Examining the Effects of Common Carrier Lockers on Residential Delivery

Caleb Diehl

A thesis submitted in partial fulfillment
of the requirements
for the degree of Master of Urban Planning

University of Washington
2021

Committee:
Qing Shen
Anne Goodchild

Program Authorized to Offer Degree:
Department of Urban Design & Planning,
College of Built Environments

University of Washington

Abstract

Examining the Effects of Common Carrier Lockers on Residential Deliveries

Caleb Diehl

Chair of the Supervisory Committee:
Qing Shen
Department of Urban Design & Planning

In recent years, e-commerce has dramatically increased deliveries to residential areas. The rise in delivery vehicle activity creates externalities for the transportation system, including congestion, competition for parking space, and emissions. Common carrier lockers have emerged as a way to manage these effects by consolidating deliveries, but they remain largely untested in the United States. This thesis examines the effects of a common carrier locker placed in a residential building in downtown Seattle, Washington. An experimental design with on-street data tests the effect of the locker on dwell times and time that delivery people spend in the building. Data collected by the locker provider gives insight into the e-commerce behavior patterns of residents. Finally, a simulation model was constructed to obtain the optimal configuration of box sizes in similar lockers. The results show that the locker had a statistically significant effect on time spent within the building, but not on dwell times or curb productivity. However, dwell times for similar vehicles in this sample decreased somewhat. The simulation demonstrated that time-based policies and flexible locker designs can prove to be effective strategies for managing demand.

Table of Contents

List of Figures

Acknowledgements

I would like to thank Andisheh Ranjbari and Giacomo Dalla Chiara for their considerable contributions to this work, including developing the framework for the discrete event simulation and regression modeling. I also would like to thank my thesis committee, Professor Qing Shen and Professor Anne Goodchild, for their time reviewing and editing this thesis.

1 Introduction

In recent years, explosive growth in e-commerce has spurred dramatic demand for deliveries in dense urban areas. Worldwide retail E-commerce sales grew 27.6% in 2020, and 31.8% in North America [1]. At the same time, rapid urbanization is taking place, and online shipments require delivery to residential locations and dense urban hubs. The increased emphasis on direct-to-consumer deliveries gives customers in residential areas more power to dictate when, where, and how their orders will be fulfilled [2].

These e-commerce trends demand that operators to deliver to many consecutive addresses, often within highly specific time windows, amid traffic congestion and limited parking. These demands cause numerous problems in the so-called "last-mile" of delivery: the final link from retailer to customer. For freight operators, friction in the last mile can disrupt vehicle routing and scheduling. Researchers estimate that up to 15% of all first delivery attempts fail [3], sometimes because the customer is not home to receive the package. From the perspective of city planners, last-mile freight challenges include illegal parking behavior, congestion, and increased vehicle miles travelled and emissions. In 2006, UPS, FedEx and other delivery companies paid New York City $102 million in parking fines annually and averaged a combined 7,000 tickets per day[4][4][4] [4], [3]. Some researchers estimate that up to 25% of emissions from the overall supply chain come from last-mile delivery [5]. To combat congestion, much last-mile research concentrates on reducing vehicle dwell time, or time stopped at the curb [3]. Shorter dwell times increase the availability of parking space, reducing congestion and emissions from parking cruising.

Residential and mixed-use areas pose particular challenges for urban freight. In recent years, the range of couriers delivering to residential buildings has grown more diverse,

expanding from traditional express carriers to include retailer-owned fulfillment services such as Amazon Prime, instant-grocery services such as Instacart, and meal-delivery services such as Doordash. Customer expectations regarding delivery speed, time windows, and ease of return have exponentially increased [6]. In contrast to the bulk shipments to commercial buildings, residential e-commerce activity in urban centers consists of repeated, small-batch deliveries. Delivery vehicles range from light-duty vans to cargo bikes and the private passenger vehicles of gig workers. The annual delivery schedule is highly peaked. As many as 20% of all deliveries fall during the holiday season from November to December [7]. This can make it difficult to plan permanent parking infrastructure or last-mile solutions to accommodate deliveries throughout the year.

In the past several years, common carrier parcel lockers have emerged as a solution to the last-mile delivery problem for online orders. A common parcel locker is a secure central hub from which a consumer can receive packages from any carrier. Delivery drivers can deposit packages into any open box in the locker. Upon delivery, customers receive an electronic notification and unique code that allows them to retrieve the package. Although these lockers have gained acceptance in some European and East Asian markets, they remain largely untested in the United States [8].

