1. The challenges of freight transport in cities

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INTRODUCTION

Large cities – particularly global cities – are the economic engines of the global economy. They are simultaneously financial and knowledge centres, gateways for international merchandise trade, and logistics hubs in the global freight network. As places of large populations and economic activity, cities are also vast local producers and consumers of goods, from automobiles to laptops to food and clothing. Cities are therefore dependent upon an efficient goods movement system. At the same time, goods movement generates serious externalities in the form of air pollution, greenhouse gas (GHG) emissions, congestion, crashes, and noise.

Urban freight activity is growing and will continue to grow because of continued globalization and urbanization, rising per capita income, and the growth of e-commerce. For example, US freight tonnage is expected to increase by about 1.2% per year through 2045, an increase of 37% from 2018. Cities are increasingly challenged to effectively manage freight demand and reduce its negative impacts.

With increasing urban freight flows come increased visibility of freight, conflicts with passenger demand, and public demands to solve freight problems. The twenty-first century has been a period of recognizing freight as an urban problem, research to understand urban freight dynamics, and extensive policy experimentation to mitigate urban freight problems. Nearly a decade ago, Giuliano and colleagues wrote a comprehensive assessment of urban freight research (Giuliano et al., 2013). It presented the major problems of urban freight and inventoried the many policy strategies either implemented or explored to address them. This 2013 assessment provides an appropriate baseline to address urban freight challenges a decade later. This chapter discusses what we have learned about urban freight and how freight problems have changed. It serves as an introduction for many of the following chapters in this Handbook.

This chapter is organized as follows. The chapter begins with the current state of knowledge of urban freight challenges. We document the overall increase in freight activity, and then discuss congestion, air pollution, traffic safety, and noise. We conclude that the problems identified a decade ago continue, though sometimes at different magnitudes or forms. In addition, a new problem has emerged: environmental justice, the disproportionate burden low-income and often minority populations experience as a result of freight-related externalities. We then discuss explanations for urban freight problems. We distinguish between last mile activity and freight flows associated with international trade, termed trade node problems. The focus for last mile problems is the rise in e-commerce and its associated impacts on supply chains and delivery patterns. Trade-related freight has not undergone such dramatic changes, but the overall increase in trade generates more congestion and pollution, while new technologies and automation suggest future structural changes. The last section of the chapter presents some concluding observations.
CURRENT STATE OF KNOWLEDGE

We begin this section with what we know about urban freight. Unfortunately, lack of consistent and comparable freight data at the sub-metropolitan level continues to be a constraint on research in this field. In general, as urbanization continues and per capita incomes rise, we can expect consumer demand for physical products to increase, leading to more freight movements. Here we provide a few statistics.

**Growth in Urban Freight Volumes**

A source for nationwide truck data in the US is the Federal Highway Administration’s (FHWA) Highway Statistics Series. It provides data on the urban portion of the National Highway System (NHS) by vehicle type. It has some major limitations: the national highway system is a small subset of urban roads, and light trucks used for commercial purposes cannot be separately identified. However, there are no comparable data for urban roads. FHWA data indicate that light-duty vehicles account for about 92% of vehicle miles travelled (VMT) on the urban portion of the NHS. Trucks account for 7% and other vehicles (e.g. motorcycles, buses) account for the remaining 1%.

Figure 1.1 shows the growth of vehicle miles travelled on urban highways from 2010 to 2019, the latest year for which data are available. The figure is indexed because the scale of car travel is so much greater than truck travel. Light-duty vehicles represent all vehicles, whether private or commercial, of less than 10,000 pounds gross vehicle weight (GVW). All trucks include vehicles with six tyres or more and at least 10,000 GVW; heavy trucks include combination trucks. Within the truck categories, travel of all trucks increased about as much as light-duty vehicles, and much more than heavy trucks, suggesting relatively more local (last mile) truck travel. More local truck travel is consistent with the rise in e-commerce.

**Urban Freight Externalities**

Giuliano et al. (2013) identified the following problems associated with urban freight: air pollution, congestion, safety, parking and circulation, and noise. A decade later, these problems still exist. The spatial distribution of these externalities has led to the recognition of another problem, environmental justice.

**Air pollution**

Air pollution is arguably the most critical freight externality. Air pollution is not only a major problem in urban freight, but a growing problem as countries employ more aggressive efforts to reduce greenhouse gas (GHG) emissions. In this section, we discuss both air toxics and GHGs.

Trucks account for a significant share of air toxics. Table 1.1 gives emissions data for nitrogen oxides (NOx), volatile organic compounds (VOC), and particulate matter smaller than 10 microns (PM10) or smaller than 2.5 microns (PM2.5) for the US. The transport sector accounts for nearly 60% of emissions of NOx and 22% of VOC, the precursors to ozone. Trucks account for about one-third of the transport share of air pollutants. Due primarily to regulation of engines and fuels, emissions of all air toxics have declined steadily since 2000. However, trade facilities remain ‘hot spots’ due to the intensity of truck and rail traffic.
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The air toxics most damaging to human health are small particulates and ozone, which is a product of NOx and VOC. Small particulate matter (PM2.5) is a well-documented health hazard. Long-term health studies demonstrate that exposure to small particulates increases risk of both mortality and morbidity from asthma, other lung diseases, and cardiovascular disease (e.g. Bose et al., 2015; Di et al., 2017; Madrigano et al., 2013). Recent research has identified a possible link to cognitive impairment as well (Yu et al., 2019). See Chapter 23 (McKinnon) for further discussion.

