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Spatial Accessibility and Equity Analysis of Amazon Parcel Lockers Facilities

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Spatial Accessibility and Equity Analysis of Amazon Parcel Lockers Facilities

Abstract

The onset of the COVID-19 pandemic has accelerated the growth of e-commerce and home deliveries. Automated parcel lockers are a way to improve delivery efficiency, but despite their rapid growth, little is known about their accessibility and equity impacts. Among e-commerce players in the U.S., Amazon stands out by its large market share. This research studies the location of Amazon lockers in Portland, Oregon utilizing highway, land use, employment, and sociodemographic datasets. Geographical tools and cluster analysis are utilized to estimate accessibility and equity metrics. Lockers tend to be located in mixed-use areas and can be utilized by a large percentage of the population. However, the equity metrics indicate that the current distribution of lockers could be improved to reach traditionally underserved populations. Given the environmental and economic advantages of lockers, policymakers should encourage the expansion of this type of last mile solution to avoid market failures in areas that are currently underserved.

Keywords: E-commerce, parcel lockers, last mile and urban logistics, accessibility, equity, market failure

1. INTRODUCTION AND MOTIVATION

The last mile is often said to be the most expensive and least efficient segment of the supply chain. The high costs of the last mile are in part driven by a lack of economies of scale due to increasingly fragmented orders. One strategy suggested for mitigating the high costs and inefficiencies in the last mile of business to consumer (B2C) deliveries is the implementation of parcel lockers that operate as unmanned pick-up or collection points, where a consumer uses a variable electronic code to open the locker and retrieve a shipment. Lockers are typically offered in various sizes, and some may also serve as drop-off points for consumer returns or to send parcels from locker to locker as well as from locker to home (or vice versa). Cost reductions gained by using lockers are significant. For example, in Poland – a country leader in the adoption of lockers – the cost of sending a parcel from locker to locker is 15% to 30% less than sending from locker to home, depending on the package size (INPOST, 2021).

Lockers have been successfully used by Amazon, the largest e-commerce company in the U.S. Amazon has a complex logistics network with a recent push towards vertical integration of e-commerce activities that includes lockers where customers can pick up parcels (Rodrigue, 2020). Amazon started implementing locker stations in 2011 and as of 2018, was the majority provider of public access lockers, located in over 900 cities in the U.S. (Holsenbeck, 2018). Its share of the U.S. e-retail market also takes a staggering lead against its competitors (Lunden, 2018). Due to Amazon's great influence on U.S. e-commerce and its rapidly expanding logistics services, the current study focuses only on Amazon lockers.

Data from the U.S. indicate that during the COVID-19 pandemic, home deliveries disproportionally benefit higher-income, more educated sectors of the population (Figliozzi & Unnikrishnan, 2021). But, even before COVID, results from the 2017 NHTS (National Household Travel Survey) indicate that in the U.S., households above the poverty line are twice as likely to make online purchases than households below the poverty line (FHWA, 2018). In this context, and since parcel lockers reduce delivery costs, it is relevant to study the distribution of lockers in relation to equity metrics.

This research studies the distribution of 176 Amazon locker locations in the Portland, OR metropolitan area to answer two research questions: (a) How are lockers distributed with respect to accessibility measures such as population coverage and employment by mode of transportation? and (b) What are the equity implications of the current distribution of lockers? To answer these questions, several datasets are analyzed utilizing geographic tools and cluster analysis. The lockers studied in this research are a closed system (i.e. only used by Amazon) but with public access. Other types of locker types can be utilized to improve transportation, accessibility and equity goals as discussed in Section 7.

Although parcel lockers are widely used in countries like Poland (Iwan et al., 2016), they are still a relatively recent phenomenon in the U.S. and to the best of the authors' knowledge no previous research effort has attempted to analyze accessibility metrics for parcel locker locations in whole urban areas of the U.S or by utilizing cluster analysis. In addition, the focus on equity and market failure utilizing multiple variable groups (income, internet access, transportation, built environment, socio-demographic, and land use variables) is novel and has not been found in the literature review.

The research is organized as follows: Section 2 reviews relevant literature. Section 3 details the data and Section 4 describes methods employed in this analysis. Section 5 presents the results of the accessibility analysis. Section 6 provides the equity analysis results. Section 7 discusses the results, mainly focusing on the potential role of government to avoid market failures in terms of parcel locker accessibility and equity. Finally, Section 8 summarizes main findings and conclusions.