The purpose of this research is to determine the impact of e-commerce deliveries and common parcel lockers on the transportation system for residential buildings in an urban mixed-use setting. Specifically, I examine the effects on three areas: carrier operations, parking infrastructure, and consumer behavior. The results can be used by policy makers to develop incentives and management plans for lockers in residential areas, either in public or private space.

The focus of the study is a locker installed in Seattle's Belltown neighborhood as part of a Department of Energy-funded study on urban goods delivery efficiency. Belltown represents a typical dense mixed-use neighborhood close to downtown. The 26-story residential building that received the locker reported several inefficiencies with its previous delivery process. Some carriers delivered packages individually to the 133 apartments, moving door-to-door throughout the building. Others deposited packages in a storage room, where the building manager had to sort through them and ensure residents received their items. The goal for the locker was to

consolidate these arrivals, improving package security, reducing the building manager's workload, and improving timeliness of deliveries.

From the operations perspective, I aim to determine whether the installation of this common carrier locker caused a change in the time that delivery drivers spend inside the building or stopped at the curb (dwell time). The effect on parking infrastructure was measured through vehicle dwell times in loading zones outside the building, and a curb productivity calculation. Data from the locker provider provided descriptive insights into the usage cycles, seasonality, and demand patterns of customers. This e-commerce consumer information can aid urban planners in designing freight infrastructure and policies to accommodate seasonal demand patterns.

This study aims to answer these questions through a variety of datasets and research methods. I compared the building with a locker installed to control buildings using a nonequivalent groups design and difference-in-difference estimation, with manually collected parking data. To obtain insight into consumer behavior, I analyzed anonymized data recorded by the locker provider and described users by characteristics such as the number and type of packages they receive.

The remainder of the thesis is organized as follows. Chapter 2 describes the existing literature on parcel lockers and residential delivery. Chapter 3 outlines the methodology, including difference-in-difference estimation, curb productivity calculation, and simulation. Chapter 4 provides results, and Chapter 5 consists of discussion and policy implications.

2 Literature Review

2.1 E-commerce delivery to residential areas

In recent years, urban residential and mixed-use areas have seen dramatic increases in delivery demand. In New York City, as of 2017, census tracts spanning just a few blocks could generate demand ranging from 200-600 packages per day [9]. A 2017 study of a 300-unit upper-middle-class apartment building in New York City, conducted using concierge package receipts, estimated the rate of package deliveries at 1.5 per week per household, or around .5 per resident [7]. Deliveries were relatively consistent on weekdays but declined by around 14.4% on weekends. The months of November and December alone accounted for more than 20% of the

deliveries. A single New York City residential building lobby can receive 60 to 100 packages per day [6]. Such a rate of delivery exhausts building managers and concierges, prompting some apartment buildings, especially in China and Europe, to routinely install common parcel lockers.

Compared to commercial delivery, residential fulfillment exerts different pressures on public street space. An increasing tableau of carriers, comprising not only postal and express parcel delivery companies, but now instant grocery and meal delivery services and retailer fulfillment services such as Amazon Prime, compete for street space [6]. The uptick in small items ordered online has increased light goods vehicle (LGV) traffic, and the behaviors and needs of these vehicles are not well understood. Compared to commercial areas, mixed-use or residential districts offer few spaces for commercial vehicles to park, and the spaces that exist are often occupied by residents. E-commerce trends toward smaller delivery time windows and on-demand delivery drive carriers to deliver smaller batches of packages compared to B2B deliveries. In addition, customers expect easy and free returns, potentially increasing demand for residential package pickups.

Common carrier lockers could permit carriers to consolidate some single package deliveries, leading to reduced congestion and emissions. In New York City, for example, one study found that increasing packages per stop from 1 to 5 could reduce the required stops per day by as much as 500 [9].

