
7th St. (Mandela Pkwy. and Center St.)	Truck delivery behavior	X	
7th St. and Wood St.	Vehicle count	X	
Poplar St. (14th St. and 16th St.)	Truck delivery behavior		X
Adeline St. (28th St. and 30th St.)	Truck delivery behavior		X
26th St. (Mandela Pkwy. and Peralta St.)	Truck delivery behavior	X	
W. Grand Ave. and Mandela Pkwy.	Vehicle count		X
Peralta St. and Hollis St.	Vehicle count		X
Chestnut St. (28th St. and 30th St.)	Truck delivery behavior		X
W. Grand Ave. and Market St.	Vehicle count	X	

Materials were distributed to the data collection team on the morning of the first data collection day, Tuesday, March 30, 2021. Teams then traveled to their sites and started data collection for the first day at approximately 10:00 am. Data collection was conducted in two shifts per day, with a change in data collection location between morning and afternoon. The shifts were approximately two hours each, with the following timing: morning data collection took place from 10:00 am to 12:00 pm, and afternoon data collection took place from 1:00 pm to 3:00 pm.

After the first day, adjustments were made to data collection sites due to low traffic volume at some locations. Two locations were changed, and the data collection strategies of two other locations were changed (presented in Table 3). For Wednesday, March 31, the following changes were made: Chestnut between 28th and 30th was changed to Wood between 14th St. and 15th St., and 14th St. and Poplar was changed to 18th and Peralta. As a result, these four locations only have a half day of data.

Table 3. Field Data Collection Sites, Modified

Intersection or Block Designation for Truck Delivery Behavior	Type of Survey	Tues AM / Wed PM	Tues PM / Wed AM
7th St. and Adeline St.	Truck count	X	
7th St. (Mandela Parkway and Center St.)	Truck delivery/Truck count	X	
7th St. and Wood St.	Truck count	X	
Poplar St. (14th St. and 16th St.)	Truck delivery behavior		X (Tuesday pm only)
18th St. and Peralta St. (updated)	Truck delivery/Truck count		X (Wednesday am only)
Adeline St. (28th St. and 30th St.)	Truck delivery behavior		X
26th St. (Mandela Parkway and Peralta St.)	Truck delivery behavior	X	
W. Grand Ave and Mandela Pkwy	Truck count		X
Peralta St. and Hollis St.	Truck count		X
Chestnut St. (28th St. and 30th St.)	Truck delivery behavior		X (Tuesday pm only)
Wood St. (14th St. and 15th St.) (updated)	Truck delivery behavior		X (Wednesday am only)
W. Grand Ave and Market St.	Truck count	X	

4.2 Results from Community Data Collection

4.2.1 Key Stakeholder Interviews and Focus Group Interviews

Community members provided expertise from many perspectives on the acceptability, feasibility, and challenges of using cargo cycles to deliver last mile packages in West Oakland. There was a sense of acceptability surrounding measures that would reduce traffic, air pollution, and noise. A shared community sentiment of "everyone is slowly being killed by the pollution and the noise" was expressed, making the potential of cargo cycles to reduce traffic congestion, air pollution, and noise pollution a promising alternative.

Focus group participants agreed that benefits of replacing motorized trucks with cargo cycles include:

1. Lower pollution
2. Less noise
3. Job opportunities for operators
4. Less damage to roads from using lighter weight cargo cycles
5. Opportunities for cargo cycle manufacturing
6. Opportunities for cargo cycle maintenance
7. Opportunities to revitalize communities by creating cargo cycle business
8. Opportunities for healthy lifestyle for cargo cycle operators.

This confirms and validates findings from the literature and provides a strong case for cargo cycle schemas.

Focus groups participants provided the following policy implications:

1. Establish parking facilities/spaces for cargo cycles to ensure safety and avoid illegal parking
2. Outreach to businesses/residents and the local community to activate demand for cargo cycle services
3. Provide cargo cycle operator trainings
4. Create protected cargo bike lanes; use physical traffic management schemas

5. Leverage safe street schemas to incentivize cargo cycles

6. Incentivize businesses to use cargo cycles and offset human cost of running cargo cycle businesses.

7. Limit speed for motorized vehicles and provide improved police enforcement to increase safety for cargo cycles

8. Acknowledge and address safety for cargo cycle operators of color who are more vulnerable to harassment and citations from the police.

9. Make cargo cycle operators jobs accessible to community members.

4.2.2 Vehicle Count Data Collection

The vehicle count data, by class, are summarized in Table 4. The highest total vehicle count was at the intersection of Grand Ave. and Mandela Pkwy., with 291 vehicles per hour during our collection time period. The lowest total vehicle count was at the intersection of 18th and Peralta, with only 28 vehicles per hour. Appendix B contains pictures of select intersections where data were collected.

Table 4. Vehicle Count Summary Table

Location: Intersection	Truck Count by Classification (per hour)*								Total Count (per hour)
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	
W. Grand Ave. and Mandela Parkway	153	68	10	10	9	14	12	15	291
32nd St. and Adeline St.	116	37	5	6	3	4	7	4	180
7th St. and Mandela Parkway	30	21	7	5	5	13	45	45	170
7th St. and Adeline	94	25	3	4	4	2	5	6	143
Peralta St. and 26th St.	57	10	5	4	1	16	6	23	120
7th St. and Wood St.	44	20	3	2	4	7	10	11	101
W. Grand Ave. and Market St.	20	22	5	4	2	7	11	6	77
Peralta St. and Hollis St.	36	15	4	2	1	1	3	4	66
14th St. and Poplar St.	11	12	2	2	2	6	10	7	51
18th St. and Peralta St.	8	5	2	0	1	1	5	7	28

*Values rounded to closest whole number

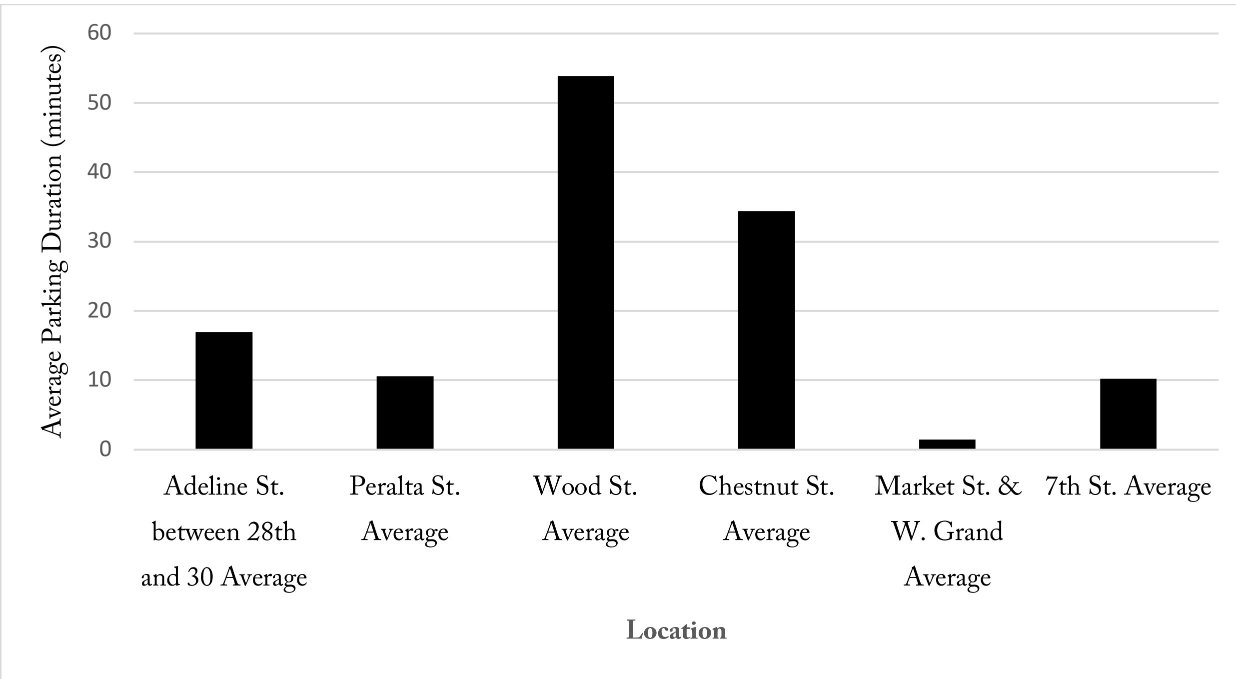
4.2.3 Truck Behavior Analysis

This section provides some basic statistical analysis of truck behavior data collected from select key intersections in West Oakland. Data collected included truck parking time and truck idling time, used as a proxy for the length of deliveries and the availability of legal parking for delivery trucks, respectively. Truck idling has implications for air and noise pollution, and illegal parking can cause traffic congestion and traffic accidents.

The average parking duration (in minutes) for each location is shown in Figure 5.

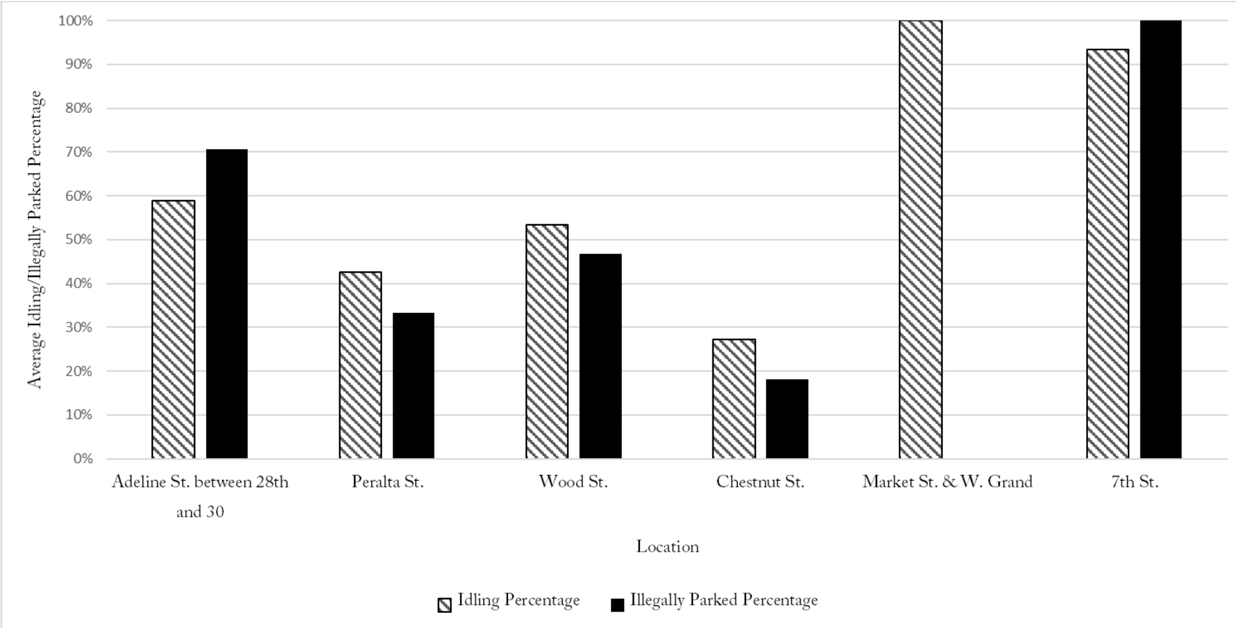
The average parking duration calculation indicates that trucks tend to park around one hour at Wood St. Chestnut St. has the second-longest average parking time at about 35 minutes. Parking times at the other locations are less than 20 minutes which indicates a fast loading/unloading operation.

Figure 5. Average Parking Duration of Delivery Vehicles



The average idling rate and illegal parking rate are calculated and plotted in Figure 6. Trucks at 7th St. and Market St. & W. Grand have the highest rates of idling when they are parked; 7th St. has the highest rates of illegal parking.