With the threats of global climate change becoming reality, there is increasing policy interest in reducing GHGs from all sectors. Over the past decade, global GHG emissions have grown about 1% annually. High-income regions, including the US, EU-28, Japan, and South Korea have reduced GHG emissions, while fast-growing developing countries have increased GHG emissions. The transport sector accounts for 21% of all global GHG emissions, and...
global transport emissions continue to increase. Within the transport sector, road passenger transport accounts for the largest share, followed by freight road transport (Figure 1.2).

GHG emission reductions from the transport sector are difficult to achieve due to the dependence of this sector on high-energy density fuels. Heavy vehicles – notably, heavy trucks, locomotives, and aeroplanes – are the most challenging, because of the energy required to move them. As light-duty vehicles become cleaner and switch to alternative fuels, the share of GHGs from freight transport will increase. Policy efforts to reduce transport sector GHG emissions are numerous and include operational efficiency, fuel efficiency, shifts to more energy-efficient modes, and efforts to manage freight demand. For more on this subject, see Chapters 2 (Holguin-Veras et al.) and 23 (McKinnon) in this volume.

Congestion
There are several commercial providers of urban congestion metrics, notably TomTom and Inrix, that track traffic levels annually for metropolitan areas around the world. These indices show that traffic congestion increased consistently until the occurrence of COVID-19 pandemic-related business interruptions and stay-at-home orders. Traffic has gradually increased in countries where the pandemic has waned. However, these indices do not separate out truck traffic.

One consistent source of truck-related congestion in the US comes from the American Trucking Research Institute (ATRI). It conducts a bottleneck study each year. It uses GPS data from participating trucking firms to estimate travel delay at 300 ‘freight-significant’ highway locations around the US. Locations are ranked on total estimated truck delay. Thus, locations with the same level of speed delay will rank differently based on the volume of trucks. The top 100 bottlenecks are identified each year. We selected the 25 top-ranked bottlenecks in 2009, 2015, and 2019 to compare congestion levels over time (Table 1.2). As measured by daily and peak average speed, congestion at these bottlenecks has increased over time.
The rankings are somewhat fluid. Of the top 25 bottlenecks in each of these years, ten appear in all three years, and six appear in two of the three years. The ten that appear in all three years tend to be major freeway-to-freeway interchanges where at least one of the freeways connects ports or industrial zones and intermodal facilities. Some are in downtown areas where overall congestion is high.

**Safety**

The main US national sources for information on truck-involved crashes are the National Highway Safety Administration (NHTSA) and the Federal Motor Carrier Safety Administration (FMCSA). Figure 1.3 shows the location of fatal truck-involved crashes in 2009, 2012, 2015,
and 2018. Fatal crashes continue to increase in frequency, and crashes in urban areas have increased more than crashes in rural areas. Thus, urban crashes constitute a growing share of the total. Truck-involved crashes have increased most on other roads – arterials and minor roads – suggesting more safety conflicts in urban areas. Pedestrian and bicyclist injuries and fatalities are of particular concern for urban freight. While the number of pedestrians killed in large truck crashes has increased, the share of fatalities has remained stable at 6–7%.

National statistics give information on trends, but do not reflect the effects of truck-involved crashes on local communities. We examined truck-involved crashes in a low-income majority-minority area in Los Angeles, Southeast Los Angeles (SELA). The SELA area includes industrial zones and warehouse clusters and is traversed by the major freeway route linking the Los Angeles and Long Beach ports to intermodal facilities in central Los Angeles. Of the Los Angeles region’s approximately one million daily truck trips, about 20% start, end, or go through the SELA area. We used heavy-duty truck crash data from 2015 through 2018 to examine crash patterns. We found that the SELA area has a higher rate of heavy truck crashes on a per square mile basis than Los Angeles County (11.4 vs 2.0 per square mile), and a slightly higher share of fatalities (3.2 vs 2.9%). About 55% of all crashes occurred on local streets. On average, four people were killed and 127 injured per year by trucks on city streets. A small number of crashes involved pedestrians (25 of 407, i.e., 6%) but crashes involving pedestrians made up 38% of the fatal accidents. Of these pedestrian accidents, 42% occurred at legal intersections. Crash risk affects choices of travel mode and route and reduces community quality of life.

Parking and circulation
Parking and circulation problems have increased as a result of more e-commerce-related activity, as well as local planning efforts to promote transit and non-motorized modes. E-commerce will be discussed in a later section of this chapter and in Chapters 19 (Jaller et al.) and 21 (Gatta et al.).

Cities around the world are engaging in transportation planning strategies to restrict motorized vehicles and provide more space for public transport and use of non-motorized modes. The concept of ‘Complete Streets’ exemplifies these efforts. Complete streets reduce space for private vehicles and increase space for bike lanes and sidewalks. The logo from the Massachusetts Department of Transportation (Figure 1.4) is illustrative. It notes that ‘complete streets are for everyone’, but there is no delivery vehicle in the figure. Complete street planning tends to ignore local freight demands; truck parking and loading zones may not be incorporated. The result is conflict among street users. One example is the complete street near the author’s university campus. Figure 1.5 shows a delivery truck parked in the bike lane, forcing bike riders into the general traffic lane.

These conflicts also have safety consequences. Conway et al. (2016) examined the impacts of locating bicycle lanes on truck routes in New York City. The study showed that bicycle-commercial vehicle collisions, though rare, occurred disproportionately where bike lanes were located on truck routes.