2. LITERATURE REVIEW

The literature related to parcel lockers has been growing more rapidly in the last few years and clearly indicates that parcel lockers have many advantages (Viu-Roig & Alvarez-Palau, 2020). The usage of parcel lockers in lieu of home deliveries allows delivery consolidation while decreasing vehicle miles traveled (Deutsch & Golany, 2018; Iwan et al., 2016; Verlinde et al., 2019). Parcel lockers can also benefit the supply chain by consolidating the pick-up of returned purchases. More than half of all online shoppers in most countries served by logistics company

UPS have returned an online purchase (Morganti, Seidel, et al., 2014), adding additional burdens and costs to supply chains. Parcel deliveries contribute to loading zone shortages in urban areas and increasing carbon emissions (Chen et al., 2017; Edwards et al., 2009; Moroz & Polkowski, 2016; SCTLC, 2018), and delivery consolidation utilizing lockers may help alleviate these issues. Data from focus groups indicate that the self-service aspect of lockers not only reduces costs but may also increase value for the customers (Vakulenko et al., 2018). In addition, the use of parcel lockers may help fulfill safety recommendations regarding the COVID-19 pandemic as they are befitting of social distancing measures and contactless delivery.

Regarding location preferences, consumers in Sweden indicated a preference for lockers near shopping areas and home. Proximity to subway or bus stops was also identified as a preference (Vikingson & Bengtsson, 2015). In Poland, consumers strongly preferred locations near their home or on the way to work, while the least attractive locations were near shopping centers and transit stops (Iwan et al., 2016; Lemke et al., 2016). In Brazil, the top three preferred locations were supermarkets, stores, and shopping malls (Oliveira et al., 2017). In Korea, Lee et al. (2019) believe placing parcel lockers along the daily life path of consumers and near public transportation will enhance their utilization. In France, Morganti et al. (2014) found that the average distance to the nearest pick-up point was only 1.6 km (1 mi.) in urban areas and 6 km (3.7 mi.) in rural areas and over 50% of the pick-up points were located within 400 m (0.25 mi) of a commuter railway station. Comparing urban, suburban, and rural regions, pick-up points were over-represented in the urban areas with respect to their share of the population. In South East Queensland (Australia), the presence of a parcel locker was associated with proximity to highways and public transport, high population density, a good balance of population and jobs, and areas with higher rates of household internet access (Lachapelle et al., 2018). Here, lower income populations might have a slight advantage when it comes to parcel locker presence. However, lower automobile ownership rates and a limited ability to travel longer distances, which are associated with lower incomes, counterbalance that benefit (Lachapelle et al., 2018). Finally, Fang et al. (2019) analyzed the distribution of Amazon Lockers in Los Angeles County and detected a positive spatial correlation of locker counts per U.S. Census tract using the Global Moran I Index. Higher education levels, internet access, and walking mode share had the highest correlations with the variable locker counts. The regression analysis produced counterintuitive signs for variables such as population and internet access likely due to multicollinearity.

A recent overview of the locker location literature comes up with six factors that affect locker location: potential 24/7 service availability, accessibility by different modes, security, environmental impacts, installation costs, and regulatory constraints (Lagorio & Pinto, 2020). The e-commerce literature indicates that household income and internet usage are key variables that affect online purchases; higher-income households with more access to computers and the internet are more likely to make purchases online (Cao et al., 2012; Crocco et al., 2013; De Blasio, 2008; Farag et al., 2007). However, underserved populations appear to be less likely to participate in online shopping activities. During the COVID-19 lockdown period, significantly higher rates of home deliveries were associated with higher income and education levels, more access to electronic devices and internet, automobile ownership and usage, larger households, and white households (Figliozzi & Unnikrishnan, 2021). For consumers reliant on transit, the installation of common carrier lockers at transit stations has been proposed to improve access (Keeling et al., 2021).