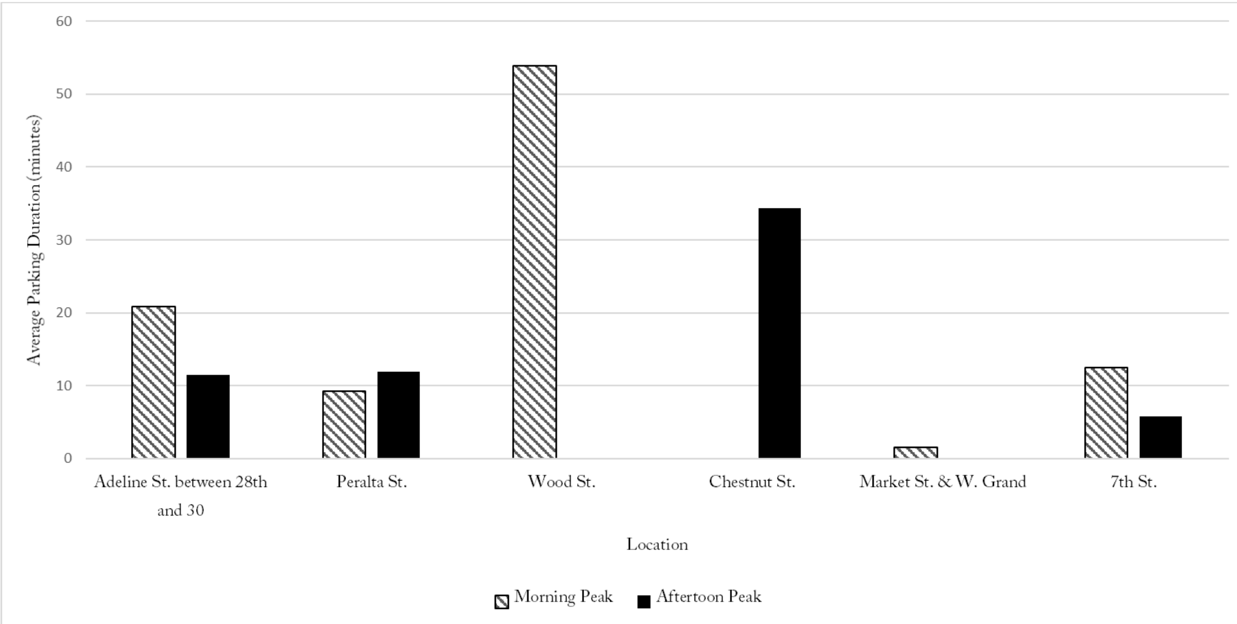
Figure 6. Average Idling/Illegal Parking Rate



Morning Peak vs. Afternoon Peak

The average parking duration at six locations are calculated for both morning peak and afternoon peak. As shown in Figure 7, parking time at Market St. & W. Grand is very short on average. Note that data were only collected at Wood St. on one day in the morning and Chestnut St. for one day in the afternoon.

Figure 7. Average Parking Time for Morning Peak/Afternoon Peak



Next, we consider idling rate and illegal parking rate. Due to the fact that we only collected morning peak data or afternoon peak data for some locations, the data in Figures 8 and 9 are incomplete. According to the current data, there is no significant difference between morning peak and afternoon peak in idling rate and illegal parking rate.

Figure 8. Average Idling Rate Morning Peak and Afternoon Peak

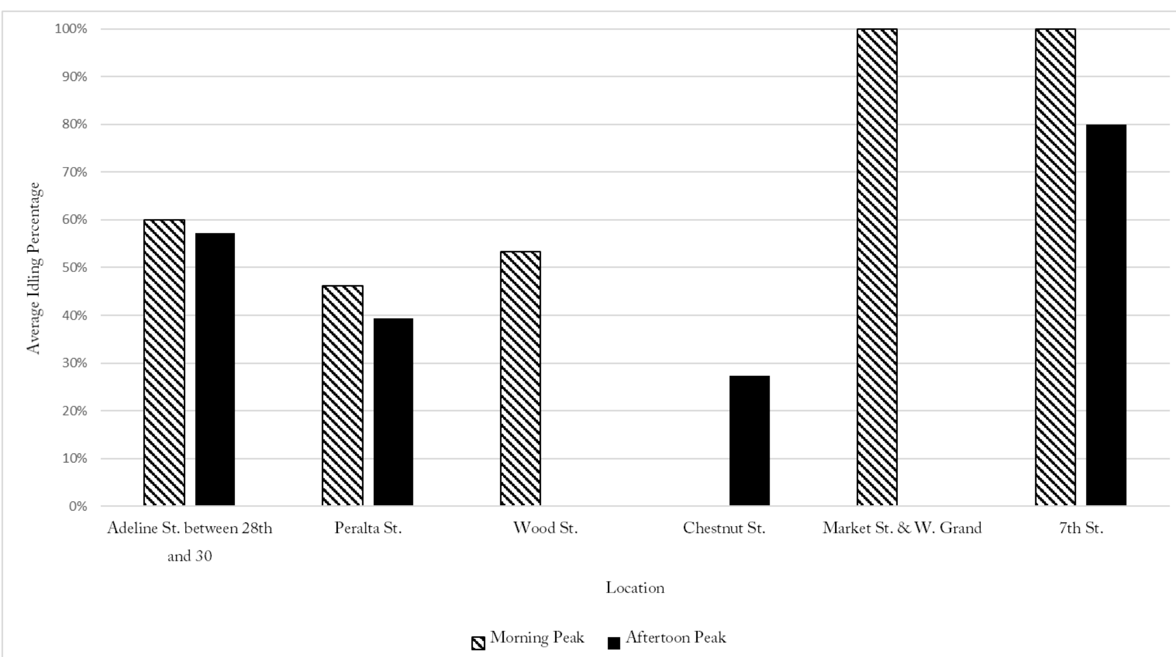
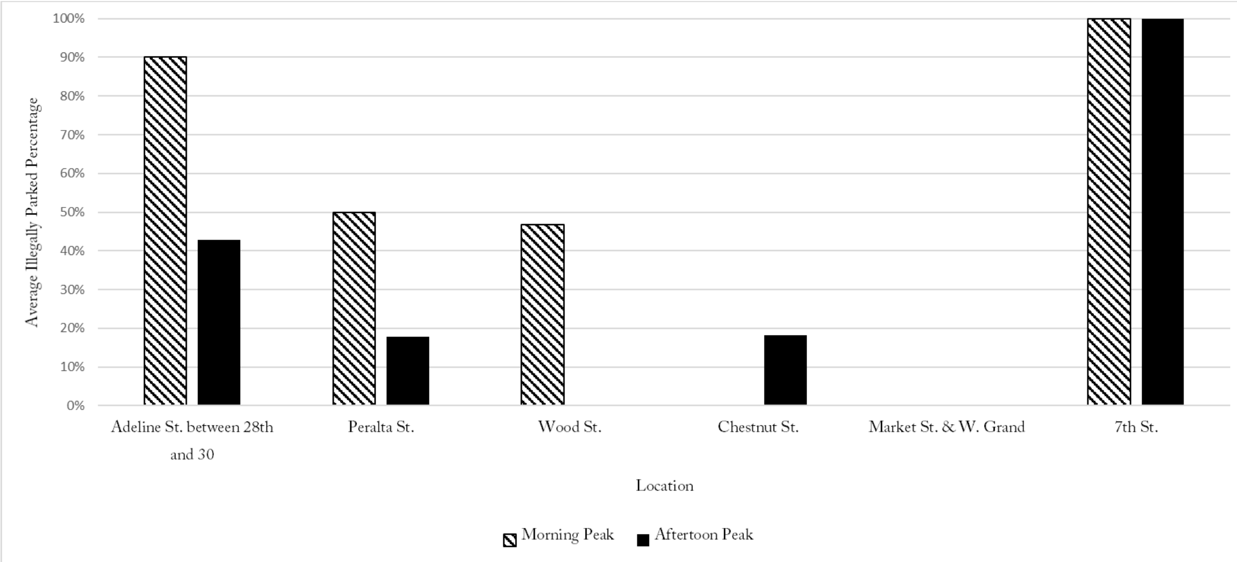
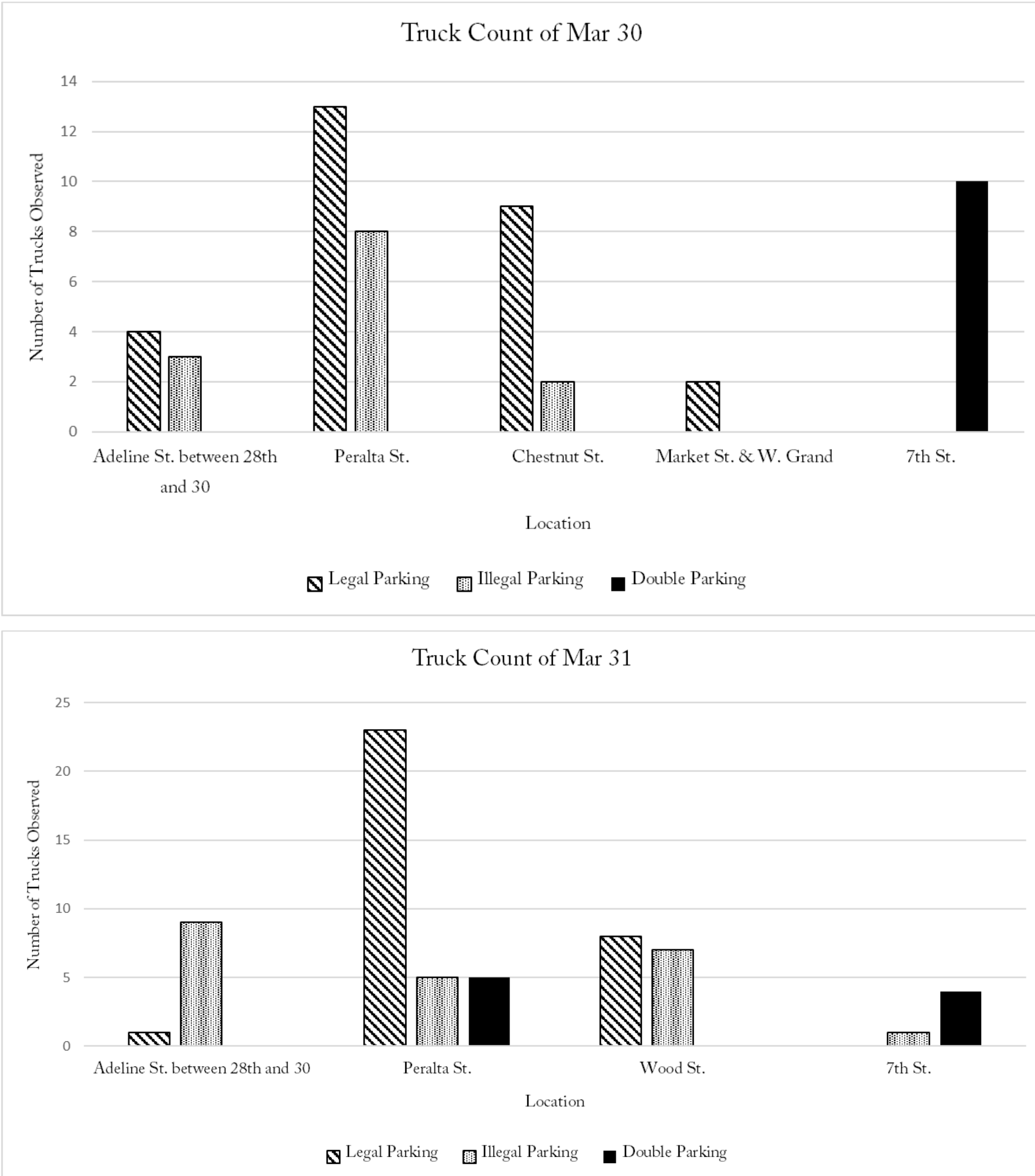


Figure 9. Average Illegal Parking Rate



Double parking existed at Peralta St. and 7th St. 7th St. has serious double parking problems. On March 30, 10 trucks double parked at 7th St. and 5 trucks double parked at 7th St. on March 31.

Figure 10. Double Parking



Information from the community level data collection, such as recommended locations for transfer hubs, percentage of deliveries that could be transitioned from trucks to cargo cycles, vehicle counts, and vehicle behaviors, were used to inform the traffic simulation models explained in Chapter 5.