Conway et al. (2018) conducted a comprehensive study of complete streets and freight and found a number of issues. With regard to driving to and from delivery stops, the study found conflicts with other users (e.g. buses), and difficulties manoeuvring narrow intersections, speed bumps, and street access. With regard to parking and loading, there are problems with parking and loading zones, as well as safe paths to buildings and sidewalks. The study recommends a number of solutions. Examples include shared parking and loading areas, right-of-way loading
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Noise
The final externality identified in the 2013 report is noise. Noise, loosely defined as an undesirable sound, is part of urban life. Long-term exposure to noise above 75 decibels (dB) can cause hearing loss and may affect both physical and mental health. Road noise accounts for a large share of urban noise, and heavy trucks generate a large proportion of road noise. A busy highway may generate 70 dB, trucks 90 dB, and an aircraft at take-off 120 dB (Rodrigue, 2021). The US Bureau of Transportation Statistics provides a national noise map, with estimates of noise from roads, highways, rail lines, and airports. Airports generate the most noise and rail lines generate more noise than highways. In the US, rail lines carry mostly freight, even in metropolitan areas. Noise maps illustrate both the geographic extent and the level of noise from transport experienced in metropolitan areas.3 With truck traffic growing each year, we can expect that noise pollution will continue to be a problem in urban freight.

Environmental justice
Our 2013 analysis did not explicitly address environmental justice, though there was growing evidence that the negative impacts of urban freight are not equitably distributed across metropolitan areas. Environmental justice concerns and our understanding of harms generated have increased over the past decade. Residential neighbourhoods located near intermodal facilities, warehouse clusters, or major rail or highway corridors tend to be low-income neighbourhoods and communities of colour. These areas are often pollution hot spots. As noted earlier, air pollution, especially small particulates, has serious negative impacts on human health.

There is extensive research documenting higher exposure levels among low-income communities and/or people of colour. Here are just a few examples. Miranda et al. (2011) conducted a national study of the US to estimate exposure to PM2.5 and ozone. They found that non-Hispanic blacks were consistently over-represented in places with the worst air quality. Bravo et al. (2016) used a measure of racial isolation (extent to which minority populations are exposed only to each other) to examine long-term PM2.5 and ozone exposure in the eastern US. They found that racial isolation is associated with higher levels of exposure in cities, suburbs, and rural areas. Yu et al. (2020) conducted a study of commuters in Beijing. Using mobile phone data, commuter locations were tracked throughout the day and local exposure to PM2.5 was estimated. Using housing price as a proxy for income, they found that pollution exposure at home was greater for lower-income households.
A fundamental issue in environmental justice is the relationship between property prices and air pollution or other negative externalities. Air quality is capitalized into land values: property buyers or renters are less willing to pay for locations with excessive air pollution, noise, or other hazards (e.g. Chay & Greenstone, 2005; Huang & Lanz, 2018). Thus, residential areas located near ports or rail terminals have lower rents and are more affordable to low-income populations. Therefore, it might be argued that low-income households are making a rational choice, trading off the PM2.5 exposure for better housing.

A critical question is whether low-income or minority households in fact have a choice. In the US, a history of discriminatory practices in the housing market and the lack of public or subsidized housing suggests no. There is broad evidence that low-income, immigrant, or other minoritized groups experience discrimination in housing or employment that results in disproportionate exposure to environmental hazards (e.g. Toussaint, 2021; Boone & Fragkias, 2013; Hajat et al., 2015). In countries with less discrimination and more supportive housing policies the answer may be different.

A second question is whether these spatial patterns simply evolved over time – for example, as ports or intermodal yards expanded, their impact grew, leading to lower rents and more low-income households in the surrounding areas – or whether polluting facilities choose to locate in low-income communities. Warehouse location in the Los Angeles region offers an interesting case study.

The environmental justice literature offers three possible explanations for why warehousing and low-income households are co-located (Mohai & Saha, 2007; Mohai et al., 2009). First, warehouse developers prefer places with cheap land and low-wage labour, and these places are often where poor or minority people are concentrated. Second, disadvantaged populations are...
less politically empowered, and hence less able to prevent the development of locally undesir-
able land uses. Third, discrimination in the housing market has constrained housing choices,

Yuan (2021) conducted a study of warehouse location changes in the Los Angeles region from 2000 to 2010. Prior research revealed the co-location of warehousing and minority populations (Giuliano & Yuan, 2017). He compared shifts in warehouse location to changes in population. He found that warehousing activity is more likely to be located near minority neighbourhoods, but not necessarily low-income minority neighbourhoods, likely because of land availability. To answer the question of whether minority populations follow warehousing or the reverse, he estimated a causal model. Results showed that warehouses follow minority populations.

Part of the solution to environmental justice problems is to mitigate the negative externality. In the case of air pollution, government regulation of vehicle emissions has resulted in major air quality improvements in higher-income countries. Nevertheless, hot spots remain, and many large cities continue to experience unhealthful levels of air pollution. The more difficult part of environmental justice is addressing discrimination that systematically disadvantages people on the basis of income, race, religion, or another factor.

EXPLAINING URBAN FREIGHT PROBLEMS

We have now identified the main problems associated with urban freight. The next step is to explain why they exist. To understand urban freight challenges, it is helpful to understand the types of urban freight activity.

Metropolitan freight activity is best understood as two main types: freight related to local supply and demand, and freight related to national or international trade. Freight related to local supply and demand is largely a function of population and employment; freight related to global trade depends on a city’s role in the global trade system.