Although previous studies have identified parcel locker location preferences, there has not been extensive research assessing existing locations of lockers in whole metropolitan urban areas of the U.S. focusing on equity metrics and utilizing clustering methods with income, internet access, transportation, built environment, socio-demographic, and land use variables. While cluster analysis has been utilized in transportation studies to analyze freight, transit, crashes, environmental justice, and mobility (Cidell, 2010; Diaz-Varela et al., 2011; du Preez et al., 2019; Haustein & Nielsen, 2016; Schweitzer, 2006) it has not yet been applied to study locker distributions and/or equity.

3. DATA COLLECTION

The study area is defined as the Oregon portion of the Portland-Vancouver-Hillsboro metropolitan statistical area. This research does not focus on lockers that can be installed inside buildings or complexes for the exclusive benefit of its residents or employees. It focuses on lockers that are mostly installed on sidewalks and public access areas. The dataset of lockers includes the name, coordinates, and host site (where available) of each locker facility. A total of 176 Amazon locker facilities were identified in the study area in October 2020 and Figure 1 shows housing density at U.S. Census block level overlaid by the locker locations.

In total, 62 variables related to age, income, housing, means of transportation to work, race and origin, educational attainment, employment, and computer and internet service accessibility were collected from the U.S. Census Bureau American Community Survey (ACS). These 62 variables are listed in Table A. 1 in the appendix. The socio-demographic data are aggregated at the block group level – the smallest level of geographic detail with a wide range of publicly available variables. Census block groups are usually comprised of contiguous clusters of census blocks, containing between 600 and 3000 people (U.S. Census Bureau, 2019), and their boundaries can be viewed in Figure 1.

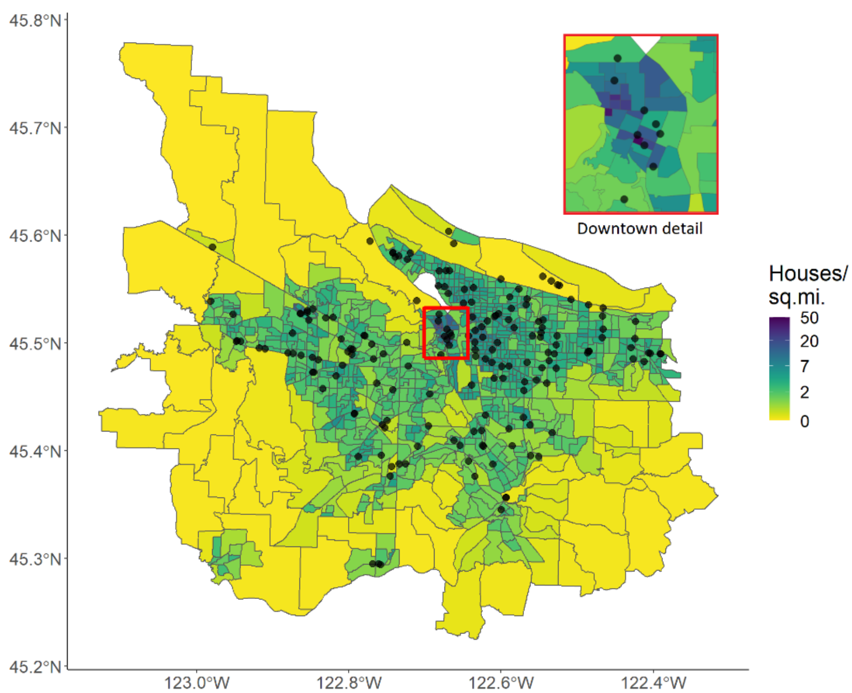

Figure 1: Study area and housing density with Amazon locker locations.

A GIS shapefile of the street network in the area provided by the local MPO was used to investigate locker locations in relation to transportation facilities. Another GIS shapefile containing Oregon zoning data was obtained from the Oregon Spatial Data Library to assess land use patterns associated with Amazon locker locations. Data on the business and employment patterns of the study area were downloaded from the U.S. Census Bureau's ZIP Code Business Patterns (ZBP) dataset for 2018. This data contains information about the number and type of business establishments, the number of employees, and payroll figures, aggregated at the ZIP Code level. The establishment types are categorized according to the North American Industry Classification System (NAICS).