5. Traffic Simulations Methods and Results

Traffic simulation models were developed to predict the amount of air pollution reduction that could be expected from the use cargo cycles in West Oakland, given information about the types of businesses in this area and the type of freight usually delivered to these businesses. Information collected at the community level, as described in Chapter 4, such as potential transfer hub locations, the percentage of freight deliveries that can be transitioned from trucks to cargo cycles, vehicle counts, and vehicle behavior were utilized to develop these models.

5.1 Methods for Traffic Simulation Model

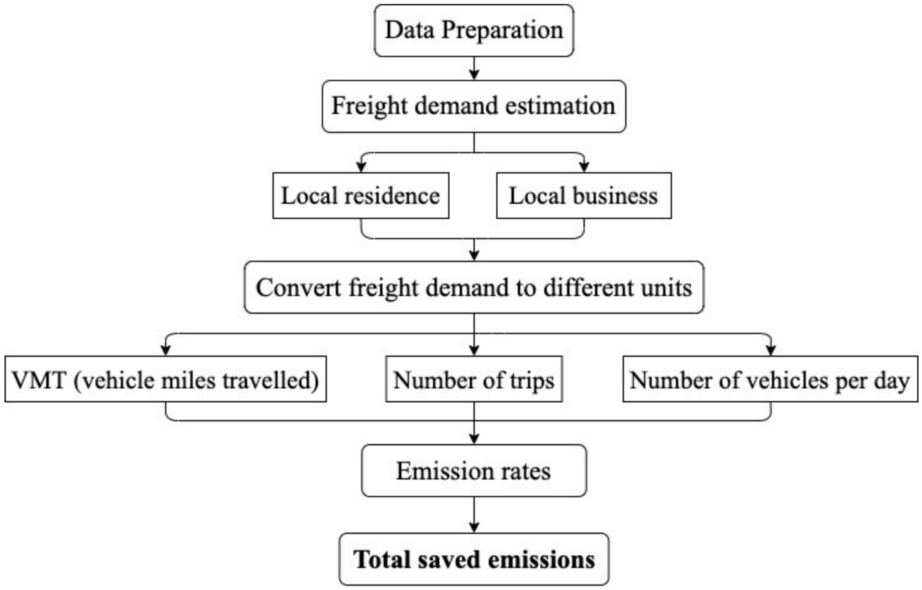
Emission reductions are closely tied to freight demand pattern, including freight attraction and freight production. The distribution of freight demand in each spatial unit will lead to different amounts of emission savings. Given the freight demand, the cargo cycle adoption rate or truck replacement rate is another important factor. If more trucks can be replaced, more emissions can then be avoided. Additionally, the geographical location of the transfer hub is essential. Setting the transfer hub at different locations will lead to different routes and consequently different emission savings.

To incorporate all these influential factors and comprehensively analyze their joint effects, this study designs a multiple-scenario simulation framework. This behavioral-consistent simulation framework will quantify the expected emission reduction in different scenarios, enabling comparisons and the formulation of policy implications. The design and scenario settings will be explained in the following section.

5.1.1 Analysis Procedure

Figure 11 shows the general procedure used in this simulation model. Field data are first collected and compiled to support the simulation. Freight demand from both local residences and local businesses are then quantified. For local residences, we assume Class 4 trucks are used as the major type of vehicles for home deliveries. For local businesses, we consider Class 1 to Class 8 trucks with different replacement percentages. Given the change of freight demand in each scenario, emission rates are used to calculate the amount of emission savings. Various types of pollutants generated through different processes are considered. As different pollutant rates have different units, the freight demand is converted into different units (i.e., VMT, number of trips, and number of vehicles per day). The total emission savings are then calculated by multiplying emission rates with the reduced freight demand. Each step is further explained in the following sections.

Figure 11. Simulation Model Framework



Data Preparation

We collected related data from multiple sources so we may merge useful information into the map of West Oakland. The data explored include:

1. Roadways, containing detailed road network information in West Oakland
2. Traffic signals, including types all traffic lights and their coordinates
3. Bikeways, covering information about bike lanes in West Oakland
4. Land use plan, which contains land use type information for each polygon.
5. Establishments, including all establishments' coordinates, employment, and other related information.

Some of the data sources are geocoded and others are not. The data are first compiled in QGIS to form an integrated geo file for further analysis. Table 5, below, lists all the useful data and their sources.

Table 5. Data Sources Used in the Simulation Model

Data	Source	Type
Land use plan	City of Oakland (https://data.oaklandca.gov/dataset/General-Plan-Land-Use/7xy4-dv3x)	shapefile
Roadways	The Metropolitan Transportation Commission (MTC) open data catalog (https://opendata.mtc.ca.gov/datasets/san-francisco-bay-region-roadways/explore?location=37.887791%2C-122.969650%2C9.92)	shapefile
Establishments	Dun & Bradstreet data for 2018, accessed through UC Berkeley libraries	csv file

Specifically, two steps are conducted to prepare the data.

(1) Setting the land use plan shapefile as a base map. The spatial unit is a polygon. Each polygon has its own land use type and other geographic information.

(2) Mapping all establishments to the base map according to their street addresses.

Specifically, to identify establishments in the area, we extracted the 2018 Dun and Bradstreet data for all registered businesses in Oakland. These data included addresses, industrial classification codes, employees at the site, business name, business description, and, if available, actual or estimated annual sales. Addresses within the study area were geocoded using QGIS and matched to a shapefile with parcel data. The resulting map is shown in Figure 12. Points are establishments in the studied region.

Figure 12. Map of Establishments

Freight Trip Estimation

Businesses and households have very different truck trip generation processes. Most businesses receive deliveries from multiple vendors, with different delivery frequencies. Some industrial sectors may also send out cargo, thus producing freight trips. Households, especially in recent years, have also created large volumes of truck trips through requesting home deliveries. The demand pattern and vehicles used, however, are very different. Therefore, the freight trips generated by local business and residents are estimated separately.

(1) Estimating freight trip attraction and production for local businesses.

Businesses of different industrial sectors may have different delivery demands. Some industrial sectors may be freight-intensive, generating higher freight demand, while others may be non-freight-intensive. We used the Freight Trip Generation (FTG) models to quantify the freight trips. The FTG models can be applied at establishment and 2-digit NAICS code levels (Holguín-Veras, 2017). All covered NAICS codes are presented in Table 5. The establishment data were used to estimate the number of freight trips generated per day for each establishment. FTG models contain the estimation of freight trip attraction (FTA) and production (FTP), where FTA represents the freight flow into each spatial unit and FTP is the freight flow out of each spatial unit.

We used a set of linear models to estimate FTG as a function of employment for different industrial sectors. Specifically, FTA and FTP for each spatial unit or polygon can be estimated according to the equations below.

- $FTA_i = \alpha + \beta \times E_i$
- $FTP_i = \alpha + \beta \times E_i$

where i is the index for polygon, E_i represents the number of employees in polygon i, and α and β are industry sector-specific parameters. Their values can be found in Holguin-Veras et al.

(2) Estimating home deliveries for local residents.

Residential freight demand, measured by home delivery frequency per day, can be similarly considered. Compared to freight trips generated by businesses, home deliveries are more homogeneous in terms of frequency. Although individual and household features have impacts on home delivery frequency, which can be captured with the disaggregate count data model, a simple estimation based on average household delivery rate is usually accurate enough at the polygon level. Also, considering the rapid change of home delivery behavior, we feel the aggregate approach is sufficient for providing reasonably good estimates of local residence freight trip generation. The calculation of home deliveries for each polygon is shown below.

$$FTA_i = PopDens_i \times Area_i \times AvgDeliveries$$

where $PopDens_i$ represents the population density of spatial unit i; $Area_i$ represents the area of spatial unit i; and $AvgDevliveries$ represents the average number of deliveries per person per day, derived from the national household travel survey (United States Federal Highway Administration, 2017).

With the implementation of cargo cycles, some trucks will unload cargos at the transfer site. The last-leg delivery will be completed by the emission-free cargo cycles. The emission reduction can be estimated based on the reduced truck trips between the transfer site and each polygon. Different scenarios are set by assuming a different percentage of truck trips that can be replaced by cargo cycles.

Convert Freight Demand to Truck Trips

As emission rates differ significantly across vehicle types, the total number of truck trips estimated in the previous section needs to be further disaggregated into truck trips of different types. For business FTA and FTP, the calibration is based on the field-collected truck composition data. Class 1 through Class 8 trucks are considered. As discussed in the previous chapter, data were collected from ten major intersections in the studied area. It is then assumed that the polygons around each intersection tend to share the same truck type composition. From here, we convert business FTA and FTP to number of different types of trucks. For home deliveries in each polygon, we convert the delivery frequency to the number of Class 4 trucks. The fact that multiple home deliveries may be made along one delivery tour is also considered.

Vehicle Miles Travelled (VMT)

As mentioned previously, a transfer site is needed to transfer cargo from trucks to cargo cycles. The selection of the transfer hub location is important, since it directly determines the travel distance and consequently the reduced VMT.

The travel distance between the transfer hub and each polygon is calculated from QGIS, assuming that the truck drivers use the shortest path. One example is shown in Figure 13. The red line represents the shortest path from the centroid of one polygon (id = 1) to the transfer hub. The shortest path would be if the truck driver starts driving south from Hollis St. to 32nd St., briefly goes east on 32^{nd} St. to Union St., travels south on Union St., west on 30th St., and ends their route by driving south on Peralta St. The total length is 1563.8 m (0.97 mile). The VMT reduction can be calculated by multiplying the reduced number of trucks serving this polygon and this distance.

Figure 13. Shortest Delivery Path: Transfer Hub to Delivery Site

Emission Rates

With the output from the previous steps, we would calculate the saved emissions. The emission rate is generated from California air resources board using the Emission Factor model (EMFAC) of 2021. We consider the following pollutants: carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (i.e., Total Organic Gases or TOGs, Reactive Organic Gases or ROGs), THC (total hydrocarbon), CH_4 (methane), carbon dioxide (CO_2), particulate matter (i.e., $PM_{2.5}$, PM_{10}), sulfur oxides (SO_x), and fuel generated through different types of emission processes (e.g., Running Exhaust Emissions or RUNEX, Idle Exhaust Emissions or IDLEX, Exhaust Tailpipe Emissions or STREX, etc.)

Given the emission rates for different types of trucks, we calculated the emission savings for each polygon. Specifically, we adopted the EMFAC2021 V1.0.1 and focused on the Alameda (SF) region (California Air Resources Board, 2021). Emission rates for different types of pollutants from different processes are generated. It should be noted that emissions generated from different processes require different inputs.

- VMT: Running Exhaust Emissions (RUNEX), Tire Wear Particulate Matter Emissions (PMTW), Brake Wear Particulate Matter Emissions (PMBW)
- Emission rate unit: grams/mile
- Number of trips: Start Exhaust Tailpipe Emissions (STREX), Hot Soak Evaporative HC Emissions (HOTSOAK), Running Loss Evaporative HC Emissions (RUNLOSS)
- Emission rate unit: g/trip

- Number of vehicles per day: Idle Exhaust Emissions (IDLEX), Diurnal Evaporative HC Emissions (DIURN)

- Emission rate unit: g/vehicle/day

For each pollutant, the total emissions saved is the sum of emissions generated by all these activities (i.e., VMT, trips, and vehicles).

5.1.2 Scenario Design

Based on the previous procedure, we can simulate the potential emissions savings that could be anticipated thanks to the implementation of cargo cycles. Given the uncertainty in the cargo cycle implementation plan at this stage, multiple scenarios are assessed and compared. Different scenarios can be designed by changing the values of the following key parameters.

- Approximate percentages of freight demand that can be replaced by cargo cycles for each industrial sector;

- Types and distribution of commercial vehicles currently used to deliver cargos;

- Number of deliveries made within one truck trip; and

- Feasible location(s) of cargo cycle transferring sites.

Truck Trip Replacement Percentage by Industrial Sector

Due to size and weight restrictions, not all freight can be delivered by cargo cycles. Based on information from the literature review and interviews with local stakeholders, the possible range of percentages of freight demand that can be replaced by cargo cycles for each industrial sector is summarized in Table 6.