Urban Freight Related to Global Trade

Large metropolitan areas are the major nodes of the global production network, containing the largest ports, airports, and intermodal facilities. In the United States, 87% of total exports come from metropolitan areas, defined as places with a population of over 50,000. In addition, the top 40 metropolitan areas accounted for about two-thirds of total exports in 2019 (US Census, Foreign Trade Statistics, 2021). Rodrigue (2004) notes that gateway cities are usually located in 'mega-urban regions', through which logistics functions are geographically and functionally integrated at the local, regional, and global levels. These regions developed historically as points of trade. With large and concentrated population and economic activity, they generate much of the trade demand and provide the array of expertise for managing global supply chains.

Globalization has been facilitated by transportation and communications technology as well as trade liberalization policies (Dicken, 2011). Goods production processes – spatially fragmented but temporally integrated – connect countries and cities into ‘global production networks’, demanding cost-efficient and timely flow of goods (Capineri & Leinbach, 2007). This has resulted in consistent growth in cross-border trade for the past several decades. In the US, total imports more than doubled from 2000 to 2019, whereas total exports grew by 133% (US Census, Foreign Trade Statistics, 2021). The extent to which globalization will continue
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to grow is uncertain. The 2020 global pandemic revealed the vulnerability of global supply chains that could result in restructuring within smaller geographies. Although it will take some time for pandemic impacts to be understood, it seems reasonable to assume that the level of globalization is less likely to change than regional trade patterns.

Urban Freight Related to Last Mile

Freight associated with local supply and demand is typically termed ‘last mile’ as it represents the last (or first) link in supply chains. ‘Last mile’ includes delivery or pickup of imports/exports, intra-metropolitan trade of commodities (local production and consumption), deliveries to or from retailers, etc. Freight related to local supply and demand is increasing for several reasons, including increasing consumer demand and the rise in e-commerce and its impacts on supply chains and distribution patterns.

What is driving increased consumer demand?
The resident population consumes food, clothing, and shelter, generating the demand for consumer goods and services that now account for nearly 70% of US economy gross domestic product (GDP). As per capita income increases, so does consumption. As households get richer, the demand for higher quality and more diverse commodities increases. Historically, the rise in consumption has been evidenced by the emergence of supermarkets, shopping malls, specialty shopping districts, and, later, big-box retail and ‘lifestyle’ shopping centres. Housing consumption also increases with increased per capita income. In the US, the average size of a new single-family home increased by 51% from 1973 to 2019. As dwelling size increases, so does the demand for more household goods.

Rodrigue (2021) categorizes consumer-based goods distributions based on supply chain and distribution patterns (Figure 1.6). It can be seen that there is great variety in the frequency of deliveries, delivery locations, parking and loading facilities, and distribution networks.

Personal consumption is not the only source of freight demand in cities. Construction activity is a constant in any city. Building materials and equipment are shipped to construction sites, and waste material is carted away. Utility systems must be maintained and repaired, and refuse must be removed from residences and commercial sites. Reverse logistics is the term used for the return of transformed goods as well as returns from online consumption activity.

Finally, cities are also nodes of production, and production generates another dimension of freight demand. Manufacturing – from automobiles to computer chips – creates products for export out of the local area. Cities with a large manufacturing presence typically have large associated rail and truck flows. Professional service activities, for example real estate, finance, or medical services, generate a different type of demand: office supplies, computer hardware and software, medical supplies, often in small and frequent deliveries. The geography of city flows is a function of industry mix as well as population characteristics and metropolitan size.

Why are last mile problems more prevalent in city cores?
Last mile problems tend to be more severe in city cores, where development density is high and street space is limited. To better understand the city core problem, it is helpful to consider how land price drives both location and consumption choices. Density of population, employment, or both is a proxy for urban form. Density reflects the value of land; as land value increases, so does rent, and as rent increases, space is more intensively used. Firms economize on space by
allocating less space per worker, as well as minimizing lobby and storage space. In the case of retailing, high land values necessitate more revenue per square foot, which means more rapid turnover of product, narrow aisles and tall shelves, as well as less space devoted to storage, compared with retail activities in lower-density environments. More intensive space utilization implies more delivery trips, all else being equal.

Households also economize on space in response to high land values. Dwelling units are smaller and inventory capacity is limited. There is less room to store food or linens. More shopping trips are taken by walking or public transit, constraining the amount of goods that can be carried home. Services conducted inside the home (e.g. clothes washing, food preparation) may be outsourced to cleaners and restaurants. This suggests that, controlling for demographic characteristics, households in high-density areas will shop more frequently, purchase in smaller lots, and consume more out-of-home services. The outcome of high land prices, then, is more frequent goods deliveries to offices, retailers, and service providers. Giuliano et al. (2016) conducted case studies of the Los Angeles and San Francisco metropolitan regions to explore the relationship between freight activity and urban density. They found a significant and positive relationship.

