Cargo E-Bike Delivery Pilot Test in Seattle

Urban Freight Lab
Supply Chain Transportation & Logistics Center
University of Washington
August 2020

THIS STUDY WAS SPONSORED BY THE SEATTLE DEPARTMENT OF TRANSPORTATION

SUPPLY CHAIN TRANSPORTATION & LOGISTICS CENTER
UNIVERSITY of WASHINGTON
Urban Freight Lab

CONTENTS

EXECUTIVE SUMMARY

This study performed an empirical analysis to evaluate the implementation of a cargo e-bike delivery system pilot tested by the United Parcel Service, Inc. (UPS) in Seattle, Washington. During the pilot, a cargo e-bike with removable cargo container was used to perform last mile deliveries in downtown Seattle. Cargo containers were pre-loaded daily at the UPS Seattle depot and loaded onto a trailer, which was then carried to a parking lot in downtown.

Data were obtained for two study phases. In the "before-pilot" phase, data were obtained from truck routes that operated in the same areas where the cargo e-bike was proposed to operate. In the "pilot" phase, data were obtained from the cargo e-bike route and from the truck routes that simultaneously delivered in the same neighborhoods. Data were subsequently analyzed to assess the performance of the cargo e-bike system versus the traditional truck-only delivery system.

The study first analyzed data from the before-pilot phase to characterize truck delivery activity. Analysis focused on three metrics: time spent cruising for parking, delivery distance, and dwell time. The following findings were reported:

- On average, a truck driver spent about 2 minutes cruising for parking for each delivery trip, which represented 28 percent of total trip time. On average, a driver spent about 50 minutes a day cruising for parking.
- Most of the deliveries performed were about 30 meters (98 feet) from the vehicle stop location, which is less than the length of an average blockface in downtown Seattle (100 meters, 328 feet). Only 10 percent of deliveries were more 100 meters away from the vehicle stop location.
- Most truck dwell times were around 5 minutes. However, the dwell time distribution was right-skewed, with a median dwell time of 17.5 minutes.

Three other metrics were evaluated for both the before-pilot and the pilot study phases: delivery area, number of delivery locations, and number of packages delivered and failed first delivery rate. The following results were obtained:

- A comparison of the delivery areas of the trucks and the cargo e-bike before and after the pilot showed that the trucks and cargo e-bike delivered approximately in the same geographic areas, with no significant changes in the trucks' delivery areas before and during the pilot.
- The number of establishments the cargo e-bike delivered to in a single tour during the pilot phase was found to be 31 percent of the number of delivery locations visited, on average, by a truck in a single tour during the before-pilot phase, and 28 percent during the pilot phase.
- During the pilot, the cargo e-bike delivered on average to five establishments per hour, representing 30 percent of the establishments visited per hour by a truck in the before-pilot phase and 25 percent during the pilot.
- During the pilot the number of establishments the cargo e-bike delivered to increased over time, suggesting a potential for improvement in the efficiency of the cargo e-bike.
- The cargo e-bike delivered 24 percent of the number of packages delivered by a truck during a single tour, on average, before the pilot and 20 percent during the pilot.

- Both before and during the pilot the delivery failed rate (percentage of packages that were not delivered throughout the day) was approximately 0.8 percent. The cargo e-bike experienced a statistically significantly lower failed rate of 0.5 percent with respect to the truck fail rate, with most tours experiencing no failed first deliveries.

The above reported empirical results should be interpreted only in the light of the data obtained. Moreover, some of the results are affected by the fact that the pilot coincided with the holiday season, in which above average demand was experienced. Moreover, because the pilot lasted only one month, not enough time was given for the system to run at "full-speed."

INTRODUCTION

Deliveries in urban areas are conventionally performed by fleets of trucks, a term we will use to refer to vans, lorries, or other, similar motor vehicles designed to transport cargo. This delivery method is currently under pressure as demand for urban deliveries grows due to the rise of e-commerce, while many carriers are striving to reduce their environmental footprint and cut their carbon emissions. There is a need to find new ways to sustainably deliver goods in urban areas while still efficiently and profitably satisfying the increasing demand for urban deliveries.

One delivery strategy that is being tested in several cities around the world relies on the complementary use of cargo e-bikes to perform last mile deliveries. Cargo e-bikes are two/three/four-wheeled vehicles with cargo carrying capacity. They are human-powered and often have an electric pedal assist.

On the one hand, cargo e-bikes present several advantages over conventional trucks in performing last mile deliveries. They can

better navigate road traffic, being smaller and more agile than trucks. They can also access urban areas to which, becausae of physical or regulatory constraints, trucks do not have access. They are easier to park, as they can often stop on sidewalks and need much less space than trucks. Consequently, by parking closer to the delivery destination, they can reduce the delivery distance—the distance a driver has to walk from the vehicle stop location to the customer location—and therefore reduce parking dwell time. Shorter parking dwell times further reduce parking and road congestion. Moreover, as cargo e-bikes do not have to compete with other vehicles for curb parking, they spend less time cruising for parking.

On the other hand, cargo e-bikes may not be as efficient as trucks at performing deliveries and pick-ups. Their limited cargo capacity means that they can perform fewer deliveries per tour, and they have to re-load cargo more often. The maximum speed a cargo e-bike can reach is lower than a truck's maximum speed, which may limit its ability to travel longer distances quickly. Moreover, being a relatively new transport mode, there is a learning curve for efficiently adopting these vehicles and using their full potential.