Table 6. Percentage of Truck Trip Replaced by Cargo Cycles for Each NAICS Code

		Percentage of Truck Trips Replaced by Cargo Cycles	
NAICS	Industry Sector	Minimum	Maximum
11	Agriculture, Forestry, Fishing and Hunting	5%	20%
22	Utilities	0%	0%
23	Construction	0%	20%
31-33	Manufacturing	5%	20%
42	Wholesale Trade	5%	40%
44-45	Retail Trade	30%	100%
48-49	Transportation and Warehousing	20%	60%
51	Information	50%	100%
52	Finance and Insurance	40%	80%
53	Real Estate Rental and Leasing	20%	60%
54	Professional, Scientific, and Technical Services	40%	80%
55	Management of Companies and Enterprises	20%	60%
56	Administrative and Support and Waste Management and Remediation Services	40%	80%
61	Educational Services	40%	100%

		Percentage of Truck Trips Replaced by Cargo Cycles	
NAICS	Industry Sector	Minimum	Maximum
62	Health Care and Social Assistance	40%	100%
71	Arts, Entertainment, and Recreation	0%	40%
72	Accommodation and Food Services	50%	100%
81	Other Services (except Public Administration)	30%	80%
92	Public Administration	30%	80%

Truck Trip Replacement Percentage by Truck Type

The percentages of truck trips that can be replaced by cargo cycles are also sensitive to the vehicle types. Intuitively, cargos carried by large trucks are usually those with high volume or weight, and these are difficult to be transferred to cargo cycles. Cargos carried by smaller vehicles, in contrast, are usually small shipments that are more likely to be transferred to cargo cycles. Similarly, the percentages of trucks that can be replaced by cargo bikes are selected based on literature review and local stakeholder input, as summarized in Table 7.

Table 7. Percentage of Truck Class

Truck Class	Weight Class	Percentage Replaced
1	< 6,000 lbs	100%
2	6,000 - 10,000 lbs	80%
3	10,001 - 14,000 lbs	70%
4	14,001 - 16,000 lbs	60%
5	16,001 - 19,500 lbs	30%
6	19,501 - 26,000 lbs	20%
7	26,001 - 33,000 lbs	5%
8	> 33,000 lbs	5%

Number of Deliveries per Tour

The number of deliveries made within one truck tour is another critical input parameter that varies widely across different regions. For example, the number of stops per delivery route typically ranges between 1 and 3 (Lin et al., 2017). The number of deliveries per stop is usually 1 or 2. Considering both factors, the number of deliveries per route in the study area may range between 1 to 6. For home deliveries, the number of stops per route could range between 1 to 50, depending on the size of the study region). The number of deliveries per stop is also 1 or 2, making the possible number of home deliveries per route range between 1 and 100.

Potential Transfer Hub Locations

Finally, several possible transfer site locations are suggested by local stakeholders, and the research team selected three of the most frequently recommended ones, shown in Figure 14.

Figure 14. Possible Locations for Transfer Sites

Among these three suggested locations, location 1 (Central West Oakland) is recommended by most focus groups. Therefore, we conducted a five-scenario sensitivity analysis based on the assumption that the transfer hub is at location 1. For the other two locations, we only assessed emissions reduction for the most likely scenario. In total, seven different scenarios are designed by considering hub location, percentage of freight demand that can be replaced by cargo cycles for each industrial sector, and number of deliveries in a truck tour (Table 8).

Table 8. Cargo Cycle Delivery Scenarios

Scenario	Description	Transfer Hub Location	Truck Trips Replaced	Business Deliveries per Trip	Home Deliveries per Trip
1	Best-case scenario with location 1	1	max	1	3
2	Second-best-case scenario with location 1	1	max	2	50
3	Most likely scenario with location 1	1	mean	2	50
4	Conservative scenario with location 1	1	min	2	50
5	Worst-case scenario with location 1	1	min	3	100
6	Most likely scenario with location 2	2	mean	2	50
7	Most likely scenario location 3	3	mean	2	50

5.2 Results from Traffic Simulation Model

5.2.1 Impacts of Cargo Cycle Adoption Rate and Delivery Pattern

Table 9 shows the emission savings for several key pollutants when the cargo cycle transfer hub is placed at Location 1.

Table 9. Detailed Emissions Saved per Day for Scenarios 1 to 5 (all with Location 1)

Scenario	VMT (miles)	$PM_{2.5}$ (g)	PM_{10} (g)	NOx (g)	ROG (g)	Total Emissions Saved (tons)
Best case	2,620.6	158.5	353.0	27,399.1	3,042.3	16.8
Second best	558.6	28.6	65.8	2,687.3	1,265.8	1.9
Most likely	415.6	21.8	50.0	2,317.8	879.4	1.6
Second worst	272.5	15.0	34.1	1,948.4	493.0	1.3
Worst case	164.6	8.9	20.2	1,048.7	322.9	0.7

The overall results suggest that the implementation of cargo cycles could lead to a meaningful amount of emission reduction. According to the EMFAC emission rate, a Class 4 truck's emission rates for $PM_{2.5}$, PM_{10}, NO_x, and ROG are roughly 0.04 g/mile, 0.12 g/mile, 0.26 g/mile, and 0.02 g/mile, respectively. As the average travelling distance within West Oakland is around 1 mile, the best-case scenario, which has a VMT reduction of 2620.6 miles per day is equivalent to the elimination of more than 1,000 Class 4 trucks traveling in West Oakland per day.

The reduction in $PM_{2.5}$, PM_{10}, NO_x, and ROG emissions decreases from the best-case scenario to the worst-case scenario. Evidently, increasing the percentage of replaced freight demand leads to an increase in the total emission savings, which is expected. If the number of deliveries within one truck trip is high, the total emission savings is low. This is because a higher number of deliveries with one truck is more efficient with respect to emissions, so there is a smaller margin of improvement to convert to cargo cycles.

5.2.2 Impacts of Transfer Hub Locations

As can be seen from Table 10, $PM_{2.5}$, NO_x, and ROG are relatively stable regardless of the hub locations. VMT and PM_{10} seem to have greater variation, especially VMT. By comparing the three potential hubs, we can see that location 3 seems to be the one with the most savings. As can be seen from Figure 14, location 3 is out of the study region, which means more VMT occur when travel occurs from each polygon to the hub. More VMT would generate more emissions.

Table 10. Saved Emissions per Day for Different Transfer Hub Locations

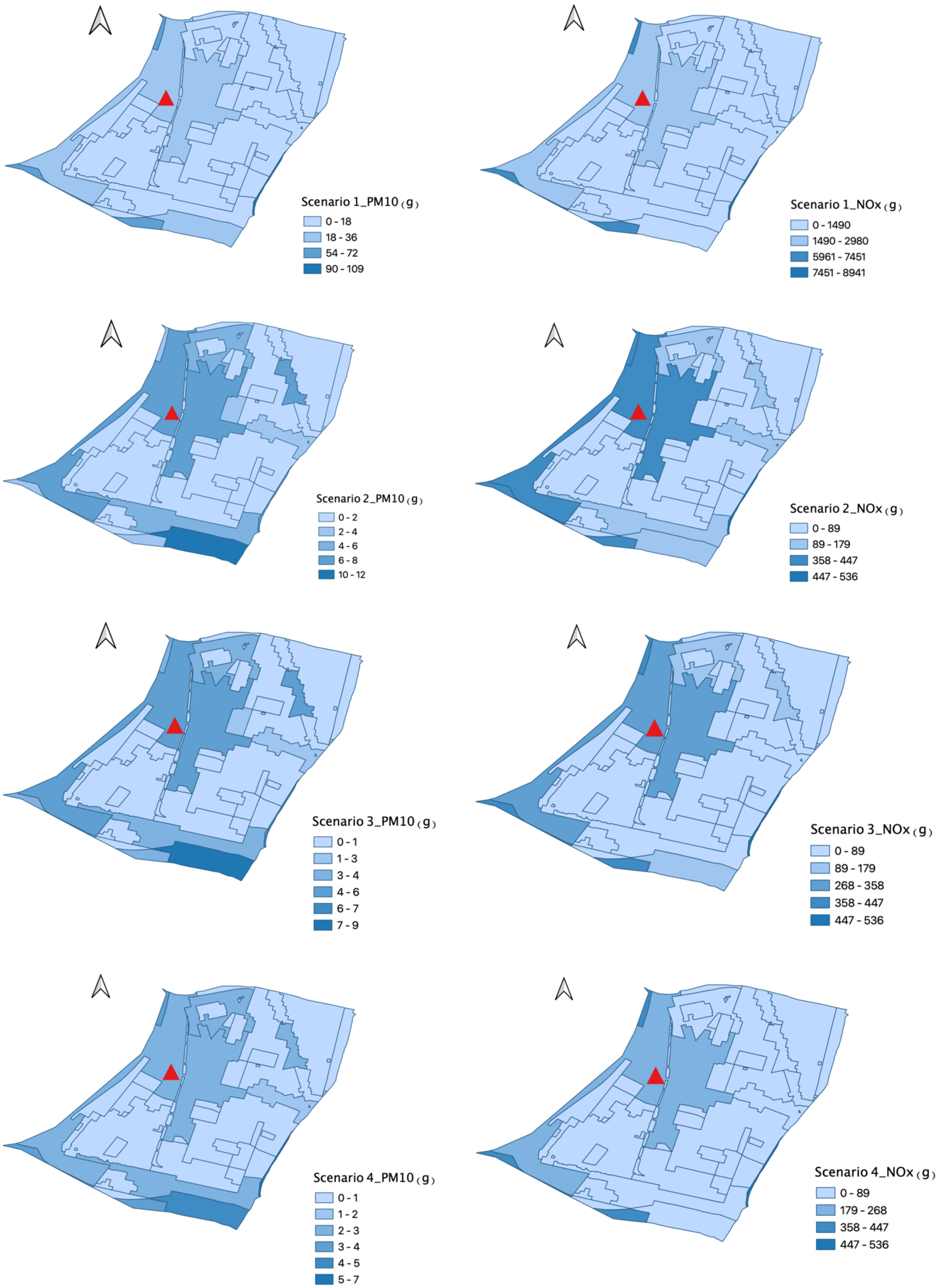
Location	VMT (miles)	$PM_{2.5}$ (g)	PM_{10} (g)	NOx (g)	ROG (g)	Total emissions saved (tons)
Location 1	415.6	21.8	50.0	2,317.8	879.4	1.6
Location 2	564.4	27.7	67.0	2,334.0	884.4	1.7
Location 3	848.0	37.1	94.2	2,369.0	890.1	2.1

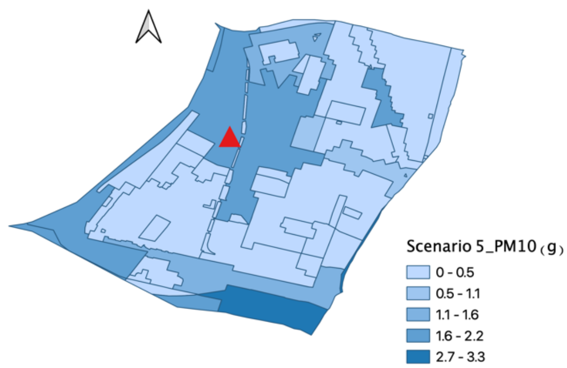
5.2.3 Spatial Variation

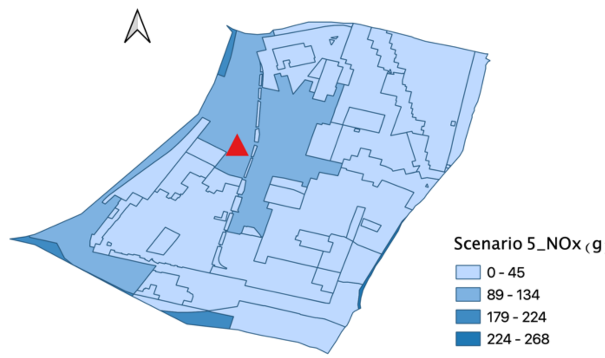
The spatial distribution of PM_{10} and NO_x for each of the seven scenarios (as described in Section 5.1.1) is shown in Figure 14. The spatial distribution patterns of different scenarios are similar, although different scenarios have different scales of PM_{10} and NO_x savings.