**Rise of e-commerce and instant deliveries**

Arguably the most significant change in last mile urban freight is the rapid growth of e-commerce. E-commerce is defined as any type of consumption that takes place via an online platform. The most common type of e-commerce is online shopping: consumers order and pay online, and the goods are delivered to the consumer’s residence. There are variations: the consumer may order online and pick up at a retail establishment, or at a local locker facility. E-commerce includes all types of consumption, from meal deliveries to cat litter or furniture purchases. The emergence of online shopping has transformed where and how goods are produced, distributed, and sold, and how consumers make shopping as well as shopping travel decisions (Mokhtarian, 2004). See Chapters 19 (Jaller et al.) and 21 (Gatta et al.) for a comprehensive discussion of e-commerce.
The rise in e-commerce has been rapid. In the US, the market share of online shopping has increased from about 3.7% in 2008 to 9.5% in 2018 and 13.5% in 2021. The annual rate of growth of online shopping sales has been around 11–13% since 2011, much greater than the rates for total retail sales, at 3–4% (US Census, 2019). The global market share of online shopping is estimated to be nearly 20% in 2021 with a value of nearly $5 trillion. China is by far the largest e-shopping market, accounting for about $2.8 trillion in purchases (Keenan, 2021). Growth of e-shopping accelerated during the COVID-19 pandemic. It remains to be seen whether the growth rate will slow as pandemic restrictions are removed.

Two hypotheses have been examined to explain the adoption of online shopping. The first is the diffusion of innovation. Those who are closest to the innovation are the first adopters. These tech-savvy people are more willing to take risks and experiment with the new technology. Once the technology is demonstrated to have benefits, others follow the lead and the technology spreads to the mainstream population. The second hypothesis is based on efficiency. Online shopping gives consumers more choices and more opportunities to obtain product information. Goods from faraway places can be obtained with a click of the mouse, not an hours-long journey (Farag, Schwanen et al., 2007; Anderson et al., 2003). Analyzing what influences consumers’ channel choice is fundamental to understanding the diffusion of online shopping (Maltese et al., 2021).

E-commerce is also changing rapidly. The variety of goods available continues to grow, and many new products have emerged, such as ingredients and instructions for home-prepared meals (e.g. Blue Apron) and subscription deliveries of frequently used products. Speed of delivery is also increasing. Large online retailers offer ‘instant deliveries’ (within two hours) in cities, and one-day delivery is now routine in many metropolitan areas. The growth of e-commerce has many impacts. Figure 1.7 shows how e-shopping has affected package delivery from 2004 to 2019. The bars show USPS mail volume; mail volume has declined consistently.

![Figure 1.7](Image)

Source: Rodrigue (2021), by permission

Figure 1.7 The growth of e-commerce: Mail carried by USPS and parcels carried by major carriers, US, 2004–2019
since 2007. The lines show parcel deliveries for UPS, USPS, FedEx, and Amazon. Total parcel deliveries have grown from 7.2 to 19.7 billion, a 174% increase. Clearly such shifts in consumer demand have significant impacts on both freight and passenger movements.

Dablanc and colleagues were among the first to track the growth of instant deliveries (Dablanc et al., 2017). Their focus was on app-based services that provide on-demand delivery usually within two hours. In contrast to the more conventional one- or two-day deliveries, instant deliveries may be performed by private individuals, independent contractors, or employees. Instant deliveries have led to restructured supply chains and emergence of new business models. Prepared food delivery is one example. ‘Ghost kitchens’, food preparation businesses with no on-site service have emerged to serve only the delivery market. These businesses tend to locate in industrial zones, hence changing geographic patterns of food deliveries. Delivery companies have added specialized food delivery services (e.g. UberEats), and in dense city cores these deliveries may be made by bicycle, scooter, car, or small truck. Market forecasts predict continued expansion and diversification of instant deliveries. Taken together, these trends suggest continued fragmentation of the goods supply chain, as more consumption is individualized and delivered to homes. Fragmentation in turn will generate more truck travel.

E-shopping and urban form

With the growth of e-shopping comes more deliveries in residential neighbourhoods, more competition for kerb space, and additional externalities. We expect online shopping frequency to be related to urban density. As noted above, shopping is more frequent in dense, urban environments. Under such circumstances, online shopping may be more attractive, especially for bulky or heavy standard products.

Table 1.3 gives information on online shopping behaviour from the US 2017 National Household Travel Survey. It includes respondents living in metropolitan areas with neighbourhood population density of at least 1,000 persons per square mile. Respondents were asked about the frequency of their online shopping. Those in the highest-density category have the lowest share of never shopping online and highest share of shopping online more than once per week. They also have the highest average monthly frequency. Note that the marked differences are between the high-density categories and the rest. From a density of 10,000 persons per square mile and below, the rate of online shopping is quite consistent. When we control for demographic characteristics, the effects of density are statistically significant only for the high-density category (Giuliano et al., 2016).

Competition and free delivery

Impacts of faster deliveries merit further discussion. E-shoppers have options: they can choose the speed of shipping (e.g. standard, two-day, next day, instant) and often the destination (e.g. residence, place of employment, pick-up station or locker, retail establishment). With all else being equal, as the speed of shipment increases, so does the cost of delivery, as products or packages are less likely to be bundled. Thus, the speed of shipment is an inverse proxy for efficiency of the freight delivery.