This study performed an empirical analysis to evaluate the implementation of a cargo e-bike delivery system pilot tested by the United Parcel Service, Inc. (UPS) in Seattle, Washington. This paper contains four other sections. Section 2 describes the Seattle cargo e-bike pilot and reports the study objectives. Section 3 describes the data used for the analysis and provides an initial empirical analysis of a truck-based delivery system. Section 4 provides an evaluation of the pilot by comparing several performance metrics used before and after the start of the pilot. Section 5 summarizes the main conclusions obtained from this study.

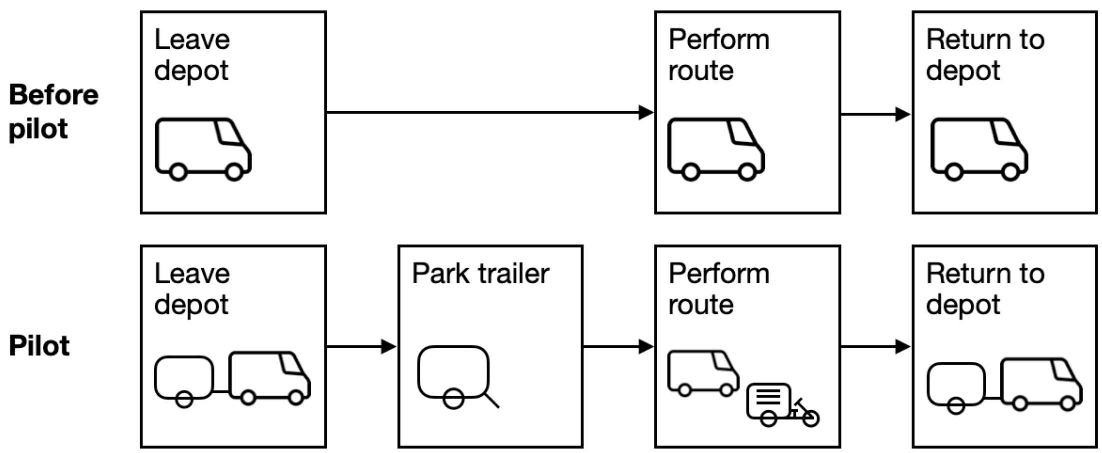
THE SEATTLE CARGO E-BIKE PILOT STUDY

Pilot Description

In 2018, the United Parcel Service, Inc. (UPS) pilot tested a new delivery system that consisted of using an electric-assisted tricycle with cargo carrying capacity, hereafter referred to as cargo e-bike, to perform deliveries and pick-ups in downtown Seattle. The cargo e-bike, shown in Figure 1, had a removable cargo container with 95 cubic feet of space that could hold up to 400 pounds. Figure 2 depicts the delivery process flow before and during the pilot study. Up to four cargo containers were pre-loaded daily at the UPS Seattle depot and loaded onto a trailer, which was then attached to a UPS vehicle and carried to a parking lot in downtown Seattle. The cargo e-bike, stored overnight in a parking location with an electric charging station, then drove to the trailer location, loaded the cargo container onto the rear of the bike, and performed circular delivery tours.

Figure 1. The UPS cargo e-bike with loaded cargo container deployed in Seattle [1]

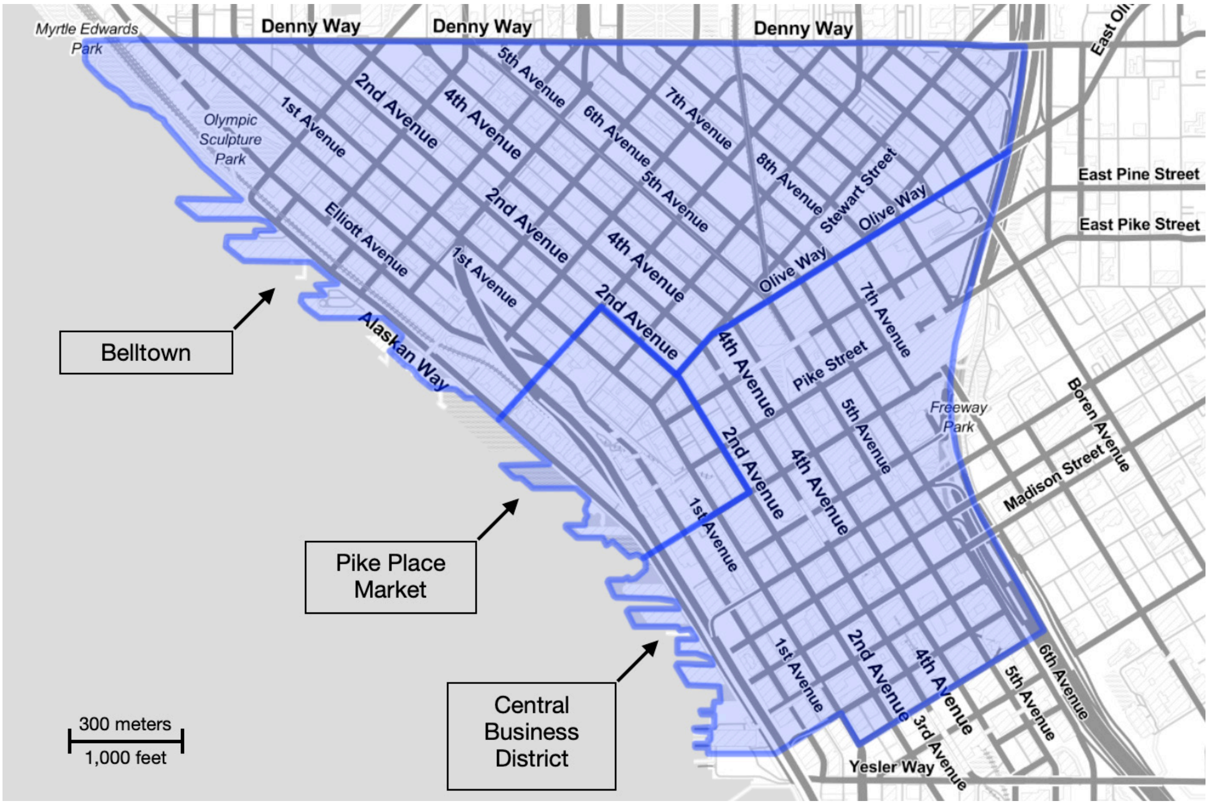
Figure 2. Delivery operations before and during the pilot study