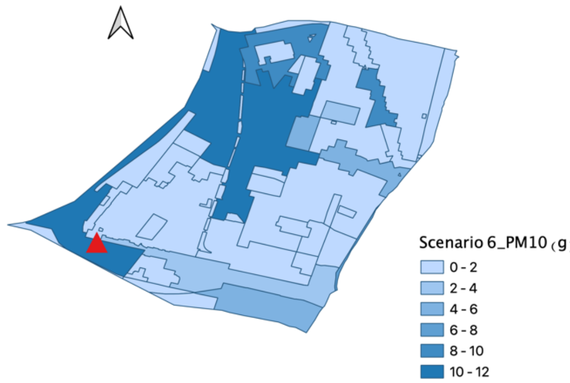
Specifically, Clawson, McClymonds, South Prescott, and Acorn (the locations of the neighborhoods as shown in Figure 14) are four neighborhoods with major emissions savings. Clawson is a residential area, and McClymonds and Acorn are designated as business use. South Prescott is mainly for business and has a USPS center in it. By replacing some freight demand with cargo cycles, the emissions can be reduced accordingly.

Figure 15. Spatial Distribution of PM_{10} and NO_x Emission Reductions per Day

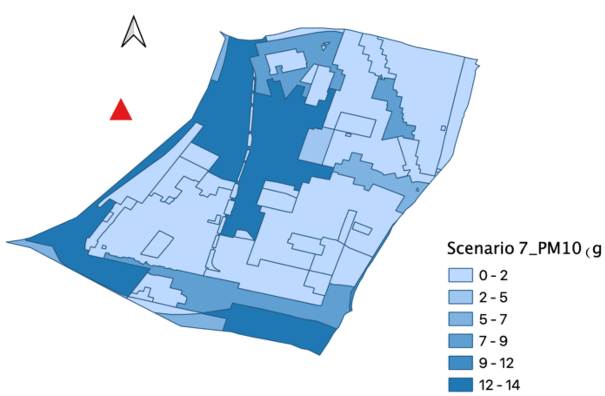


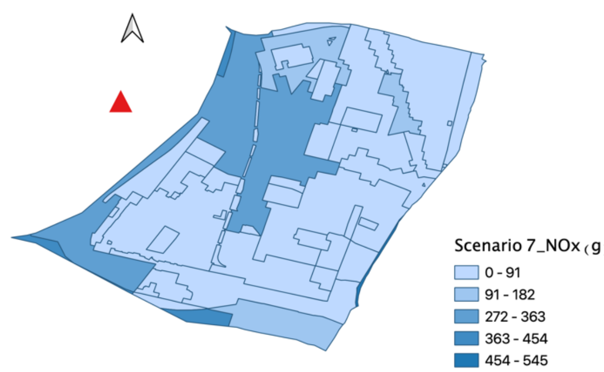

Scenario 5_PM10 (g)
0 - 0.5
0.5 - 1.1
1.1 - 1.6
1.6 - 2.2
2.7 - 3.3


Scenario 5_NOx (g)
0 - 45
89 - 134
179 - 224
224 - 268


Scenario 6_PM10 (g)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12


Scenario 6_NOx (g)
0 - 89
89 - 179
268 - 357
357 - 447
447 - 536


Scenario 7_PM10 (g)
0 - 2
2 - 5
5 - 7
7 - 9
9 - 12
12 - 14


Scenario 7_NOx (g)
0 - 91
91 - 182
272 - 363
363 - 454
454 - 545

6. Policy Implications

This chapter synthesizes our findings from the literature review, community level data collection, and traffic simulation and proposes policy recommendations that would improve the feasibility of implementing cargo cycles for last mile delivery.

6.1 Dimensions of Policy Influence

There is no doubt that non-motorized modes of transportation generally advance sustainability goals, decrease emissions, lower pollution levels, and improve health outcomes and quality of life. Replacing motorized trucks with cargo cycles for last mile trips can provide a desirable option under certain conditions, as discussed earlier, including certain area characteristics and the availability of transfer hubs. The shift to cargo cycles requires policy interventions at the municipal government level to change behaviors and effectively promote the acceptability and diffusion of this mode of transport.

There are four dimensions of influence where interventions are recommended to achieve cargo cycle diffusion in a particular corridor.

6.1.1 Dimension 1: Political and Legal

Local government can enact restrictions on the use of motorized vehicles in particular zones during certain times (usually when high levels of congestion are present), create pedestrian zones, or enforce speed limit restrictions. These restrictions serve as impediments for motorized forms of transportation and create incentives for the use of non-motorized or e-cargo vehicles.

Local government can also further incentivize cargo cycle use by piloting cargo cycling and evaluating its effectiveness and feasibility in real-life scenarios. Pilot tests can provide a jump start for companies by making it more affordable and easing the financial burden of purchasing cargo cycles by providing them for rent or for free on a trial basis. Tax incentives can also provide incentives for start-up cargo cycle businesses.

6.1.2 Dimension 2: Physical and Spatial

The physical environment is critical to the diffusion of cargo cycle use as a last mile alternative to motorized vehicles. Mainstreaming cargo cycle use in strategic local transportation plans will ensure that considerations specific to cargo cycles are integrated into those plans. Cycling infrastructure and other active transportation measures must also be developed with cargo cycle considerations and specifications in mind.

Moreover, parking for cargo cycles is critical to the success of these plans. Having parking infrastructure built with cargo cycle specifications promotes the use of this type of vehicle.

Appendix B shows a picture of a current city-provided bike corral. One of the goals of cargo cycles is to reduce congestions, so parking considerations is an integral measure to ensure that parked cargo cycles do not create more congestion in roadways and sidewalks.

Specific physical infrastructure features enables the accessibility of cargo cycles to navigate curbed streets. Lowering curb stones is a measure that is often needed to provide such accessibility. Wide enough bicycle lanes to accommodate cargo cycles and to reduce possible accidents with and the disruption of the flow with commuting and recreational bicyclists should also be considered.

Cargo cycles schemes are successful only when micro consolidation centers are available in the city center to allow loading and distribution in the last mile trips. Local government can make these centers available and provide equitable access to cargo cycle businesses.

6.1.3 Dimension 3: Economic

Local government can model the change in behavior by adopting cargo cycle use within its municipal fleet for last mile deliveries and services such as street cleaning, waste collection, etc.

There is a need for an awareness campaign targeting businesses to ensure that cargo cycle use is scaled up. Creating public-private partnerships to ensure business development for cargo cycle is a best practice.

6.1.4 Dimension 4: Cultural and Social

While focus groups have indicated a general cultural and social acceptability of non-motorized modes of travel and a concern over pollution and the impact of unsustainable modes of transportation on human health and quality of life, there is a need to ensure that residents, business owners, and other key stakeholders are on board with the change. Public awareness campaigns are critical to ensuring successful diffusion, scale-up, and behavioral change. The use of social and professional networks, community forums, and roundtables are proven avenues to ensure community acceptability and adoption of change.

Observers noted that the pandemic, with the restrictions it has necessitated on social gathering and the emphasis placed on distancing and remote operations of every kind, has increased demand for online shopping and the delivery of goods and products, and this pattern will probably remain in a post-pandemic world. Demands for goods fueled by panic buying increased demands on the trucking industry. Murray et al. (2021) posit that the pandemic increased demands for specific goods and large trucking industry experienced an increase in their operations (Murray et al., 2021). This has significant implications for cargo cycle operations. Cargo operators, policy planners, and government officials can leverage this window of opportunity that opened and the change in users' behavior to incentivize cargo operations to meet the increased demand.

Qualitative and quantitative evaluations of cargo cycle schemes' impact is critical to the improvement of these schemes. Evaluation efforts must track intermediate and long-term outcomes and impacts.

The above policy recommendations are consistent with the strategic directions of West Oakland, which announced in July 2021 that it is pursuing amendments to the planning code to protect the health of residents and create industrial land use policies that embrace sustainability, prioritize jobs for Oakland residents, and advance environmental justice goals (City of Oakland, 2018). West Oakland's Community Action Plan includes strategies that have been adopted that are favorable to the effort of replacing motorized trucks with cargo cycles (BAAQMD and WOEIP, 2019). Ongoing support from the local government, community members, and research can facilitate the implementation cargo cycle schemes.

6.2 Strategies that De-Incentivize Truck Operations

There is a movement in Oakland policies to lessen air emissions from truck traffic through promotion of freight movement by alternative means. The West Oakland Community Action Plan (WOCAP), which outlines strategies to reduce transportation-related emissions, includes recommendations that are consistent with overall directions of de-incentivizing truck operations (BAAQMD and WOEIP, 2019) . WOCAP's Strategies #7 and 8 call for amending existing business ordinances and administrative policies to accelerate the relocation of non-conforming businesses that support trucks (Strategy #7) (BAAQMD and WOEIP, 2019). Those supporting businesses include truck yards and service, repair, and fueling businesses in West Oakland. These amendments are in line with de-incentivizing the use of trucks in the area which would allow for the emergence of alternative modes of freight delivery in West Oakland including cargo cycles.

Other strategies consistent with overall strategic direction of limiting truck operations in West Oakland also include:

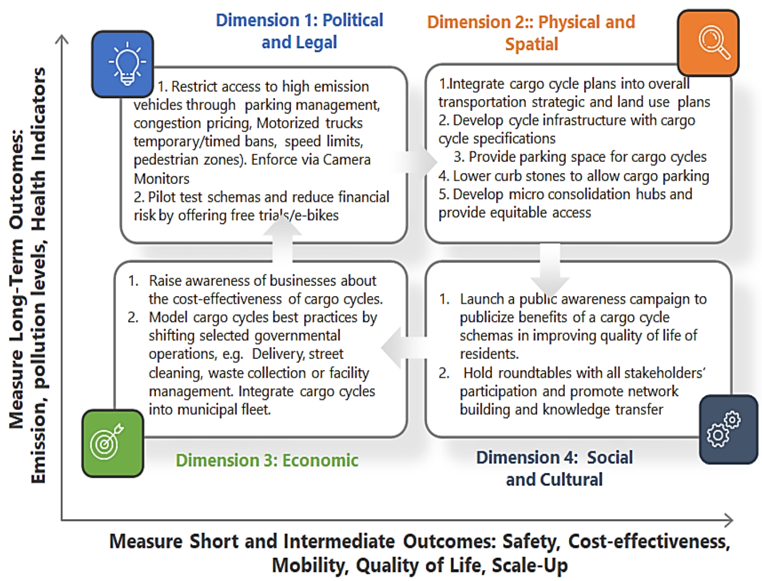
- Consider ways to manage truck operations in the West Oakland neighborhood, including ways to address concerns about parking, idling, noise, and emissions.
- Traffic calming measures and truck management including mandatory reporting by businesses of number of trucks and parking demand as conditions for licensure.
- Implementation of traffic demand management strategies as part of development of new buildings, as described by WOCAP Strategy #40 (BAAQMD and WOEIP, 2019) .
- Strategies that incentivize non-motorized schemes.
- WOCAP Strategy #56 describes several projects to improve bicycle and pedestrian infrastructure including upgrading sidewalks, curb ramps and crossings as well as providing protected bikeway lanes (BAAQMD and WOEIP, 2019). As the city moves to implement

these strategies, it can take into considerations the need of cargo cycles and adopt designs that accommodate the weight and size of these vehicles. Bicycle and pedestrian improvement plans in Oakland also include establishing permanent parking locations for cargo which would serve as a solid foundation for a shift in freight modes in the city.

- WOCAP Strategy #81 requires the City of Oakland to "work with local businesses, partner agencies and community members to develop a green business strategic plan to attract, retain and support innovative green companies (BAAQMD and WOEIP, 2019)."

The findings of this study provide empirical evidence that substantiates the merits of introducing cargo cycle schemes in West Oakland. This direction is also consistent with several strategic directions the city adopted to reduce pollution of all kinds, enhance safety, and improve public health.

Figure 16. Recommendations for Cargo Cycle Schemas along Dimensions of Influence



7. Summary & Conclusions

From the literature review, we found that there are public health benefits to air and noise pollution reduction such as a reduction in rates of cardiovascular disease, respiratory disease, and mortality. In addition, although bicycle riding could expose riders to air pollution and possible collisions with vehicles, Europe-specific research has shown that bicycle riding has an overall net benefit.