Currently the major e-retailers are competing on free shipping. When shipping is free, even for one- or two-day or instant deliveries, e-shoppers have no incentive to choose cheaper and slower shipping. Free shipping also incentivizes smaller volume purchases and more returns. As long as shipping is free, there is no reason to bundle purchases to save money. As long
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Table 1.3  Online shopping frequency and population density

<table>
<thead>
<tr>
<th>Residential Density (persons/square mile)</th>
<th>Sample</th>
<th>Frequency</th>
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<tr>
<td></td>
<td>Obs</td>
<td>Share (%)</td>
<td>Never (%)</td>
<td>Less than 1/week (%)</td>
<td>More than 1/week (%)</td>
<td>Average per month</td>
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<tr>
<td>High (&gt;25,000)</td>
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<td>3</td>
<td>36</td>
<td>37</td>
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<tr>
<td>Medium high (10,000–25,000)</td>
<td>8,081</td>
<td>9</td>
<td>40</td>
<td>38</td>
<td>22</td>
<td>2.91</td>
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<tr>
<td>Medium (4,000–10,000)</td>
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<td>21</td>
<td>40</td>
<td>40</td>
<td>20</td>
<td>2.66</td>
</tr>
</tbody>
</table>

Source: 2017 National Household Travel Survey

as returns are free, the shopper may purchase three different sizes of shirt, keep the one that fits and return the rest. Both free shipping and free return options are important for the competitiveness of online retailing, so it is not surprising that free shipping is so widely offered. However, free shipping, and especially free one- or two-day or instant shipping is a powerful force of fragmentation of purchases and deliveries, and hence a negative force on the efficiency of freight deliveries.

Of course, shipping is not free. To address the high cost of home delivery, carriers have experimented with alternative strategies to replace home delivery services. Delivery lockers and pick-up points are common in some countries in Europe. In the US, Amazon has implemented delivery lockers, and UPS is using ‘Access Points’. The purpose is to generate small clusters of deliveries, thus avoiding the additional costs of delivering to multiple single destinations. However, with free delivery available, there is little attraction for the customer to choose a locker pick-up. Studies show that about 90% of online shoppers request home deliveries in France. The estimate for UPS is 74% (Morganti et al., 2014). Whether online retailers will be able to continue to absorb shipping costs while maintaining a price advantage remains to be seen. Meanwhile, fragmentation of deliveries may be expected to continue.

Overall impact of e-shopping

The net effect of e-shopping remains uncertain. While delivering multiple packages via truck may be more efficient than several shoppers each making individual trips to purchase the same merchandise, it is doubtful that all individual shopping trips are eliminated. Some e-shoppers may browse in stores, shop both online and in-store, or substitute travel for other purposes. On the freight delivery side, it seems clear that e-shopping leads to more freight shipments. Online shopping requires delivery to a residence or a local, common pickup point. Small-scale deliveries (small packages in small trucks) are less efficient than the large-scale deliveries made to retail establishments. Although e-shopping eliminates at least some large-scale deliveries due to loss of in-store business, these losses will be more than offset by the added truck travel generated by small-scale deliveries. Efficiency of freight deliveries is further reduced by the rate of failed local deliveries and the higher rate of returns associated with online shopping. The outcome is increased truck travel. Finally, the trend of faster deliveries
(one- or two-day shipping, or ‘instant delivery’ within two hours) intensifies freight inefficiencies by prioritizing speed over larger loads, all else being equal. Understanding consumers’ preferences between online and offline is essential for estimating their ensuing transport and environmental implications (Marcucci et al., 2021).

**Strategies to reduce last mile problems**

Much of the remainder of this Handbook is devoted to solving last mile problems. I present only a brief review here. Last mile problems are often unique and highly localized, and hence typically require customized solutions. Very generally, mitigation strategies may be characterized as voluntary, regulatory, or technological. Often last mile problems do not fall neatly into one jurisdiction such as a municipality, and in some countries local authority is limited by state or federal law. Therefore, voluntary, collaborative industry–government partnerships are established to develop policies or guidelines, such as delivery hours or freight consolidation centres. Incentives may be offered to support off-hours deliveries or the use of low-emission vehicles. In such a context, a participatory planning approach, based on sound behavioural analyses, is needed to identify the most effective and accepted solutions (e.g. Gatta et al., 2019; Le Pira et al., 2017; Marcucci et al., 2017). See Chapters 2 (Holguin-Veras et al.), 9 (Lebeau et al.) and 13 (Delle Site) for more on these strategies.

When regulatory authority exists and the political environment is supportive, jurisdictions may impose regulations. Examples include low-emission zones, truck fees, or emission-reduction targets. Technology plays an important role not only in increasing the efficiency of urban freight but also in making it possible to manage existing street and kerb resources as efficiently as possible. For example, smart parking systems can provide information on space availability so that deliveries can be more efficiently planned. On the industry side, efforts to consolidate residential deliveries through lockers and pickup points are aimed at reducing costs and miles travelled. Section II of this Handbook provides many models and examples of last mile strategies.

**Trade Nodes**

Global trade generates another layer of freight and logistics demand to serve both local and non-local supply and demand. Whereas domestic freight flow per capita is fairly consistent across cities, international trade flow is concentrated in cities that serve as global trade hubs. Trade-related flows are regional, and therefore have impacts throughout metropolitan areas. Major facilities like ports or warehouse clusters are generators of heavy truck traffic, creating hot spots of congestion, air pollution, noise, and conflicts with passenger traffic. Highways that serve as main linkages with these facilities and the national network have greater concentrations of heavy trucks. Metropolitan areas that serve as major trade nodes have high volumes of both truck and rail traffic. High volumes of rail freight traffic contribute to congestion at rail crossings and conflicts with rail passenger services.

In contrast to the rapid increase in e-commerce around the world, global merchandise trade in 2019 was about $0.5 trillion dollars greater than in 2012 (unadjusted dollars). Trade declined by $1.5 trillion in 2020, reflecting the business interruptions associated with the COVID-19 pandemic (see Figure 1.8). Major changes in ocean carrier alliances, the use of ever-larger container ships, and tariff conflicts between the US and China have each played a role in the volatility of global trade. At the national and sub-national levels, changing supply
chains (e.g. migration of manufacturing to Southeast Asia) and competition among ports for large-ship business are leading to changes in ocean shipping flows. Supply chain disruptions during the pandemic may further affect supply chains as global producers seek more flexible and resilient product chains, which could mean geographically smaller and less dispersed production and distribution chains. The lack of dramatic growth in international trade suggests that trade node problems are much the same today as they were a decade ago.