The Seattle Department of Transportation (SDOT) granted an e-bike class-2 permit for the cargo e-bike to operate in Seattle, which limited its speed to 20 miles per hour and allowed it to ride and park on shared-use paths, including sidewalks and bike lanes ([2], [3]).

The pilot study started in November 2018 and lasted for a month, during which the bike performed deliveries in the Pike Place Market, Central Business District, and Belltown neighborhoods of downtown Seattle (see map in in Figure 3).

Figure 3. Seattle neighborhoods in the study area



Study Objectives

UPS shared data with researchers at the University of Washington's Urban Freight Lab on the delivery operations performed both by the cargo e-bike and by trucks thath operated in the same delivery area as the cargo e-bike.

Data were obtained for two study phases. In phase 1, the "before-pilot" phase, data were obtained from truck routes that operated in the same areas where the cargo e-bike was proposed to operate during the pilot. In Phase 2, the "pilot" phase, data were obtained from the cargo e-bike route and from the truck routes that simultaneously delivered in the same neighborhoods.

Data were subsequently analyzed to assess the performance of the cargo e-bike system versus. the traditional truck-only delivery system. Several evaluation metrics, defined in Table 1, were developed and empirically estimated for the different modes (trucks and cargo e-bike) and the two study phases (before-pilot and pilot phases) to evaluate the operational efficiency of the new cargo e-bike delivery system. Metrics 1 through 3 were developed to empirically describe the truck-specific delivery processes for study phase 1 (before the pilot). Metrics 4 through 7 were developed to compare the delivery operations of both the before-pilot and pilot phases.

Table 1. Metrics developed to analyze delivery operations during phase 1 (before pilot phase) and/or phase 2 (pilot phase)

METRIC		DESCRIPTION	PHASE 1 ANALYSIS	PHASE 2 ANALYSIS
1	Cruising for parking	Time spent searching for available parking near a delivery destination	✔	
2	Delivery distance	Distance walked by the driver to reach a delivery destination from the vehicle parking location	✔	
3	Dwell time	Total time the vehicle was parked while the driver performed deliveries and pick-ups	✔	
4	Delivery area	Area where the driver performed deliveries and pick-ups	✔	✔
5	Delivery locations visited	Total number of delivery locations visited by a driver	✔	✔
6	Packages delivered	Total number of packages delivered	✔	✔
7	Failed delivery rate	Numbe of packages that the driver failed to deliver	✔	✔

DATA DESCRIPTION

Terminology

This section defines some of the technical terms used in the rest of this paper.

- *Delivery:* location where packages were delivered and/or picked up.
- *Stop:* location where the vehicle was parked.
- *Trip time:* time it took to drive between two stop locations.
- *Tour:* chain of trips performed in a day by a driver.
- *Route:* set of tours performed by a single driver across multiple days; deliveries of a given route are usually located within the same urban area.
- *Dwell time:* length of time a vehicle was parked while the driver performed deliveries/pick-ups.
- *Cruising for parking:* time spent searching for parking near the delivery destinations.
- *Delivery distance:* distance between the stop location and the respective delivery location.

Data Obtained

Data were obtained for two study phases (Figure 4): the "before-pilot" phase, which lasted from August to November 2018, and the "pilot" phase, which lasted from November to December 2018. During the before-pilot phase, four truck routes were observed. During the pilot phase, one cargo e-bike route and two truck routes were observed (Table 2).

Figure 4. Study phases

Table 2. Summary of data sets obtained

DATA SET	MODE	DATA TYPE	PHASE	DATES	DAYS	NUM. OF ROUTES
1	Truck	Stop	Before	10-03-2018 to 11-09-2018	28	4
2	Truck	Delivery	Before & pilot	08-01-2018 to 01-10-2019	112	2
3	Bike	Delivery	Pilot	11-13-2018 to 12-20-2018	21	1

For each observed route, two types of data were recorded: stop data and delivery data. Stop data included vehicle stops and corresponding trip times. In particular, the latitude and longitude coordinates of the location where the vehicle stopped, and the start and end timestamps of the stop were recorded. Stop data were obtained from Global Positioning System (GPS) tracking devices deployed in the delivery vehicles. Delivery data included activities performed by the driver walking from vehicle stop locations to delivery destinations to perform deliveries and pick-ups. In particular, the latitude and longitude coordinates of the location where the delivery took place and the start and end timestamps of the delivery were recorded. Delivery data were obtained from the mobile delivery device at the point of delivery to the consignee.