4. METHODS

The dataset containing information about the Amazon lockers was obtained using the Google Places API adapting a Python code from Fang et al. (2019). After locating the lockers, a kernel density estimation (KDE) was applied to each observation (point) to distribute its spatial influence based on a given bandwidth; i.e., a locker located at the border of two Census blocks services the population in both areas, but beyond a certain bandwidth, the influence tapers to almost null. The density of Amazon lockers across the study area was calculated using KDE with the function *density.ppp* from the package *spatstat* in R (Baddeley et al., 2015). A gaussian kernel function was chosen for the KDE, the standard form of which is shown in Equation 1 where d represents the distance from the locker. The kernel (K) is scaled as in Equation 2 where h represents the bandwidth and e is Euler's number or constant.

$$K(d) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}d^2} \qquad \textbf{Equation 1}$$

$$K_h(d) = \frac{1}{h} K\left(\frac{d}{h}\right) \qquad \textbf{Equation 2}$$

For this analysis, the bandwidth was chosen to represent the maximum distance a consumer would be likely to walk to retrieve a parcel. Oliveira et al. (2019) used a 1000 m (0.6 mi.) radius (bandwidth) when calculating the kernel density of potential collection and delivery points in Brazil. In New Zealand the median tolerable walking distance to a collection point was 1.46 km (0.9 mi) (Kedia et al., 2019). In Seattle, light rail passengers most frequently chose up to a six block distance (approximately ¼ to ½ mile given the average size block) when asked how far they would be willing to walk with a parcel (SCTLC, 2018). Other studies noted a consumer preference for minimizing the required travel distance to lockers for parcel retrieval (Iwan et al., 2016; Lemke et al., 2016; Vikingson & Bengtsson, 2015). A conservative bandwidth of a half mile was selected for the current KDE.

A small percentage of missing data was encountered across four of the 62 ACS variables used. The percentage of missing values within these four variables ranged from 1.1% to 9.5% over all 952 block groups within the study area. Rather than exclude observations (i.e. block groups) with missing values from the analysis, the missing values were imputed using the *imputePCA* function in the R package, *missMDA* (Husson & Josse, 2020).

The literature review indicates that income and access to computers and internet service are key variables affecting online purchases. Mode share and built environment variables are of interest from a transportation policy point of view. Also, variables such as education, race, age, home ownership, household size, and employment status are key variables from an equity perspective. Hence, four groups of ACS variables were created to represent different aspects of locker access equity: (1) income, (2) computer and internet access, (3) prevalent built environment and transportation mode, and (4) other non-income demographic factors such as age, race or origin, household occupancy, educational attainment, and work status. Income was placed in a separate group because it is key factor affecting both online purchases and equity. All variables used in the analysis and their basic descriptive statistics are provided in Table A. 1 of the appendix. For each of the four ACS variable groups, a cluster analysis was performed.

Clustering classifies observations into groups (clusters) by computing a measure or distance of the similarity between each pair of observations. Traditional clustering methods like k-means aim to minimize total intra-cluster variation (also known as total within-cluster variation). Traditionally, the within-cluster variation (*W*) is defined as the sum of squared Euclidean distances between items and a centroid:

$$W(C_k) = \sum_{x_i \in C_k} (x_i - \mu_k)^2 \qquad \textbf{Equation 3}$$

where:

x_i is a data point belonging to the cluster C_k

μ_k is the mean value of the points assigned to the cluster.

Each observation (x_i) is assigned to a given cluster such that the sum of squares (SS) distance of the observation to their assigned cluster centers (μ_k) is minimized. The total within-cluster variation is defined as follows:

$$TWC = \sum_{k=1}^{k} W(C_k) = \sum_{k=1}^{k} \sum_{x_i \in C_k} (x_i - \mu_k)^2 \qquad \textbf{Equation 4}$$

The total within-cluster sum of square measures the compactness (i.e., goodness) of the clustering and the goal is to make it as small as possible while keeping a reasonably low number of clusters that are easy to interpret or visualize.

The cluster analysis for each equity category was an iterative, multi-step process. The first step was to perform a hierarchical cluster analysis using Ward's method (R function *hclust* with method = "ward.D2"). This hierarchical cluster analysis produced an object describing the resulting dendrogram, which was then cut into k clusters. The centroids of these clusters were used to define the initial points for a k-means cluster analysis (R function *kmeans*). The process was iterated for multiple values of k ranging from two to six. Solutions with random centroids were also obtained to see if there was a TWC improvement. Interpretability of the results, mapping of the clusters and their spatial contiguity, plots of the total within sum of squares (TWC), and the percent deviations of the cluster averages from the median cluster averages were utilized to select an appropriate value for k.