Focus group participants shared opinions about the benefits of using cargo cycles for freight delivery instead of using motorized trucks. The main opinions were that the use of cargo cycles could decrease air pollution levels, lower noise pollution levels, create job opportunities for cargo cycle operators, reduce damage to roads, and develop opportunities for local cargo cycle businesses including making customized cargo cycles and cargo cycle maintenance. The physical activity requirements of cargo cycle delivery can also contribute to a healthy lifestyle for cargo cycle operators. The focus group data validate findings from the literature and support the further use of cargo cycles for freight delivery on a commercial scale. Focus group participants provided the following recommendations to support an increase in use of cargo cycles: (a) establish parking facilities/spaces for cargo cycles to ensure safety and avoid illegal parking; (b) perform outreach to businesses/residents and the local community to activate demand for cargo cycle services; (c) provide cargo cycle operator trainings; (d) create protected cargo bike lanes; (e) use physical traffic management schemas; (f) leverage safe street schemas to incentivize cargo cycles; (g) incentivize business to use cargo cycles and offset the human cost of running cargo cycle business; (h) limit speed for motorized vehicles and provide improved police enforcement to increase safety for cargo cycles; (i) address safety for cargo cycle operators of color who are more vulnerable to harassment and discrimination and more exposed without the physical shield of motorized vehicles; and (j) make cargo cycle operator jobs accessible to community members.

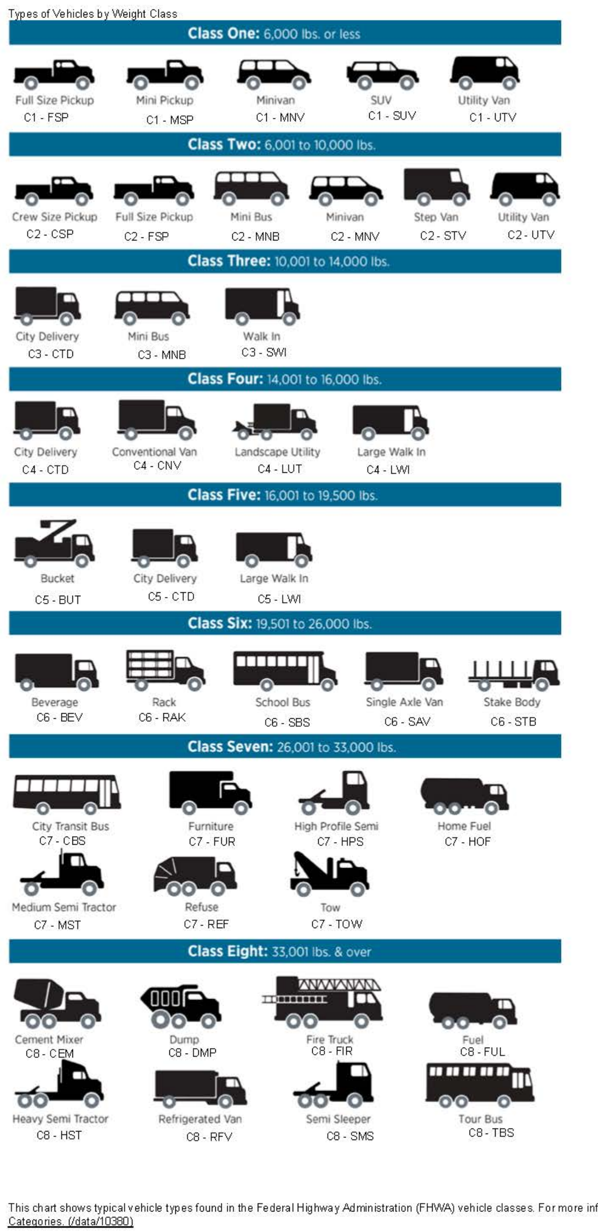
The traffic simulation found that there would be a meaningful reduction in air pollution with a transition to cargo cycles for a portion of freight deliveries. When simulating scenarios based on location 1, at W. Grand Ave. and Mandela Pkwy., the scenario with the maximum estimated percent of freight delivery converted to cargo cycles found that the use of cargo cycles could potentially reduce the vehicle miles traveled (VMT) by over 2,600 miles per day. This VMT reduction offers an emissions reduction (for $PM_{2.5}$, PM_{10}, NO_x, and ROG) equivalent to taking about 1,000 Class 4 box trucks off the roads of West Oakland per day. The location of the transfer hub matters. Location 3, near the current Good Eggs distribution center on Maritime St. on the west side of West Oakland, brings the greatest VMT reduction because it is the furthest distance from potential delivery endpoints in West Oakland. West Oakland will need infrastructure support for motor vehicles and bicycles to make the transition to cargo cycles feasible, since the transfer hub is a place where delivery trucks will drop off freight and the cargo cycles will pick up the cargo and begin the last mile delivery. Careful planning is needed to support the safety of all operators in this purposeful connecting point of ongoing truck and bicycle traffic.

We estimated a total emissions savings range of between 0.7 and 16.8 tons per day based on the location of the transfer hubs and assumptions about freight attraction and delivery. In addition, the decrease in truck traffic is also likely to decrease noise and improve the safety of other road users, as well as creating local options for sustainable freight movements and increased community involvement. Although modest, these impacts are to be viewed from the lens of a community already affected by cumulative exposures to air, noise, and traffic concerns from decades of public and private decision-making. Each local truck trip that can be transitioned to a cargo cycle delivery has the potential to reduce air emissions, noise pollution, and traffic congestion at the local level and benefit West Oakland residents.

Appendix A

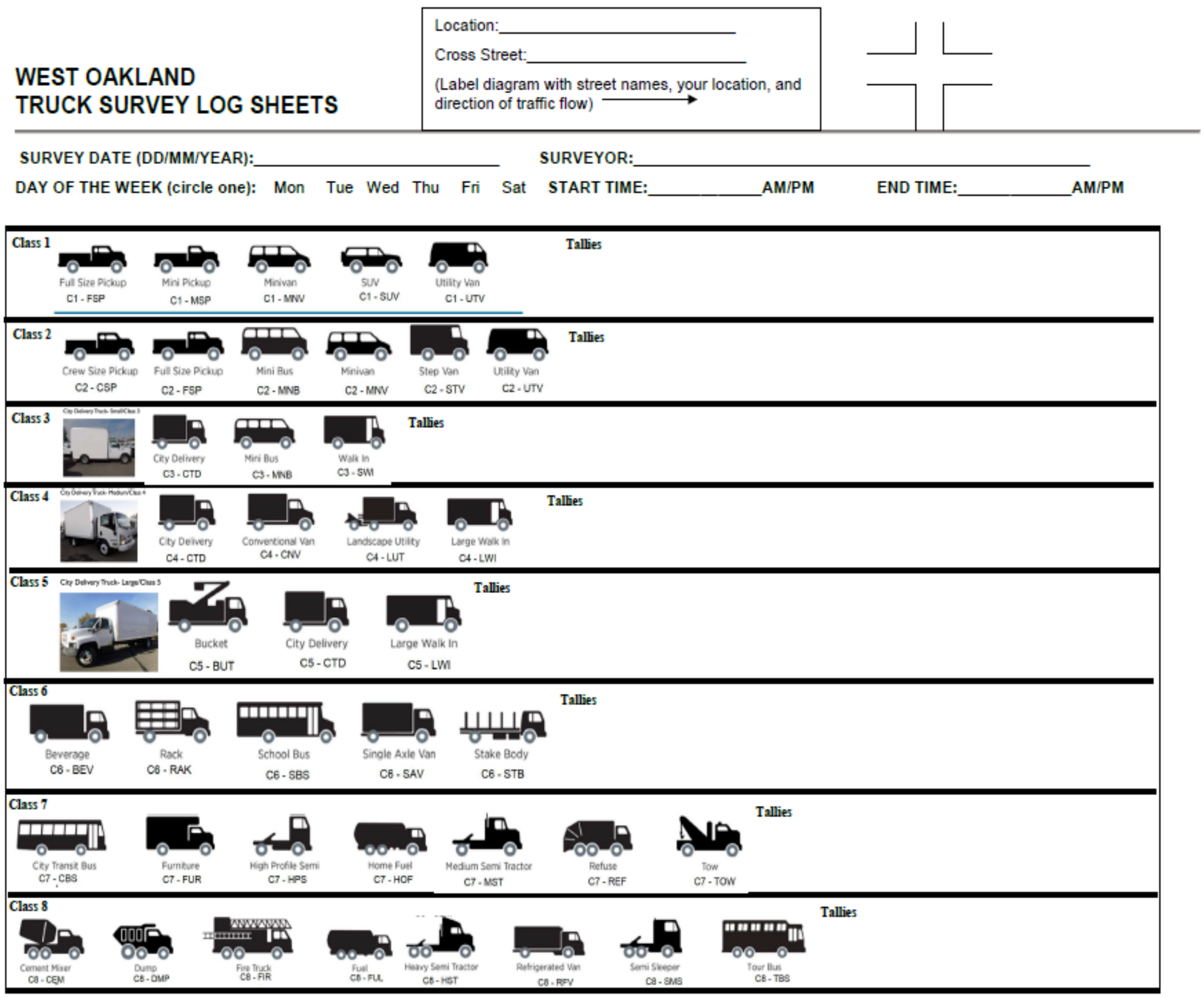
Vehicle Count and Vehicle Behavior data collection sheets are included in this Appendix.

Figure 17. Guide to Vehicle Class Data Collection



This data collection sheet was adapted from a graphic from the Alternative Fuels Data Center (United States Department of Energy, 2012).

Figure 18. West Oakland Truck Survey Log Sheet



WEST OAKLAND
TRUCK SURVEY LOG SHEETS

Location:________________________
Cross Street:________________________
(Label diagram with street names, your location, and direction of traffic flow)

SURVEY DATE (DD/MM/YEAR):________________________ SURVEYOR:________________________

DAY OF THE WEEK (circle one): Mon Tue Wed Thu Fri Sat START TIME:__________AM/PM END TIME:__________AM/PM

Class 1 — Full Size Pickup C1 - FSP; Mini Pickup C1 - MSP; Minivan C1 - MNV; SUV C1 - SUV; Utility Van C1 - UTV — Tallies

Class 2 — Crew Size Pickup C2 - CSP; Full Size Pickup C2 - FSP; Mini Bus C2 - MNB; Minivan C2 - MNV; Step Van C2 - STV; Utility Van C2 - UTV — Tallies

Class 3 — City Delivery C3 - CTD; Mini Bus C3 - MNB; Walk In C3 - SWI — Tallies

Class 4 — City Delivery C4 - CTD; Conventional Van C4 - CNV; Landscape Utility C4 - LUT; Large Walk In C4 - LWI — Tallies

Class 5 — City Delivery Truck- Large/Class 5; Bucket C5 - BUT; City Delivery C5 - CTD; Large Walk In C5 - LWI — Tallies

Class 6 — Beverage C6 - BEV; Rack C6 - RAK; School Bus C6 - SBS; Single Axle Van C6 - SAV; Stake Body C6 - STB — Tallies

Class 7 — City Transit Bus C7 - CBS; Furniture C7 - FUR; High Profile Semi C7 - HPS; Home Fuel C7 - HOF; Medium Semi Tractor C7 - MST; Refuse C7 - REF; Tow C7 - TOW — Tallies

Class 8 — Cement Mixer C8 - CEM; Dump C8 - DMP; Fire Truck C8 - FIR; Fuel C8 - FUL; Heavy Semi Tractor C8 - HST; Refrigerated Van C8 - RFV; Semi Sleeper C8 - SMS; Tour Bus C8 - TBS — Tallies

This data collection sheet was adapted from a West Oakland Truck Survey data collection sheet. (Lau et al., 2009)

Figure 19. Truck Delivery Behavior Data Sheet

Truck Delivery Behavior
Location/block description:
Date:
Day of the week:
Start Time:
End Time:
Surveyor:

Truck type (code)	Delivery Start Time	Delivery End Time	Idling? (Idle time if different from delivery time)	Illegally parked? (E.g. double parked, red zone)

Appendix B

Photos from the fieldwork in West Oakland, CA.

Figure 20. City of Oakland Bike Corral on Peralta St. at Helen St.

Photos of select vehicle count/truck delivery behavior data collection efforts in West Oakland, CA

Figure 21. 7th St. at Wood St.

Figure 22. Peralta St. at 26th St.