**Congestion**

Last mile freight activity particularly impacts local roads, whereas trade-related goods movement impacts highways and road systems near major freight facilities. Last mile freight activity includes more light- and medium-duty trucks, whereas trade-related freight moves on rail and heavy-duty trucks. Port, airports, intermodal facilities, and warehouse clusters are attractors of heavy-duty trucks, and highways linking these facilities typically have higher-than-average shares of truck traffic. Heavy-duty trucks (HDTs) have a disproportionate impact on congestion due to both performance of the vehicles and avoidance behaviour of other drivers (Moridpour et al., 2015; Kong et al., 2016).

Although it is well understood that the performance characteristics and avoidance behaviour of other drivers cause HDTs to have a disproportionate impact on traffic, the extent to which truck traffic contributes to congestion and therefore delay of other vehicles is less well understood (Simoni et al., 2020). Giuliano et al. (2018) developed the concept of ‘freight impact area’, defined as segments of highways with high congestion and a high volume of

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**Figure 1.8   World Merchandise Trades, US $ million, 2012–2020**

*Source: WTO Open Data Portal*
trucks. The measure of impact is total peak hour delay for all vehicles. The measure was applied to the Los Angeles and San Francisco regions in California. Table 1.4 gives results for the top 15 freight impact areas in the Los Angeles region.

Together the top 15 freight impact areas account for 53,615 hours of vehicle delay each afternoon peak period per day. Over the course of a year, the delay would be about 14 million vehicle hours – substantial by any standard. We cannot distinguish what share of the delay is caused by trucks. However, we can say that congested locations with high proportions of trucks are associated with significant delays for both passenger and freight vehicles.

How trade-related freight affects metropolitan areas also depends on mode shares. In the US, rail carries over 40% of all freight ton-miles; in the EU-28, the share is around 17%. The vast majority of rail infrastructure in the US is owned by the freight rail carriers; urban passenger rail services typically lease access from the freight carriers to operate passenger service. This arrangement leads to conflicts between passenger and freight demands. Passenger service does not generate profits for the freight carrier and at the same time constrains freight operations. Road is the dominant mode for freight in the EU-28. Metropolitan and intercity rail passenger services in the EU-28 are far more developed than in the US, and rail ownership structures differ across countries, with the legacy of each nation having its own rail system helping to explain the dominance of road transport in the EU. Figure 1.9 shows mode shares for 2010, 2015, and 2018 for the US and 2010, 2015 and 2019 for the EU-28, respectively. Mode shares have remained relatively stable, but the trend is in the wrong direction from an energy efficiency perspective, as in both regions the road share is increasing.

### Warehousing and distribution facilities

A second aspect of trade-related impacts is the growth and evolution of warehouse and distribution facilities. Warehousing and distribution have been influenced by continued globalization, competition and restructuring of wholesaling and retailing, and technology. Rodrigue (2021) describes the shift from push to pull distribution systems, where products are delivered on an as-needed, just-in-time basis to minimize inventory holdings. The objective is velocity – move the item from production to sale as quickly as possible. These distribution systems have been complicated by e-shopping and short delivery times. Distribution centres must be close to the population served to provide short delivery times. At the same time, warehouse

**Table 1.4** Descriptive statistics of key variables of the top 15 freight impact areas on the National Highway System in the Los Angeles region

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (miles)</td>
<td>2.24</td>
<td>0.11</td>
<td>9.95</td>
</tr>
<tr>
<td>Average total volume per direction, PM Peak</td>
<td>43,241</td>
<td>32,529</td>
<td>61,762</td>
</tr>
<tr>
<td>Average truck volume per direction, PM Peak</td>
<td>3,252</td>
<td>2,594</td>
<td>4,062</td>
</tr>
<tr>
<td>Average share of trucks (%)</td>
<td>8.00</td>
<td>4.38</td>
<td>10.85</td>
</tr>
<tr>
<td>Congestion speed (miles/hour)</td>
<td>18.61</td>
<td>8.10</td>
<td>29.93</td>
</tr>
<tr>
<td>Total peak hour all-vehicle delay (vehiclenhour)</td>
<td>3,574.3</td>
<td>344.0</td>
<td>11,741.6</td>
</tr>
<tr>
<td>Total peak hour freight delay (truckxhour)</td>
<td>285.0</td>
<td>20.4</td>
<td>1,103.7</td>
</tr>
</tbody>
</table>

*Source:* Giuliano et al. (2018)
Handbook on city logistics and urban freight

Source: US Bureau of Transportation Statistics, Eurostat

Figure 1.9  Freight mode shares, US and EU-28
automation has increased scale economies: the upfront expenses of automation require large-scale operation to recoup costs. The demand for large-scale facilities translates to demand for cheap land, which is more available at the periphery of metropolitan areas – far away from instant delivery customers. The result is an emerging network of distribution. Import products are shipped to large warehouses which serve as hubs for consolidating shipments to other domestic markets and distributing product to fulfilment centres located closer to the metropolitan area population. These in turn serve as hubs for local distribution.