Table 3 shows the data structure for both the delivery and stop data sets, with the only difference being that each row of such a table for the stop data set corresponded to a vehicle stop, whereas each row of such a table for the delivery data set corresponded to a delivery performed. In addition to the stop/delivery location and start/end times, the date, and a unique and anonymized route identifier were recorded.

Table 3. Sample data format for delivery and stop data sets

DATE	ROUTE ID	LOCATION	START TIME	END TIME
12-01-2018	1	47.607340, -122.335916	09:00:16	09:05:01
12-01-2018	1	47.611569, -122.339283	09:08:46	09:27:15
12-01-2018	1	47.612405, -122.334336	09:32:06	09:42:27

Truck Data Description

CRUISING FOR PARKING

Cruising for parking was defined as the time a driver spent searching for available parking near the desired delivery destination. Previous scientific studies highlighted the problem of cruising for parking for passenger vehicles (see for instance papers by [4], [5] and [6]), quantifying cruising time in several cities between 30 seconds and 15 minutes per trip. Those studies found that cruising vehicles represented between 7 and 74 percent of total road vehicle traffic.

Passenger vehicles are not the only ones cruising for parking. Commercial vehicles are also affected by the lack of available parking. To estimate cruising for parking time for commercial vehicles, trip times obtained during the before-pilot phase (data set 1 in Table 2) were analyzed. In total, 2,894 trip times were recorded across four truck routes. Each trip time was then benchmarked with its respective travel time, estimated by using the Google Maps Distance matrix Application Programming Interface (API)[7]. The API uses historical traffic conditions to estimate total travel time, but it does not take into account the time a vehicle takes to find available parking once it is near the destination. Therefore, the resulting deviation, found by subtracting the respective API's travel time estimate from the actual trip time, was an estimate of the time spent cruising for parking. By performing such operations across the whole data set, we obtained an estimated empirical distribution of the time spent cruising for parking for the data analyzed. The summary statistics of this obtained distribution are reported in Table 4. On average, the observed trucks spent 2.13 minutes per trip cruising for parking. Because the average total trip time was 8.2 minutes, cruising accounted for the 28 percent of total trip time. Moreover, given that a tour contained 25 trips on average, a driver experienced approximately 53 minutes () per tour cruising for parking.

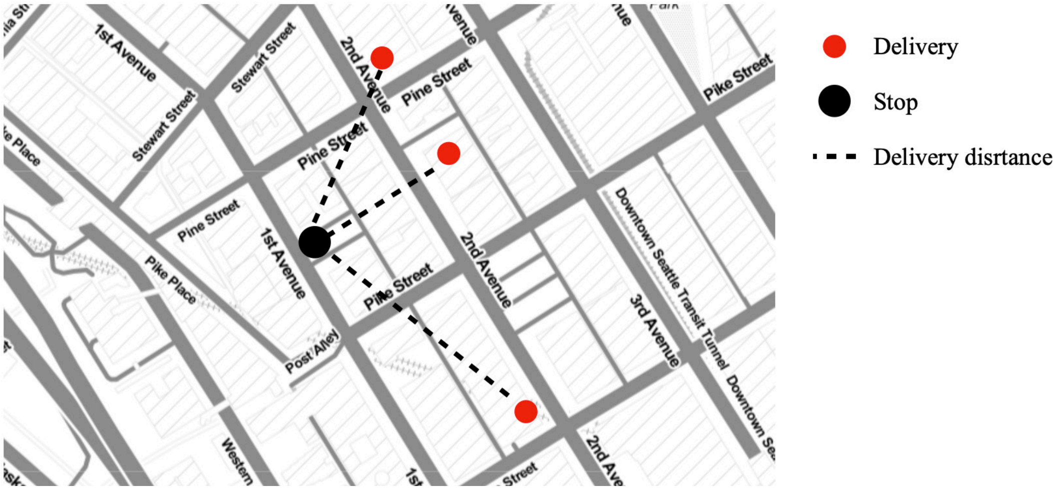
Table 4. Summary statistics of the estimated cruising time distribution

SUMMARY STATISTIC	VALUE
1st Quartile of the trip cruising time distribution	0.47 minutes/trip
Median trip cruising time	2.13 minutes/trip
Mean trip cruising time	5.43 minutes/trip
3rd Quartile of the trip cruising time distribution	7.88 minutes/trip
Mean total tour cruising time	57.50 minutes/tour

DELIVERY DISTANCE

Delivery distance was defined as the distance between a delivery location and the vehicle stop location (see Figure 5). The Euclidean distance was used to estimate the actual distance, calculated by measuring the length of a straight line connecting the two locations. The delivery distance was seen as a lower bound to actual walking distance, the distance a driver walked to perform a delivery, as the latter often included navigating physical barriers, such as finding a building's entrance, taking elevators, etc.