Figure 23. Mandela Pkwy at Grand Ave.

Figure 24. Grand Ave. at Market St.

Bibliography

Aclima. (2022). *Interactive Air Quality Report*. Retrieved March 20, 2022 from https://www.aclima.io/blog/mapping-street-level-and-real-time-air-quality-in-west-oakland-e70d0e4ddb8c

Agency for Toxic Substances and Disease Registry. (August 2, 2020). *ToxFAQs for Lead*. Retrieved March 2, 2022 from https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=93&toxid=22

Alameda County. (2016). The Alameda County Public Health Department Community Assessment, Planning, and Education (CAPE).

Alameda County Department of Public Health. (2014). *Alameda County Health Data Profile*. Retrieved from https://acphd-web-media.s3-us-west-2.amazonaws.com/media/data-reports/city-county-regional/docs/acphd-cha.pdf

Alexeeff, S. E., Roy, A., Shan, J., Liu, X., Messier, K., Apte, J. S., Portier, S., Sidney, S., & Van Den Eeden, S. K. (2018). High-resolution mapping of traffic related air pollution with google street view cars and incidence of cardiovascular events within neighborhoods in Oakland, CA. *Environmental Health: A Global Access Science Source*, 17(1), 1-13. https://doi.org/doi:10.1186/s12940-018-0382-1

Aljohani, K., & Thompson, R. G. (2018). A stakeholder-based evaluation of the most suitable and sustainable delivery fleet for freight consolidation policies in the inner-city area. *Sustainability*, *11*(1), 124.

Aljohani, K., & Thompson, R. G. (2016). Impacts of Logistics Sprawl on Urban Environment & Logistics: Taxonomy and A Review of the Literature. *Journal of Transport Geography*, *57*.

Aljohani, K., & Thompson, R. G. (2020). Last mile delivery activities in the city centre – Insights into current practices and characteristics of delivery trips. *Transportation Research Procedia*, *46*, 261-268.

Allen, J., Browne, M., Woodburn, A., & Leonardi, J. (2012). The role of urban consolidation centres in sustainable freight transport. *Transport Reviews*, *32*(4), 473-490. https://doi.org/http://dx.doi.org/10.1080/01441647.2012.688074

An, Z., Jin, Y., Li, J., Li, W., & Wu, W. (2018). Impact of Particulate Air Pollution on Cardiovascular Health. *Curr Allergy Asthma Rep*, *18*(3), 15. https://doi.org/10.1007/s11882-018-0768-8

Apte, J. S., Messier, K. P., Gani, S., Brauer, M., Kirchstetter, T. W., Lunden, M. M., . . . Hamburg, S. P. (2017). High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data. *Environ Sci Technol*, *51*(12), 6999-7008. https://doi.org/10.1021/acs.est.7b00891

BAAQMD & WOEIP. (2019). *Owning our Air: The West Oakland Community Action Plan-Volume 1: The Plan*. https://www.baaqmd.gov/community-health/community-health-protection-program/west-oakland-community-action-plan

Babisch, W. (2003). Stress hormones in the research on cardiovascular effects of noise. *Noise Health*, *5*(18), 1-11. https://www.ncbi.nlm.nih.gov/pubmed/12631430

Barajas, J. M. (2018). Not all crashes are created equal: Associations between the built environment and disparities in bicycle collisions. *Journal of Transport and Land Use*, *11*(1), 865-882. https://www.jstor.org/stable/26622434

Barajas, J. M. (2021). Biking where Black: Connecting transportation planning and infrastructure to disproportionate policing. *Transportation Research Part D: Transport and Environment*, *99*, 103027. https://doi.org/https://doi.org/10.1016/j.trd.2021.103027

BBC Autos. (2014). *Cargo bikes, built for the short haul*. http://www.bbc.com/autos/story/20140815-rise-of-the-short-haul- truckers

Bikes, P. (2022). *Portal Bikes Stories*. Retrieved March 01, 2022 from http://www.portalbikes.org/portalstories

Cairns, S., & Sloman, L. (2019). Potential for E-Cargo Bikes to Reduce Congestion and Pollution from Vans in Cities. https://www.bicycleassociation.org.uk/wp-content/uploads/2019/07/Potential-for-e-cargo-bikes-to-reduce-congestion-and-pollution-from-vans-FINAL.pdf

California Air Resources Board. (2008). *Diesel Particulate Matter Health Risk Assessment for the West Oakland Community*. Retrieved from https://www.arb.ca.gov/ch/communities/ra/westoakland/documents/westoaklandreport.pdf

California Air Resources Board. (2021). *2021 Emissions Factors*. https://arb.ca.gov/emfac/emissions-inventory/d1d0f9ab8cd8704cc0d2c3c3401a03b9d6b9dca8

California Air Resources Board. (2022). *Inhalable Particulate Matter and Health ($PM_{2.5}$ and PM_{10})*. Retrieved March 2, 2022 from https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health#:~:text=on%20particle%20size.-,PM2.,tissue%20damage%2C%20and%20lung%20inflammation

Caubel, J. J., Cados, T. E., Preble, C. V., & Kirchstetter, T. W. (2019). A Distributed Network of 100 Black Carbon Sensors for 100 Days of Air Quality Monitoring in West Oakland, California. *Environ Sci Technol*, *53*(13), 7564-7573. https://doi.org/10.1021/acs.est.9b00282

Chen, H., Kwong, J. C., Copes, R., Tu, K., Villeneuve, P. J., van Donkelaar, A., . . . Burnett, R. T. (2017). Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study. *Lancet*, *389*(10070), 718-726. https://doi.org/10.1016/S0140-6736(16)32399-6

Choubassi, C. (2015). An Assessment of Cargo Cycles in Varying Urban Contexts. *The University of Texas at Austin*.

Choubassi, G., Seedah, D; Jang N., & Walton, M. (2016). Economic Analysis of Cargo Cycles for Urban Mail Delivery. *Journal of the Transportation Research Board*, *2547*.

City Data. (2019). *West Oakland neighborhood in Oakland, California (CA), 94607, 94608 detailed profile*. Retrieved February 10, 2021 from http://www.city-data.com/neighborhood/West-Oakland-Oakland-CA.html

City of Oakland. (2018). *West Oakland Specific Plan Environmental Impact Report*. https://www.oaklandca.gov/resources/read-the-final-west-oakland-specific-plan-environmental-impact-report

City of Oakland. (2021). *Draft EIR for the Oakland A's Waterfront Ballpark District Project*. https://www.oaklandca.gov/documents/draft-eir-for-the-oakland-as-waterfront-ballpark-district-project

Conway, A. (2015). Cargo Cycles for Local and last mile delivery: Lessons from New York City. *Transportation Research and Education Center*, *Friday Seminar Series 21*.

Conway, A., Fatisson, P. E., Eickemeyer, P., Cheng, J., & Peters, D. (2011). Urban micro-consolidation and last mile goods delivery by freight-tricycle in Manhattan: Opportunities and challenges. *Transportation Research Board*.

Copenhagenize Design Co. (n.d). *Copenhagenize Design Co*. http://www.copenhagenize.com/2014/02/cargo-bike-parking-designcopenhagenize.html

Cyclelogistics Federation. (2014). *Cyclelogistics Federation*. http://federation.cyclelogistics.eu/

De Buen Kalman, R. (2021). Can't drive today? The impact of driving restrictions on bikeshare ridership in Mexico City. *Transportation Research*, *91*. https://doi.org/https://doi.org/10.1016/j.trd.2020.102652

De Decker, K. (2012). *Cargo cyclists replace truck drivers on European city streets*. http://www.lowtechmagazine.com/2012/09/jobs-of-the-future-cargocyclist

De Hartog, J. J., Boogaard, H., Nijland, H., & Hoek, G. (2010). Do the health benefits of cycling outweigh the risks? *Environmental health perspectives*, *118*(8), 1109-1116.

Deghri, M. (2015). *About Deghri*. http://deghri.com/about-deghri/

Doorley, R., Pakrashi, V., & Ghosh, B. (2017). Health impacts of cycling in Dublin on individual cyclists and on the local population. *Journal of Transport & Health*, *6*, 420-432.

E-Commerce News Europe. (2017). E-Commerce News Europe. https://ecommercenews.eu/dhl-tests-cargo-bicycles-germany-netherlands/

Environmental Protection Agency. (2007). *The Plain English Guide to the Clean Air Act*. Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/peg.pdf

Environmental Protection Agency. (2016). *EPA identifies noise levels affecting health and welfare*. https://archive.epa.gov/epa/aboutepa/epa-identifies-noise-levels-affecting-health-and-welfare.html

Environmental Protection Agency. (2017). *Progress Cleaning the Air and Improving People's Health*. http://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health#cars

Environmental Protection Agency. (May 26, 2021). *Particulate Matter (PM) Pollution*. Retrieved March 2, 2022 from https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

EPA. (2021). *Understanding Emission Sources Helps Control Air Pollution*. Retrieved July 26, 2021 from https://gispub.epa.gov/air/trendsreport/2021/#air_trends

European Cycle Logistics Federation. (2015). Cyclelogistic moving Europe forward. *Austrian Mobility Research*.

Federal Highway Administration, U. S. D. o. T. (2010). *United States Department of Transportation Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations*. https://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/policy_accom.cfm

Fikar, C., Hirsch P. & Cronalt M. (2018). A decision support system to investigate dynamic last-mile distribution facilitating Cargo-Bikes. *International Journal of Logistics*, *21*(3), 300-317.

Fishman, E., Schepers, P., & Kamphuis, C. B. (2015). Dutch Cycling: Quantifying the Health and Related Economic Benefits. *Am J Public Health*, *105*(8), e13-15. https://doi.org/10.2105/AJPH.2015.302724

Fondation Solidarite. (2015). *La Petite Reine on a Bike on the Road to Employment*. http://www.citizen-commitment.com/en/citizen-commitment/news/19/la-petite-reine-on-a-bike-on-the-road-to-employment

Gantz, T., De La Garza, E. J., Ragland, D. R., & Cohen, L. (2003). Traffic safety in communities of color.

Gonzalez, P. A., Minkler, M., Garcia, A. P., Gordon, M., Garzon, C., Palaniappan, M., . . . Beveridge, B. (2011). Community-based participatory research and policy advocacy to reduce diesel exposure in West Oakland, California. *Am J Public Health*, *101 Suppl 1*, S166-175. https://doi.org/10.2105/AJPH.2010.196204

Gruber, J., Kihm, A. (2015). Reject or embrace? Messengers and electric cargo bikes.

Gruber, J., Narayanan, S. (2019). travel time differences between cargo cycles and cars in commercial transport operations. *Transportation Research.*

Haag, M., & Hu, W. (2019). Park It, Trucks: Here Come New York's Cargo Bikes. *The New York Times*. https://www.nytimes.com/2019/12/04/nyregion/nyc-cargo-bikes-delivery.html

Haake, D. (2020). COVID-19: Impacts on Freight Transportation. *Institute of Transportation Engineers Journal*, *90*(11).

Hammer, M. S., Swinburn, T. K., & Neitzel, R. L. (2014). Environmental noise pollution in the United States: developing an effective public health response. *Environ Health Perspect*, *122*(2), 115-119. https://doi.org/10.1289/ehp.1307272

Han, I., Samarneh, L., Stock, T. H., & Symanski, E. (2018). Impact of transient truck and train traffic on ambient air and noise levels in underserved communities. *Transportation Research Part D: Transport and Environment*, *63*, 706-717.

Hartmann, D., Wallace, J., Limpsasuvan, V., Thompson, D., & Holton, J. (2000). Can ozone depletion and global warming interact to produce rapid climate change? *Proceedings of the National Academy of Sciences*, *97*(4), 1412-1417. https://doi.org/DOI:10.1073/pnas.97.4.1412

Health Effects Institute. (2010). *Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects* (17). https://www.healtheffects.org/system/files/SR17TrafficReview_Exec_Summary.pdf

Holguín-Veras, J., Lawson, C., Wang, C., Jaller, M., González-Calderón, C., Campbell, S., & Ramirez-Ríos, D. (2017). Using commodity flow survey microdata and other establishment data to estimate the generation of freight, freight trips, and service trips: guidebook.