2.2 Last-mile logistics and Common Pick-up Points

In the field of urban logistics, the last mile in the supply chain is the smallest unit of analysis, but perhaps the most critical [10]. Congestion, missed deliveries and other obstacles in the last-mile from retailer to consumer account for as much as 28% of total transport costs and 25% of emissions from the overall supply chain [5], [10]. Contrary to the popular view of urban freight, many last-mile activities take place outside the vehicle. A study in London found that drivers spent up to 62% of the time for urban delivery tours walking, with an average distance of 105 meters from the vehicle to each customer [11]. Drivers parked for up to 77% of the tour and drove at an average of only 7 kilometers per hour in the delivery area. Therefore, streamlining the flow of activities in and around buildings is of paramount importance. Urban Freight Lab researchers coined the term “Final 50 feet” to describe the supply chain segment beginning when delivery vehicles pull into a parking space and ending when consumers receive goods [12]. The

researchers identified reducing failed deliveries and dwell time in curbside loading zones as the top two strategies for streamlining the Final 50 feet [12].

Despite the impacts of increased last-mile pressures, the effects on urban planning, mobility, and transportation in dense urban centers remain underexamined [13]. The University of Washington's Urban Freight Lab has led research in this area with a number of studies in downtown Seattle. In one report, researchers found that only 13% of buildings in downtown Seattle maintain loading bays, forcing 87% of deliveries to curb and alley space [12].

A broad category of proposed solutions, from the perspective of logistics and business management, centers on consolidating online orders into centralized, secure pickup locations [14]. This strategy can eliminate the need for carriers to deliver to multiple addresses in the same building, ride freight elevators, or search for customers to sign for a package—activities that consume up to 61% of the total delivery time in the last mile [12]. In Europe and Australia, some retailers have experimented with common pick-up / drop off points (CDPs): convenience stores, post offices, or other local hubs that store packages for consumers. A feasibility analysis of common pick-up and drop points in the United Kingdom found that CDPs were successful for areas with failed delivery rates exceeding 20% [15]. In France, carriers ship up to 20% of parcel deliveries to households to common pick-up points in dense urban areas, suggesting the rising popularity of common distribution points for online orders [16].

2.3 Common Carrier Locker Systems

While research into common distribution points lays a foundation for solving the last-mile problem, a research gap still exists in understanding the performance of common parcel lockers. Most operations research addresses larger scale routing and scheduling problems rather than individual locker characteristics [17]. For example, Deutsch and Boaz maximized total profit from deliveries by choosing the optimal number, locations, and size of lockers, taking into account the cost to consumers of travelling to the locker [18]. In a typology of parcel lockers, Rohmer and Gendron (2020) identified two business models: carrier-owned parcel lockers such as those operated by Amazon or the United Parcel Service (UPS) and common carrier lockers [17]. The latter category consists of lockers operated by third-party service providers, postal services, or transit agencies and made available to a number of carriers. The authors defined three primary operations research problems concerning lockers: network design and facility

location, vehicle routing, and matching customer orders with lockers with appropriate capacity. These goals focus primarily on business success, and not benefits for residents or the general public.

Most existing parcel locker research concerns aggregate analysis of economic and environmental benefits at the neighborhood or city level. Several studies, including an analysis of lockers provided by Polish postal service InPost, concluded that, compared to other last-mile solutions such as common drop-off points, lockers generated the greatest reductions in vehicle miles travelled (VMT) and carbon emissions [19], [20]. Van Duin et al. (2020) quantified the economic and environmental benefits of lockers through an activity-based estimation model [21]. Compared to home delivery, lockers reduced emissions, primarily by limiting failed deliveries. Lachapelle et al. applied a clustering algorithm to land-use data from an Australian city to identify four typologies for neighborhoods with parcel lockers [22]. Despite the apparent public benefits, few lockers were located in transit-accessible areas, and most were found in areas with considerable parking space. In 2019, the University of Washington's Urban Freight Lab conducted a pilot of a common carrier locker system in downtown Seattle, one of the few tests of such systems in the United States [8]. Researchers noted a 78% reduction in delivery times within the building, 0 failed deliveries to the locker, and a reduction in vehicle dwell times and idling. Common parcel lockers also produced travel time savings in residential areas in South Korea [23].