Figure 5. The delivery distance was defined as the Euclidean distance between the delivery and the respective stop location



The longer the delivery distance is, the longer the driver walks, the longer the dwell time is. While a shorter delivery distance is desired to minimize the delivery effort and reduce vehicle dwell time, this is not always possible for the following reasons: (1) parking closer to a delivery destination may not exist; (2) if a closer parking location exists, it may be already occupied; and (3) because of urban parking and traffic congestion, the time-cost of moving the vehicle and finding another parking location closer to the delivery destination may be larger than the time-cost involved with walking for a longer time.

After matching deliveries with the respective stop locations (data sets 1 and 2 in Table 2), we calculated the respective delivery distances for each matched delivery and then obtained its empirical distribution. Figure 6 shows the empirical distribution of the calculated delivery distances, and Table 5 reports its main summary statistics. Most of the estimated delivery distances were about 30 meters (98 feet). Given the average length of a blockface in downtown (about 100 meters long, 328 feet), most deliveries were less than a blockface away. Around 10 percent of the observed deliveries had a delivery distance of longer than 100 meters.

Figure 6. Empirical distribution of the Euclidean distance between deliveries and stop locations

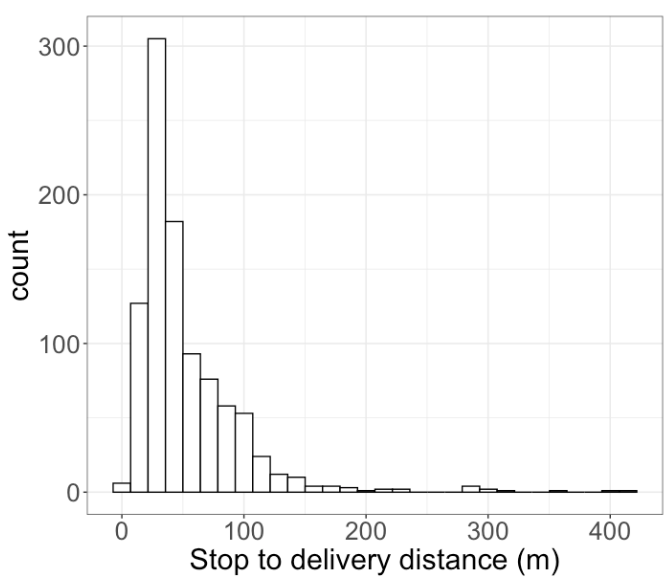


Table 5. Summary statistics of the empirical distribution of the Euclidean distance between deliveries and stop locations

SUMMARY STATISTIC	VALUE
1st Quartile	27.68 meters
Median	38.40 meters
Mean	53.25 meters
3rd Quartile	67.77 meters
Observations > 100 meters	10 percent

DWELL TIME

Dwell time was defined as the time a vehicle was parked while the driver performed deliveries and pick-ups at nearby locations. Longer dwell times could be associated with a driver performing more deliveries from the same stop, handling a large number of packages, or delivering to locations that were farther from the stop location.

Using stop data (data set 1 in Table 2) we computed the respective dwell times. The resulting empirical distribution of dwell times is shown in Figure 7. Table 6 reports its main summary statistics. The peak of the distribution was centered at 5 minutes; hence, for most stops the vehicle was not parked longer than 5 minutes. However, the distribution was right-skewed, with a median of 17.5 minutes and a mean of 26.2 minutes, indicating the presence of few stops with very long dwell times.

Figure 7. Empirical distribution of the stop dwell times

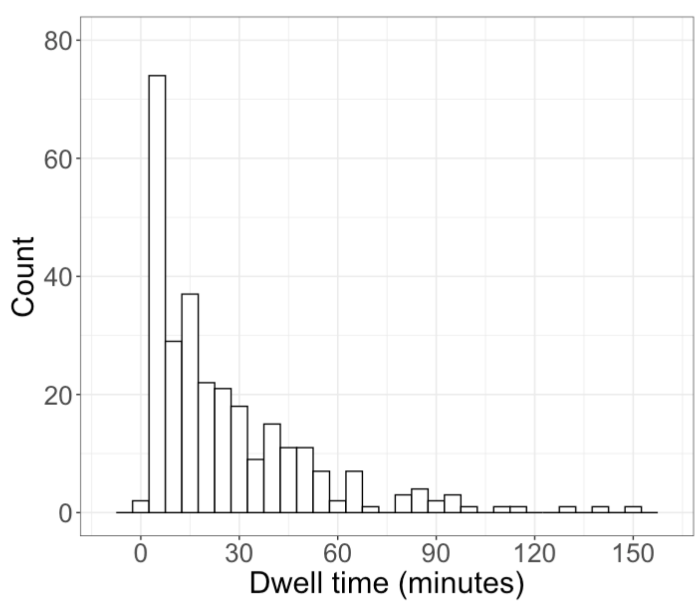


Table 6. Summary statistics of the empirical distribution of the Euclidean distance between deliveries and stop locations

SUMMARY STATISTIC	VALUE
1st Quartile	6.85 minutes
Median	17.51 minutes
Mean	26.18 minutes
3rd Quartile	38.51 minutes