Until the rapid rise of e-commerce, the dominant trend in warehouse location was decentralization, driven by scale economies and the search for low-priced land. Decentralization has been documented in the US (e.g. Atlanta, Los Angeles, and Chicago (Dablanc & Ross, 2012; Dablanc et al., 2014; Goodchild & Dubie, 2016), Sweden, the UK, and Japan (Heitz et al., 2018; Allen et al., 2012; Sakai et al., 2015). Kang (2020) conducted a more extensive study of the 48 largest US metropolitan areas using data from 2003 to 2013. He found that warehouse location with respect to the Central Business District (CBD) increased by 1.06 miles over that time period. Location shifts were greater for larger warehouses and for the largest metropolitan areas, where land prices are higher.

Centralizing effects are demonstrated by rent and vacancy rates of in-city space. According to CBRE data, rental rates have increased faster than the long-term average (about 2% per year) every year since 2012, and for the past five years have increased by 5% annually (SCDigest Editorial Staff, 2020). Rents for smaller in-city warehouses have increased much more, reflecting the growing demand for spaces that make same-day deliveries possible.

Centralizing effects are also seen in the conversion of urban spaces to fulfilment and distribution functions. In the US, vacant department store, industrial, or office space are being adapted for warehousing (Panepinto, 2018), and some retailers are repurposing their space to include local fulfilment operations (Sparkman, 2019). In Paris, joint public/private ventures have resulted in mixed use redevelopment that includes logistics spaces; see Chapter 12 (Dablanc). To conclude, warehousing trends are affecting all parts of metropolitan areas.

Solving trade node problems

Giuliano (2020) identifies a long list of potential near-term mitigation strategies and evaluates them with respect to cost, effectiveness in reducing congestion, co-benefits, technical difficulty, and implementation feasibility. Strategies fall into four categories: infrastructure, efficiency improvements, emission reduction, and policy tools. Strategies identified as being most effective are summarized in Table 1.5. Giuliano (2020) does not include

<table>
<thead>
<tr>
<th>Table 1.5</th>
<th>Effective strategies to reduce trade node problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>Strategy</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>On-dock rail, railroad grade separations</td>
</tr>
<tr>
<td>Efficiency improvements</td>
<td>Integrated freight information systems, cargo matching, smart truck parking, terminal appointment systems, freight advanced traffic management systems</td>
</tr>
<tr>
<td>Emission reduction</td>
<td>Low emission standards, more energy-efficient modes</td>
</tr>
<tr>
<td>Policy tools</td>
<td>Port cargo and gate tolls, terminal turn time limits for trucks</td>
</tr>
</tbody>
</table>
some obvious possibilities, for example truck mileage taxes, truck-only highway lanes, or zero-emission heavy-duty trucks due to high costs and/or limited political feasibility. We may expect that political feasibility will change as climate change impacts become more serious.

In the longer term, the solution space will change. The beginnings of heavy-truck automation are being demonstrated in long-haul travel and will eventually be tested in urban environments. New technologies of production – 3D printing – will likely restructure global production systems, and possibly dramatically shrink supply chain geographies. Section V of this Handbook discusses new technology and innovations.

CONCLUSIONS

This chapter has provided an overview of the many challenges facing urban freight. Congestion, air pollution, traffic safety, and noise are challenges that have existed for decades. Continued globalization, urbanization, per capita income growth, and changing consumption patterns assure that goods movement will continue to increase. I have also identified environmental justice as a growing challenge, one that will require not only regulation, but also less race, ethnic, or religious discrimination in society.

I noted that big changes in freight are in motion. I conclude with some thoughts on the future. First, the transportation revolution taking place will affect last mile transport. Platform-based services such as ride-hailing, car sharing, and bike sharing are ubiquitous in large cities. Platform-based services are now penetrating goods movement with instant delivery services and cargo-matching services. Robots are used widely in warehousing and drones are in various stages of application for local delivery. Delivery robots and automated vehicles are delivering food and other items. Clearly last mile freight activity is changing fast, and our efforts to address congestion and safety will have to account for this more complex delivery system. At the same time, technology offers new opportunities to achieve more efficient and sustainable last mile transport.

Second, this Handbook is being written at a time of great uncertainty with regard to international trade. Tariff conflicts between the US and China, the US renegotiation of the Canada-US-Mexico trade agreement, Britain’s withdrawal from the EU, and the impacts of the pandemic remain to be sorted out. Some reshoring of key products or industries may occur as reliability becomes more valuable. Thus, the future growth and geographic pattern of international trade is difficult to predict.

At the same time, we expect more aggressive climate change mitigation efforts, and these will add pressure to parts of the supply chain that have been largely exempt (e.g. ocean carriers, US railroads). California provides an example of what other states and countries may do to decarbonize the freight sector. California policies include a broad carbon cap and trade system, specific targets for achieving a zero-emissions truck fleet, regulations to reduce carbon in existing fuels, regulations requiring ocean carriers to run on electricity while in port, and regulations being planned to achieve zero-emission cargo handling equipment at ports. In addition, California is funding research and development on battery and hydrogen-fuel-cell-powered locomotives. Efforts to reduce GHG emissions throughout the economy will surely accelerate change in the freight sector.
NOTES

2. Energy density is measured as the amount of energy available per volume of fuel.
3. The US National Noise Map is available at https://data.bts.gov/stories/s/National-Transportation-Noise-Map/ri89-bhxh/. Examples are not shown here as they are difficult to interpret without colour.
5. See Purdon et al. (2021), for details on California policy.

REFERENCES


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