The results of the iterative clustering process indicated the block groups would be best divided into three clusters for the income, computer and internet access, and transportation equity categories. The non-income demographic category was best represented by four clusters. For each equity category, the KDE was integrated over the cluster areas to obtain a total expected locker count per cluster. Next, the share of each cluster's population within various distances of a locker was estimated by constructing radial buffers around the lockers as a function of transporation mode. For pedestrians, conservative buffers of 0.25 miles and 0.5 miles were selected based on the range of walking distances cited in the reviewed literature. To estimate a range of reasonable biking buffers studies by Blanc & Figliozzi and Kedia et al. (2016; 2019) were utilized. Median actual biking distances in the Portland area for shopping, errands, or personal business were stated as 1.3 miles to 3.1 miles. Thus, biking buffers of 1.5 miles and 3 miles were determined as reasonable. Finally, driving buffers of 3 miles and 5 miles were selected based on the average car trip length of 4.4 miles in the Portland region (Small, 2016). When analyzing buffers it is important to consider that proximity is key, especially for users that walk or cycle to the locker. It should also be considered that in many cases, users pick up a package at the end of a trip chain, for example when returning home after work or after running errands.

5. ACCESSIBILITY ANALYSIS

This section discusses locker accessibility in terms of business location characteristics, land use, and proximity to transportation facilities, home, and work.

5.1 CHARACTERISTICS OF BUSINESS LOCATIONS

The majority of lockers (122 of 176 lockers, or 69.3%) are located inside or on the property of a convenience store. The next most common hosts for an Amazon locker are drugstores (22 lockers, or 12.5%), department stores (9 lockers, or 5.1%) and grocery stores (8 lockers, or 4.5%). The remainder of the hosts included gyms, banks, restaurants, storage facilities, a hotel, a retirement community, a go-kart center, and other retailers. This distribution is compatible with the literature, which indicated one of the best sites for parcel lockers is next to convenience stores (Iwan et al., 2016). The distribution of locker hosts observed in the Portland area also seems reasonable when considering a few of Amazon's business partnerships. For instance, early in the locker implementation, convenience store brand 7-Eleven partnered with Amazon to host locker facilities. Amazon has partnered with the drug store, Rite Aid, more recently (Cosgrove, 2019). Amazon suggests that hosting a locker can increase foot traffic and drive sales of small dollar-amount purchases (Amazon, 2019). Amazon also has business partnerships with Chase Bank and Sprint, which helps to explain the few, somewhat unlikely locker hosts of a communications store and two banks. Additionally, Amazon owns grocer Whole Foods and installing lockers in those grocery stores may provide benefits for both businesses.

5.2 TRANSPORTATION AND LAND USE

The nearest roadway to each locker facility was identified and the distance to it was calculated to explore locker access from different types of road facilities. In addition, the distances from each locker facility to the nearest roadway of each classification (collector, arterial, highway, and freeway ramp) were calculated. While the average and median distances from lockers to freeway ramps or highways were close to one mile or more, the average and median distances from lockers to arterials and collectors were much smaller, ranging from a couple hundred feet to less than a quarter mile. It follows that most Amazon lockers were located closest to an arterial road (101 lockers, or 57.4%), followed by a collector road (52 lockers, or 29.5%), a highway (15 lockers, or 8.5%), and a freeway ramp (8 lockers, or 4.5%). Arterial roads typically provide high visibility to businesses and serve higher volumes of motorized traffic compared to lower classed roads. Recalling that the majority of locker hosts were convenience stores which tend to thrive in high traffic areas, it is logical that most of the lockers were located closest to arterial roads. Transit routes are also more likely to follow arterial roads, but access by bicycle or walking may be reduced if low traffic stress bicycle and pedestrian facilities are not provided.

The zoning shapefile was overlaid by the Amazon locker locations and the land use category corresponding to each location was extracted in R. The locker facilities were predominantly located in mixed-use commercial and residential zones (120 lockers, 68.2%), with commercial zones being the next most common (44 lockers, 25%), followed by industrial (8 lockers, 4.5%). The zoning types corresponding to areas of very low population density such as forest, farm, rural, natural areas, or parks did not contain any locker facilities.