PILOT ANALYSIS

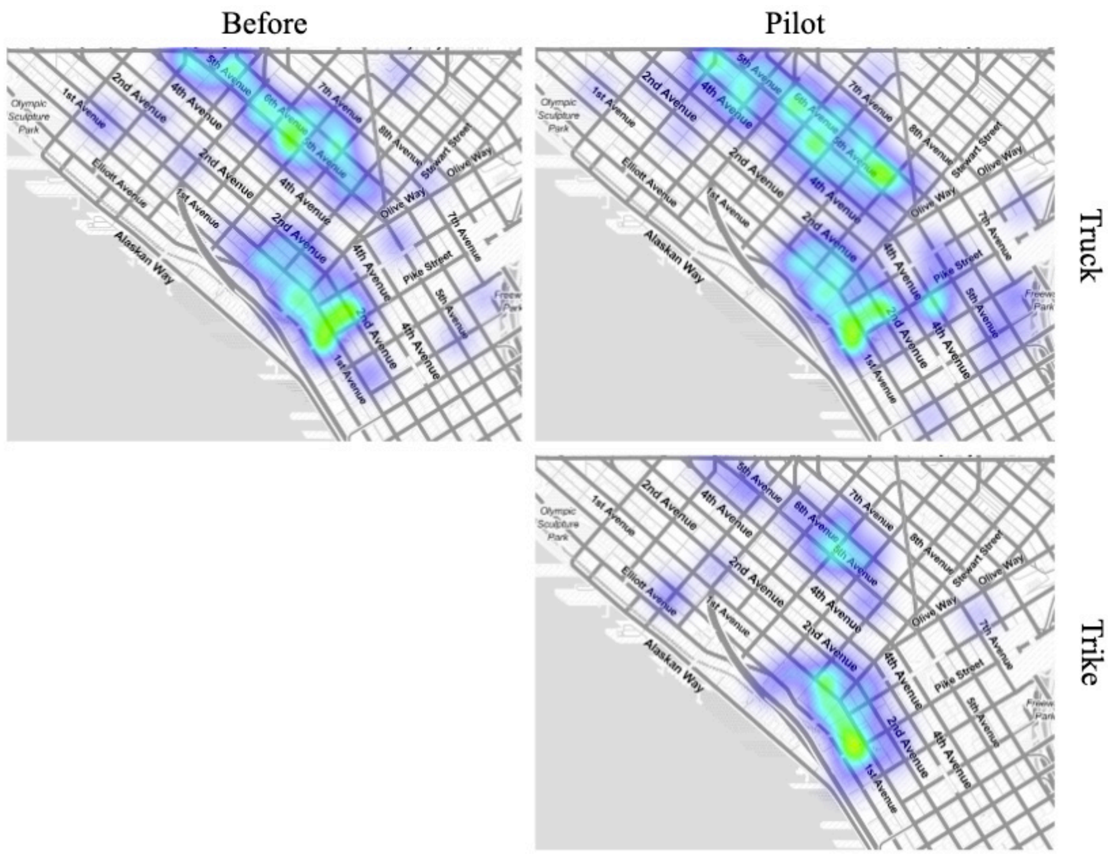
Delivery Area

The delivery area for a vehicle route was defined as the geographic area that included the deliveries and pick-ups performed by the driver of that route. This section discusses a comparison of the delivery area of the cargo e-bike route with the delivery areas of the truck routes, for both the before-pilot and pilot study phases. Data sets 2 and 3 (see Table 2) were used to plot the respective delivery areas.

Figure 8 shows a 2-by-2 grid on the study area map displaying the delivery areas for the two truck routes observed in the before-pilot phase (top-left map), two truck routes for the pilot phase (top-right map), and the cargo e-bike route during the pilot phase (bottom-right map). The higher intensity of the colors indicates that a larger number of deliveries/pick-ups were performed in that area.

The delivery area for the cargo e-bike was smaller and concentrated mostly in the Pike Place Market neighborhood, with some deliveries also in the Belltown district. The delivery area of the truck routes spanned all three districts, with the majority of deliveries performed in the Pike Place Market and Belltown districts. Visual inspection suggests that the delivery area of the truck routes did not significantly change before/after the pilot. Moreover, during the pilot, the truck routes continued to perform deliveries and pick-ups in the same delivery area as the cargo e-bike. Therefore, the cargo e-bike was deployed and operated in the same area where trucks were also operating, indicating that it complementary to the trucks rather than a substitute for the trucks.

Figure 8. Delivery area by mode and study phase



Deliveries Performed

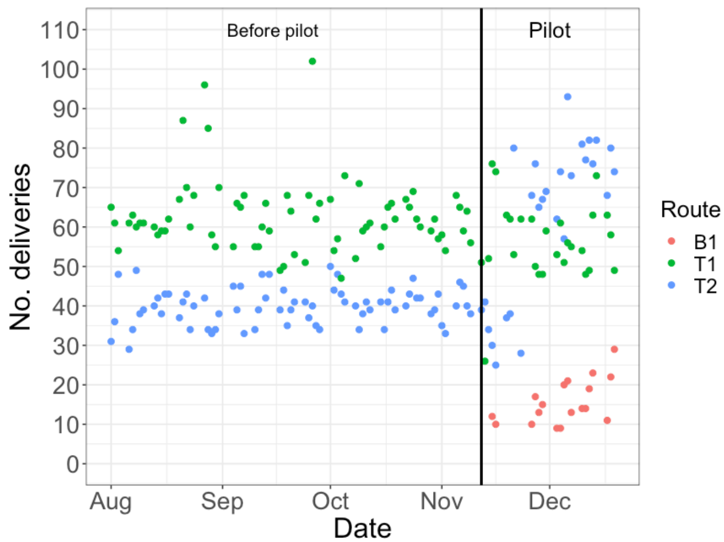
This section describes the numbers of establishments that drivers delivered to for different modes and study phases. Figure 9 shows the number of delivery locations visited for each observed vehicle tour, for two truck routes (named T1 and T2) and one cargo e-bike route (named B1), over time.