2.4 Consumer Behavior With Respect to Parcel Lockers

Another subset of research examines parcel lockers from the consumer perspective through survey, focus group, or interview-based methodologies. Lockers shift some delivery costs from carrier to consumer [21]. Carriers must continue to satisfy their customers, so the more user-friendly and convenient common carrier lockers are, the more quickly they will become widespread. An online survey of 15-64 year-old locker users in Jakarta, Indonesia found that most customers still preferred traditional home delivery over the locker, citing timeliness and convenience [24]. However, some favored lockers for their lower delivery costs and more up-to-date package information. Researchers in Brazil used a stated preference survey to understand customer demand for automated delivery stations (lockers) [16]. 63% of respondents said they would use the system, naming safety and security as primary concerns. Customers

stated their preferred location for the locker as supermarkets (26%), followed by stores (22%), and shopping malls (21%). An intercept survey of Link light rail riders in Seattle found that customers at two stations received online orders on average once or twice per week [25]. The majority of these respondents preferred to receive orders via home delivery, but 63% of people at one station, and more than 40% at two other stations, said they would consider switching to a common carrier locker in the transit station. With a focus group of 26 Swedish customers, Vakulenko and Hellstrom (2018) found that if participants had one positive experience with the locker, they were likely to continue using it, generating a cycle of positive interactions [26], [27]. They characterized parcel locker benefits as either functional, emotional, social, or financial. In another study, researchers asked Polish Generation Y consumers if they would switch to locker delivery for environmental reasons [28]. They found that young people did not necessarily perceive the lockers as more eco-friendly, but that they were willing to pay more for sustainable delivery. Rather than sustainability, Generation Y consumers cited lower delivery cost and ability to pick up orders at any time of day as the primary advantages of lockers.

A critical question for researchers studying consumer attitudes toward lockers concerns access mode and maximum tolerable travel distance. Common drop-off points can only reduce congestion and emissions if customers walk, bike, or chain trips together to collect their packages [15]. The same holds true for lockers. Nahry and Vilardi estimated the maximum distance consumers would travel to reach the locker to be 3.86 kilometers [24]. In one survey, a majority of the Generation Y consumers picked up their parcels by car on the way to another destination, while 44% walked [28]. Similarly, in the survey of Brazilian consumers, 59% said they would use private vehicles to collect packages [16]. Van Duin et. al noted that lockers only reduced emissions if consumers did not need to travel more than .94 km in urban areas, or 6 km in ex-urban areas, to retrieve their packages [21]. If lockers are to provide a sustainable alternative to door-to-door delivery, most consumers must be willing to complete their portion of the last-mile via a low-emissions travel mode.

2.5 Research Gaps and Study Contributions

With the exception of the 10-day Urban Freight Lab pilot, existing research contains, as of this writing, no known examples of experimental tests of the effectiveness of individual common carrier locker systems on last-mile delivery [8]. Most existing research concentrates on

the network effects of lockers distributed throughout a city, aggregate efficiency gains for carriers, or generalized measures of emissions reductions. Geographically, the existing literature almost entirely focuses on countries where parcel lockers have become commonplace, such as Australia, Japan, Germany or Poland. No existing studies examine how parcel lockers change delivery driver behavior at the block or individual building level, although these decisions have the most critical effects on the time required for deliveries. Furthermore, research has largely been limited to privately owned lockers, such those operated by Amazon or the United Parcel Service (UPS), or government-run facilities such as Australia Post lockers, rather than common lockers.

This study seeks to fill these gaps by quantifying the effects of locker systems on delivery vehicle dwell time, volume carried into specific buildings, and time spent inside the building. In a study of ridehailing pick-ups and drop-offs in Seattle, Goodchild et al. (2019) provided a framework for measuring the effects of various strategies on curbside congestion by developing a metric for vehicle productivity and comparing dwell time distributions [29]. This study will borrow from these methodologies in conjunction with a nonequivalent groups pre-test / post-test design to pinpoint the causal impacts of a single common parcel locker on delivery time and dwell time.

Another goal of this study is to fill the gaps in understanding individual-level consumer e-commerce behavior in the United States. In particular, more research is needed in the area of modeling customer demand for lockers. If proven effective, lockers could be placed in transit stations or other public areas. Accurate and timely consumer behavior data can help transportation planners to manage these spaces to maximize public benefits and avoid negative externalities. In conjunction with surveys and other data sources, automated locker data can fill a gap in objective measures of e-commerce behavior. For example, studying the time packages remain in the locker can inform efforts to nudge customers, promoting greater turnover of locker boxes. Separating seasonal cycles from long-term trends in package demand can help planners or building managers actively manage the locker. Segmenting customers through clustering can inform marketing efforts and give a clearer picture of customer demographics. However, few, if any, studies have addressed these aspects using objective data from locker providers. Besides maximizing efficiency for carriers, understanding customer behavior can inform cities of the use,