5.3 PROXIMITY TO HOME AND WORK

One of the most often cited preferences of consumers for locker locations was near their home. Buffer ranges around the lockers were created for the walking, biking, and driving distances. A range of the number of households within the buffers was then estimated using areal proportioning for the entire study area as a metric to gauge the average locker proximity to residences. These results are displayed in Table 1 along with the range of percentages of total houses in the study area within the locker buffers. These calculations estimate that almost 85% of households in the study area are within 1.5 miles of an Amazon locker and 97% of households are within five miles.

Table 1: Range of estimated number of households within reach of Amazon lockers by mode.

Mode (Dist. Range)	Households		Employment	
	HH (Thous.)	% of Total HH	Emp. (Thous.)	% of Total Emp.
Walk (0.25-0.5 Mi.)	81-232	12.6-36.1	103-285	11.7-32.4
Bike (1.5-3.0 Mi.)	546-605	84.9-94.0	673-785	76.4-89.1
Drive (3.0-5.0 Mi.)	605-624	94.0-97.0	785-828	89.1-93.9

The map in Figure 2 displays the locations of the lockers with a 0.5-mile buffer, shaded according to the estimated number of households (in thousands) within the buffer. The map shows that lockers with the greatest number of households within the buffer distance tend to be located in the city center and in the close-in neighborhoods. This observation was consistent across all buffer distances.

Another frequently cited preference was for locker locations near the consumer's workplace. Table 1 gives the estimated ranges for the number of employees and the percentage of the study area's total employment within the range of buffer distances established for walking, biking, and driving. Approximately three-quarters of employees are within 1.5 miles of an Amazon locker. The lockers with a 0.5-mile buffer are again shown in Figure 3 but shaded according to the estimated employment within the buffer area. Note that in this figure, the scale is logarithmic. The employment density is much higher in the central city region, thus, the lockers with the greatest number of employees within 0.5 miles also tend to be located in that area.

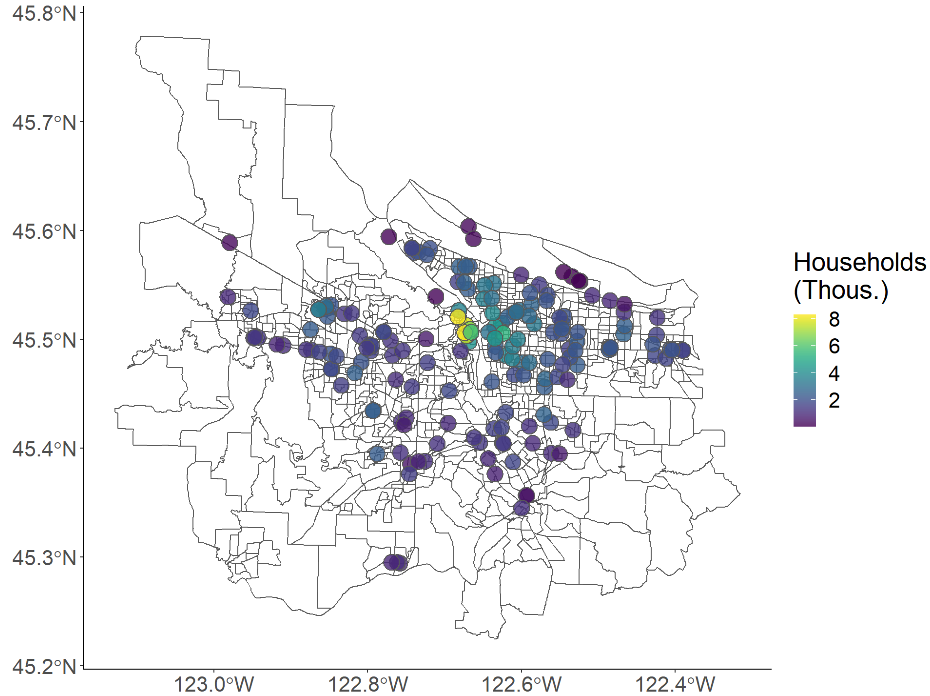

Figure 2: Estimated number of households within a 1/2 mile of an Amazon locker.