Hull Grasso, S., Barnes, P., & Chavis, C. (2020). Bike Share Equity for Underrepresented Groups: Analyzing Barriers to System Usage in Baltimore, Maryland. *Sustainability*, *12*(18), 7600. https://www.mdpi.com/2071-1050/12/18/7600

Hurtley, C., & World Health Organization. Regional Office for Europe. (2009). *Night noise guidelines for Europe*. World Health Organization Europe. http://www.euro.who.int/%5F%5Fdata/assets/pdf%5Ffile/0017/43316/E92845.pdf; http://www.euro.who.int/Document/E92845.pdf

Jacobsen, P. L. (2015). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury prevention*, *21*(4), 271-275.

Jorna, R., Mallens, M., & B. V., M. (2013). Promoting electric bikes and scooters for delivery of goods and passenger transport in urban areas. *Intelligent Energy Europe*.

Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. *Environ Pollut*, *151*(2), 362-367. https://doi.org/10.1016/j.envpol.2007.06.012

Keall, M. D., Shaw, C., Chapman, R., & Howden-Chapman, P. (2018). Reductions in carbon dioxide emissions from an intervention to promote cycling and walking: A case study from New Zealand. *Transportation Research Part D: Transport and Environment*, *65*, 687-696.

Kim, J. K., Ulfarsson, G. F., Shankar, V. N., & Kim, S. (2008). Age and pedestrian injury severity in motor-vehicle crashes: a heteroskedastic logit analysis. *Accid Anal Prev*, *40*(5), 1695-1702. https://doi.org/10.1016/j.aap.2008.06.005

Koning, M., & Conway, A. (2016). The good impacts of biking for goods: Lessons from Paris city. *Case Studies on Transport Policy*, *4*(4), 259-268. https://doi.org/https://doi.org/10.1016/j.cstp.2016.08.007

Lau, V., Martien, D., & Fairley, D. (2009). *West Oakland Truck Survey*. https://www.baaqmd.gov/~/media/files/planning-and-research/care-program/final-west-oakland-truck-survey-report-dec-2009.pdf

Lennard, S. H. C. (2019). Livable Cities: Concepts and Role in Improving Health. In M. Nieuwenhuijsen & H. Khreis (Eds.), *Integrating Human Health into Urban and Transport Planning: A Framework* (pp. 51-71). Springer International Publishing. https://doi.org/10.1007/978-3-319-74983-9_4

Lenz, B., & Riehle, E. (2013). Bikes for urban freight? Experience in Europe. *Transportation Research Record*, 2379(1), 39–45.

Lin, S., Bard, J. F., Jarrah, A. I., Zhang, X., & Novoa, L. J. (2017). Route design for last-in, first-out deliveries with backhauling. *Transportation Research Part C: Emerging Technologies*, *76*, 90-117.

Lipigas. (2015). *Quienes Somos*. https://www.lipigas.cl/empresas/quienes-somos.html

Liu, C., Chen, R., Sera, F., Vicedo-Cabrera, A. M., Guo, Y., Tong, S., . . . Kan, H. (2019). Ambient Particulate Air Pollution and Daily Mortality in 652 Cities. *N Engl J Med*, *381*(8), 705-715. https://doi.org/10.1056/NEJMoa1817364

MacIver, L. (2019). *AB617 in West Oakland Community-Based Air Pollution Abatement Planning*. Goldman School of Public Policy Environmental Center, University of California, Berkeley. https://www.baaqmd.gov/~/media/files/ab617-community-health/west-oakland/final_ab-617-in-west-oakland-pdf.pdf?la=en&rev=38499a739e29437b810741e80e2e86b7

MacIver, L., London, J., Sampson, N., Gordon, M., Grow, R., & Eady, V. (2022). West Oakland's Experience in Building Community Power to Confront Environmental Injustice Through California's Assembly Bill 617. *American Journal of Public Health*, *112*(2), 262-270.

Maizlish, N., Woodcock, J., Co, S., Ostro, B., Fanai, A., & Fairley, D. (2013). Health cobenefits and transportation-related reductions in greenhouse gas emissions in the San Francisco Bay area. *Am J Public Health*, *103*(4), 703-709. https://doi.org/10.2105/AJPH.2012.300939

Markham, D. (2017). *Treehugger*. http://www.treehugger.com/bikes/oslo-norway-giving-residents-1200-toward-purchasingelectric-cargo-bike.html

Matz, C. J., Egyed, M., Hocking, R., Seenundun, S., Charman, N., & Edmonds, N. (2019). Human health effects of traffic-related air pollution (TRAP): a scoping review protocol. *Syst Rev*, *8*(1), 223. https://doi.org/10.1186/s13643-019-1106-5

Maus, J. (2013). *Bike Portland*. https://bikeportland.org/2012/06/26/e-assist-cargo-bikes-miss-out-on-ev-truck-incentiveprogram-73882

McCann, B., & Rynne, S. (2010). Complete Streets: Best Policies and Implementation Practices. *American Planning Association*.

McCartney, K. (2016). Cargo Bike Sharing Programs in Europe. http://www.shareable.net/blog/8-cargo-bike-sharing-programs-in-europe

McNeil, N., Dill, J., MacArthur, J., Broach, J., & Howland, S. (2017). Breaking barriers to bike share: Insights from residents of traditionally underserved neighborhoods.

Melo, S. & Baptista, P. (2017). Evaluating the impacts of using Cargo Cycles on Urban Logistics: Integrating traffic, environmental and operational boundaries. *European Transportation Research*.

Messier, K. P., Chambliss, S. E., Gani, S., Alvarez, R., Brauer, M., Choi, J. J., . . . Lunden, M. M. (2018). Mapping air pollution with Google Street View cars: Efficient approaches with mobile monitoring and land use regression. *Environmental science & technology*, *52*(21), 12563-12572.

Mid Ohio Regional Planning Commission. (2012). *Complete Street Toolkit*. Retrieved from https://www.morpc.org/wordpress/wp-content/uploads/2017/12/CS_Toolkit_Web_Lo_Res.pdf

Mizdrak, A., Blakely, T., Cleghorn, C. L., & Cobiac, L. J. (2019). Potential of active transport to improve health, reduce healthcare costs, and reduce greenhouse gas emissions: A modelling study. *PLoS One*, *14*(7), e0219316. https://doi.org/10.1371/journal.pone.0219316

Morris, J. A. (2010). Design with the Majority: The Collaborative Design of a Cargo Bicycle for Uganda. In VentureWell. Proceedings of Open, the Annual Conference (p. 1). National Collegiate Inventors & Innovators Alliance.

Murray, D. C., Williams, N. J., Weakley, T., & King, A. (2021). *COVID-19 Impacts on the Trucking Industry* Transportation Research Board 100th Annual Meeting, Washington, D.C.

My Amsterdam Bike. (2016). *MyAmsterdamBike.com*. http://myamsterdambike.com/5-businesses-embracing-cargo-bike/

Narain, U., & Sall, C. (2016). *Methodology for Valuing the Health Impacts of Air Pollution: Discussion of Challenges and Proposed Solutions*. World Bank. https://openknowledge.worldbank.org/handle/10986/24440

New York City Department of Transportation. (n.d). *Safe Bicycling in New York City*. https://www1.nyc.gov/html/dot/downloads/pdf/bicyclerules-english.pdf

New York City Department of Transportation. (2021). *Commercial Cargo Bicycle Pilot A New Mode for Last Mile Deliveries in NYC Evaluation Report*. https://www1.nyc.gov/html/dot/downloads/pdf/commercial-cargo-bicycle-pilot-evaluation-report.pdf

New York State Department of Transportation. (2022). Complete Streets. Retrieved March 1, 2022 from https://www.dot.ny.gov/programs/completestreets

Orchard, K., & Cluzel, C. (2018). Cycle Freight Study. An Independent Study Commissioned by Transport for London. *Element Energy, Cambridge*, 1-33.

Patterson, R. F., & Harley, R. A. (2019). Effects of Freeway Rerouting and Boulevard Replacement on Air Pollution Exposure and Neighborhood Attributes. *Int J Environ Res Public Health*, *16*(21). https://doi.org/10.3390/ijerph16214072

Pucher, J., & Buehler, R. (2008). Cycling for Everyone: Lessons from Europe. *Journal of the Transportation Research Board*, *2074*, 58-65.

Quijano, T. (2011). *The EU Meets to Discuss How to Promote Cargo Cycling*. http://thecityfix.com/blog/the-eu-meets-to- discuss-how-to-promote-cargo-cycling/

Ren, R., Hu, W., Dong, J., Sun, B., Chen, Y., & Chen, Z. (2019). A Systematic Literature Review of Green and Sustainable Logistics: Bibliometric Analysis, Research Trend and Knowledge Taxonomy. *Int J Environ Res Public Health*, *17*(1). https://doi.org/10.3390/ijerph17010261

Rojas-Rueda, D., de Nazelle, A., Tainio, M., & Nieuwenhuijsen, M. J. (2011). The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *British Medical Journal*, *343*.

Rough Guides Ltd. (2015). *Getting Around*. http://www.roughguides.com/destinations/south-america/bolivia/getting-around/

San Francisco Planning Department. (2022). *San Francisco General Plan: Air Quality Element*. https://generalplan.sfplanning.org/I10_Air_Quality.htm

Schliwa, G., Armitage, R., Aziz, S., Evans, J., & Rhoades, J. (2015). Sustainable city logistics—Making cargo cycles viable for urban freight transport. *Research in Transportation Business & Management*, 50-57.

Schwela, D., & Wiele, V. D. (2009). *Air Quality Management: Sustainable Transport: A Sourcebook for Policy Makers in Developing Cities*. http://www.sutp.org/files/contents/documents/resources/A_Sourcebook/SB5_Environment%20and%20Health/GIZ_SUTP_SB5a_Air-Quality_EN.pdf.

Sheth, M., Burina, P, Good Child, A & McCormeet E. (2019). Measuring delivery route cost tradeoffs between effective-assist Cargo Bicycles and delivery trucks in dense urban areas. *European Transport Research*.

Simoni, M., Baldacci, S., Maio, S., Cerrai, S., Sarno, G., & Viegi, G. (2015). Adverse effects of outdoor pollution in the elderly. *J Thorac Dis*, *7*(1), 34-45. https://doi.org/10.3978/j.issn.2072-1439.2014.12.10

Smart Growth America. (2017). *Integrating Complete Streets, Vision Zero and Transportation Equity, Webinar Recap.* https://smartgrowthamerica.org/integrating-complete-streets-vision-zero-transportation-equity-webinar-recap/

Southerland, V. A., Anenberg, S. C., Harris, M., Apte, J., Hystad, P., Donkelaar, A. V., . . . Roy, A. (2021). Assessing the Distribution of Air Pollution Health Risks within Cities: A Neighborhood-Scale Analysis Leveraging High-Resolution Data Sets in the Bay Area, California. *Environmental health perspectives*, *129*(3), 037006. https://doi.org/doi:10.1289/EHP7679

Tainio, M., de Nazelle, A. J., Götschi, T., Kahlmeier, S., Rojas-Rueda, D., Nieuwenhuijsen, M. J., & Woodcock, J. (2016). Can air pollution negate the health benefits of cycling and walking? *Preventive medicine*, *87*, 233-236.

Tschofen, P., Azevedo, I. L., & Muller, N. Z. (2019). Fine particulate matter damages and value added in the US economy. *Proc Natl Acad Sci U S A*, *116*(40), 19857-19862. https://doi.org/10.1073/pnas.1905030116

United States Department of Energy. (2012). *Maps and Data - Types of Vehicles by Weight Class*. https://afdc.energy.gov/data/10381

United States Department of Tranpsortation. (2018). *United States Department of Transportation Noise Map*. https://maps.bts.dot.gov/arcgis/apps/webappviewer/index.html?id=a303ff5924c9474790464cc0e9d5c9fb

United States Federal Highway Administration. (2017). *National Household Travel Survey*. https://nhts.ornl.gov/

Utz, L., & Currie, M. (2008). *Coffee Cargo Bikes in Rwanda* http://usingbicycles.blogspot.co.uk/2008/07/video-hauling-coffee-in-rwanda.html

Vuori, I. (2007). Physical activity and health: Metabolic and cardiovascular issues. *Advances in physiotherapy*, *9*(2), 50-64.

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