In the before-pilot phase, on average the T1 and T2 routes delivered to, respectively, 62 and 40 establishments in a single tour. During the pilot they delivered to 56 and 62 locations per tour. In comparison, the B1 route visited on average 16 establishments per tour during the pilot phase. Therefore, on average, the cargo e-bike delivered to 31 percent of the establishments that a truck delivered to during the before-pilot phase, and 28 percent of the locations that a truck delivered to during the pilot.

However, Figure 9 also shows that the number of locations the cargo e-bike delivered to had an upward trend, indicating a potential for improvement in cargo e-bike efficiency over time.

The number of deliveries performed also increased for the T2 route during the pilot phase. Most likely, this was due to the presence of a helper in the vehicle supporting the driver to make deliveries during the holiday season.

Figure 9. Number of delivery locations visited per tour by the two truck routes (T1 and T2) and by the cargo e-bike route (B1), over time.



To better compare cargo e-bike and truck route performance, the average number of delivery locations visited per hour was calculated for each mode and study phase, considering only deliveries performed between 9:00 am and 1:00 pm. Figure 10 shows a comparison of the resulting distributions for the cargo e-bike and truck routes for the before-pilot and pilot phases.

On average, a truck route visited 17 delivery locations per hour before the pilot started and 20 delivery locations per hour during the pilot phase. In comparison, the cargo e-bike visited five delivery locations per hour, which represents 30 percent of the number of delivery locations visited by a truck in the before-pilot phase and 25 percent of the number of delivery locations visited by a truck in the pilot phase.

Figure 10. Boxplots showing the distributions of the number of delivery locations visited per hour (considering only the morning shift from 9:00 am to 1:00 pm) by the two truck routes (T1 and T2) and by the cargo e-bike route (B1). The horizontal lines of the boxplots represent, starting from the top, the third, second, and first quartiles of the empirical distribution.

Packages Delivered and Failed First Deliveries (FFD)

We compared cargo e-bike performance with truck performance by observing the number of packages delivered per tour and the number of failed first deliveries (FFD), i.e., the number of packages that were failed to be delivered during a tour.

Figure 11 shows the distributions of the average number of parcels delivered per tour by mode and study phase. A truck delivered on average 248 packages per tour during the before-pilot phase and 296 packages during the pilot. In comparison, the cargo e-bike delivered 59 packages per tour during the pilot phase, which represents 24 and 20 percent of the number of packages delivered by a truck in the before-pilot phase and pilot phase, respectively.

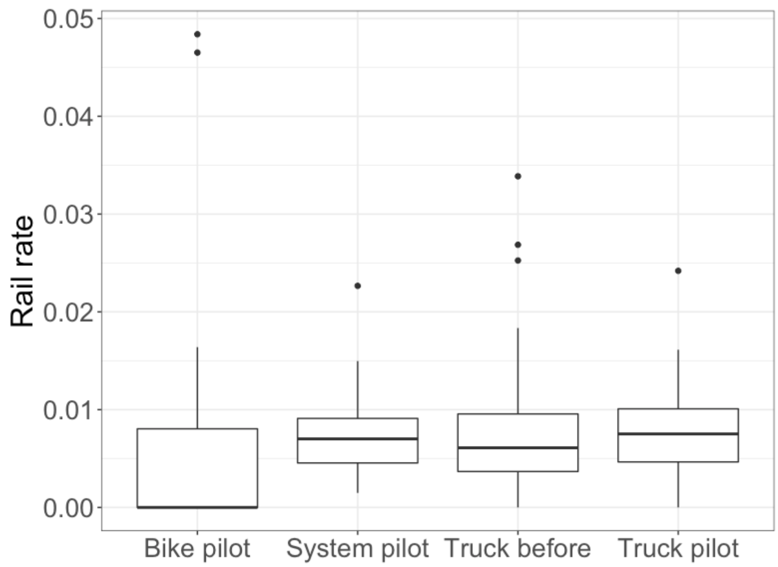
Figure 11. Distributions of the average number of packages delivered per tour by mode and study phase. The horizontal lines of the boxplots represent, starting from the top, the third, second, and first quartiles of the empirical distribution.

The number of failed first deliveries (FFD) for each vehicle tour was obtained for both the before-pilot and pilot phases. The cargo e-bike experienced mostly no FFDs, with an average FFD rate of 0.5 packages a day. A truck experienced, on average, five FFDs during the pilot phase and four FFDs before the pilot.