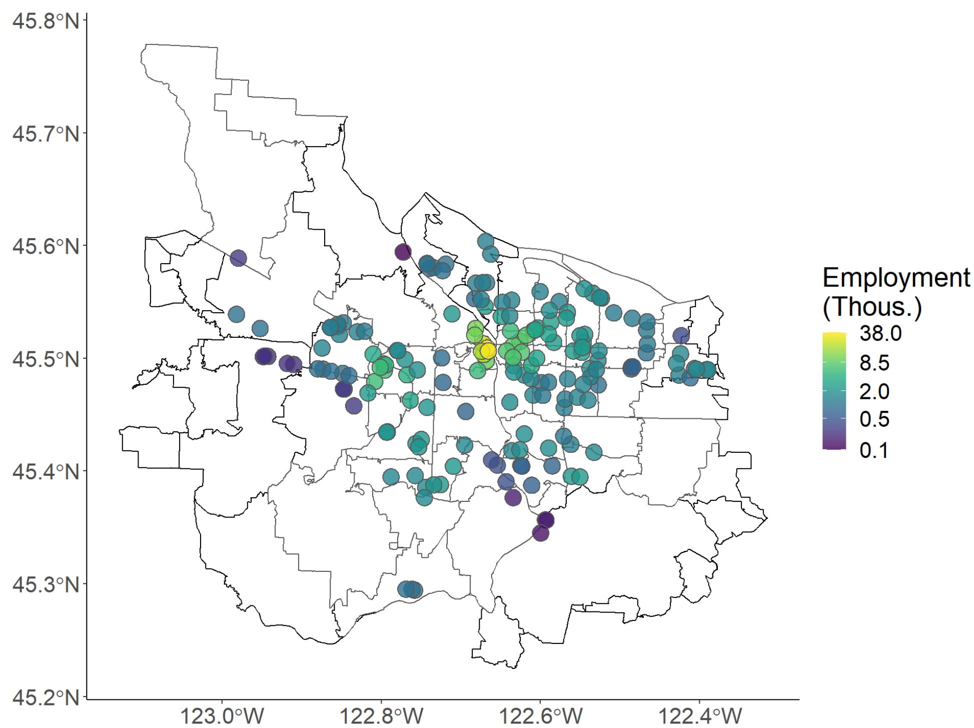

Figure 3: Estimated employment within a 1/2 mile of an Amazon locker.

6. EQUITY ANALYSIS

Evaluating equity is complex and can take many forms depending on the categorization of populations, the performance measures evaluated, and what impacts are considered. Establishing parcel locker facilities in traditionally underserved communities (such as non-white, low-income, transportation disadvataged, etc.) is important to achieve equitable access to basic services such as mail and package distribution. This section discusses the results from the cluster analyses with respect to the distribution of Amazon lockers.

6.1 INCOME

A map depicting the results of the cluster analysis for the income category can be seen in Figure 4. It appears that block groups in Cluster 3 are more prominent in the eastern portion of the study area and block groups in Cluster 1 are generally found in the central region, relative to east-west. Block groups in Cluster 2 appear to comprise the largest portion of land area in the study region.