We computed the FFD rate by dividing the tour FFD by the total number of packages delivered in a tour. Figure 12 reports the empirical distributions of the observed FFD rates for each mode and study phase, as well as the system failed rate, defined as the combined FFD rate for the cargo e-bike and truck routes during the pilot phase. A daily FFD rate of 0.008 was observed for the trucks, both before and during the pilot. This means that about 0.8 percent of the packages were returned in a truck tour. For the cargo e-bike the daily failed rate is 0.007, which means that about 0.7 percent of the packages were returned in a tour. However, the median failed rate for the cargo e-bike was 0, which reflects the fact that on most days the cargo e-bike did not return any packages, and the larger mean FFD rate was due to a few days on which the cargo e-bike experienced a larger than average FFD rate.

In comparing the different failed rate distributions by using a statistical test of hypothesis, the FFD rate for the cargo e-bike was shown to be statistically significantly lower than the truck FFD rate. However, in considering the system FFD rate, no statistically significant difference was observed before and after the pilot.

Figure 12. Empirical distributions of daily failed first delivery rates for each mode and study phase. The system failed rate during the pilot was computed by summing the failed rates of the cargo e-bike and truck routes during the pilot phase.



CONCLUSION

In 2018, the United Parcel Service, Inc. (UPS) pilot tested a cargo e-bike system to perform last mile deliveries in downtown Seattle, Washington. The pilot started in November 2018 and lasted for one month. Data of delivery activity before the pilot (when deliveries were performed only by trucks) and during the pilot (in which both trucks and a cargo e-bike delivered in downtown Seattle) were provided to researchers at the University of Washington's Urban Freight Lab to compare the two delivery systems and evaluate the pilot.

The study first analyzed data from the before-pilot phase to characterize truck delivery activity. Analysis focused on three metrics: time spent cruising for parking, delivery distance, and dwell time. The following findings were reported:

- On average, a truck driver spent about 2 minutes cruising for parking for each delivery trip, which represented 28 percent of total trip time. On average, a driver spent about 50 minutes a day cruising for parking.
- Most of the deliveries performed were about 30 meters (98 feet) from the vehicle stop location, which is less than the length of an average blockface in downtown Seattle (100 meters, 328 feet). Only 10 percent of deliveries were more 100 meters away from the vehicle stop location.
- Most truck dwell times were around 5 minutes. However, the dwell time distribution was right-skewed, with a median dwell time of 17.5 minutes.

Three other metrics were evaluated for both the before-pilot and the pilot study phases: delivery area, number of delivery locations, and number of packages delivered and failed first delivery rate. The following results were obtained:

- A comparison of the delivery areas of the trucks and the cargo e-bike before and after the pilot showed that the trucks and cargo e-bike delivered approximately in the same geographic areas, with no significant changes in the trucks' delivery areas before and during the pilot.
- The number of establishments the cargo e-bike delivered to in a single tour during the pilot phase was found to be 31 percent of the number of delivery locations visited, on average, by a truck in a single tour during the before-pilot phase, and 28 percent during the pilot phase.
- During the pilot, the cargo e-bike delivered on average to five establishments per hour, representing 30 percent of the establishments visited per hour by a truck in the before-pilot phase and 25 percent during the pilot.
- During the pilot the number of establishments the cargo e-bike delivered to increased over time, suggesting a potential for improvement in the efficiency of the cargo e-bike.
- The cargo e-bike delivered 24 percent of the number of packages delivered by a truck during a single tour, on average, before the pilot and 20 percent during the pilot.
- Both before and during the pilot the delivery failed rate (percentage of packages that were not delivered throughout the day) was approximately 0.8 percent. The cargo e-bike experienced a statistically significantly lower failed rate of 0.5 percent with respect to the truck fail rate, with most tours experiencing no failed first deliveries.

The above reported empirical results should be interpreted only in the light of the data obtained. Moreover, some of the results are affected by the fact that the pilot coincided with the holiday season, in which above average demand was experienced. Moreover, because the pilot lasted only one month, not enough time was given for the system to run at "full-speed."

REFERENCES

[1] United Parcel Service, “UPS To Launch First-Of-Its-Kind U.S. Urban Delivery Solution In Seattle,” *UPS pressroom*, 2018. [Online]. Available: https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1540482965617-103. [Accessed: 01-Jun-2020].

[2] State of Washington U.S.A., *Electric-Assisted Bicycles*, vol. Chapter 60. Senate Transportation, State of Washington, U.S.A., 2018.

[3] Washington Bikes, “Here’s what you need to know about Washington’s new e-bike law,” 2018. [Online]. Available: http://wabikes.org/2018/06/06/heres-need-know-washingtons-new-e-bike-law/. [Accessed: 01-Jun-2020].

[4] D. C. Shoup, “Cruising for parking,” *Transp. Policy*, vol. 13, no. 6, pp. 479–486, Nov. 2006.

[5] D. C. Shoup, *Parking and the City*. Routledge, 2018.

[6] A. Millard-Ball, R. C. Hampshire, and R. Weinberger, “The curious lack of cruising for parking,” *Land use policy*, vol. forthcomin, 2019.

[7] Google Maps Platform, “Distance Matrix API,” *Developer Guide*, 2019. [Online]. Available: https://developers.google.com/maps/documentation/distance-matrix. [Accessed: 01-Jun-2019].

SUPPLY CHAIN TRANSPORTATION & LOGISTICS CENTER

UNIVERSITY *of* WASHINGTON

Urban Freight Lab

SCTL CENTER

UNIVERSITY OF WASHINGTON

BOX 352700

SEATTLE, WA 98195

Phone: 206.221.6407

Email: sctl@uw.edu