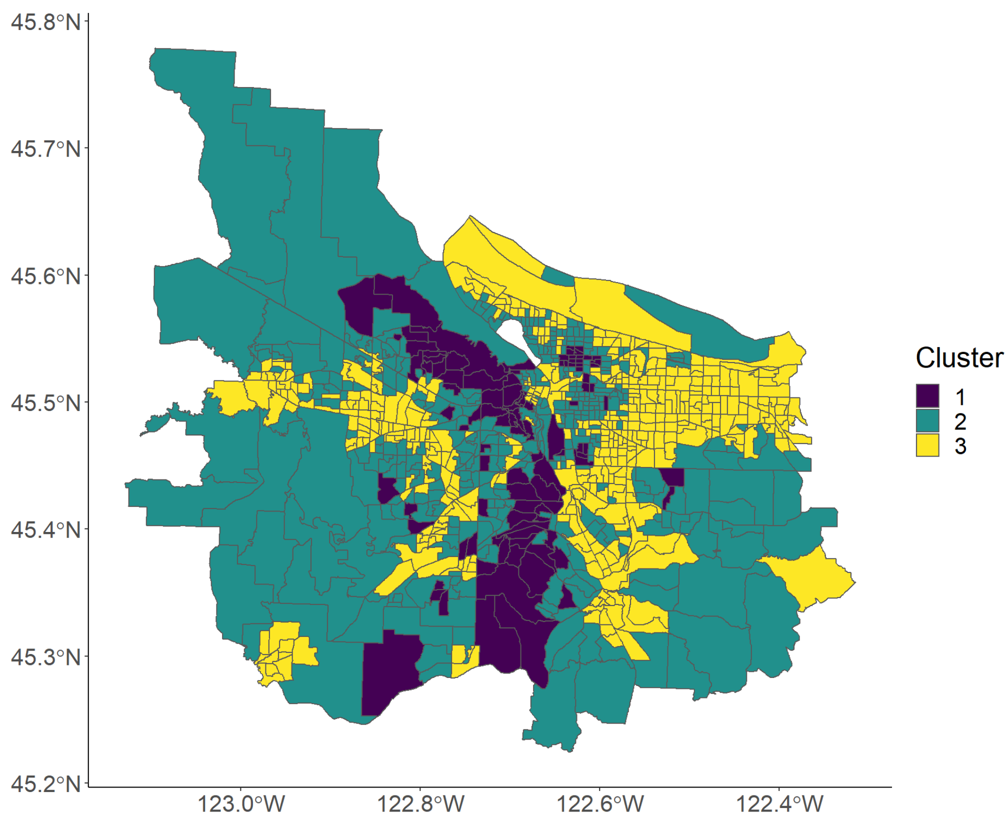

Figure 4: Income cluster results.

Table 2 provides a quantitative description of the characteristics of each income cluster. The key variables showing the most variance among clusters are displayed. Higher income population and households (relative to the median cluster) tend to comprise Cluster 1, and lower-income population and households tend to be located in Cluster 3. The differences between groups are substantial. The average densities of Amazon lockers per square mile (based on the integrated KDE), per thousand population, and per thousand households, and the average household incomes for the Income clusters are also provided in Table 2. The density of lockers per square mile within Cluster 3 is three to four times greater than in Cluster 1 or Cluster 2 (0.51 versus 0.15 and 0.12, respectively). The average expected density per thousand population and per thousand households is also greatest in Cluster 3, though the differences from the other two clusters are less pronounced. The range of population in thousands per cluster within the walking, biking, and driving locker buffer ranges is also shown in Table 2. The percentage of the total cluster population within the buffers is also given. These results further suggest that Cluster 3 has greater access to the Amazon lockers overall, and particularly by pedestrian or bicycle modes.

Table 2: Income cluster characteristics

Key Variables	Cluster 1 “High”	Cluster 2 “Medium”	Cluster 3 “Low”
Median Housing Unit Value*	$674,054	$434,858	$286,790
Average HH Income	$186,975	$109,166	$65,941
Median HH Income	$145,813	$89,369	$54,805
Per Capita Income	$71,278	$45,256	$27,469
Size or Quantity			
Lockers	14.2	63.1	98.2
Population (Pop.)	156,386	681,403	806,872
Households (HH)	57,842	272,153	313,740
Area (Mi.2)	92.4	542.0	191.0
Densities			
Lockers per Sq.Mi.	0.15	0.12	0.51
Lockers per 1000 Pop.	0.09	0.09	0.12
Lockers per 1000 HH	0.24	0.23	0.31
Access by Mode as % Pop.			
Walking (0.25-0.5) Mi..	3.9-17.1	9.5-28.8	14.7-41.2
Biking (1.5-3.0 Mi.)	73.0-97.8	75.2-89.1	92.0-96.2
Driving (3.0-5.0 Mi.)	97.8-100.0	89.1-95.7	96.2-97.0

*Owner-occupied

6.2 COMPUTER AND INTERNET ACCESS

Figure 5 shows the results of the cluster analysis for the computer and internet access category. The spatial distribution of the clusters here appears to be somewhat more dispersed than those generated by the income category, although there does appear to be some correlation between Clusters 1 and 3 in Figure 5 and Clusters 1 and 3 in Figure 4.

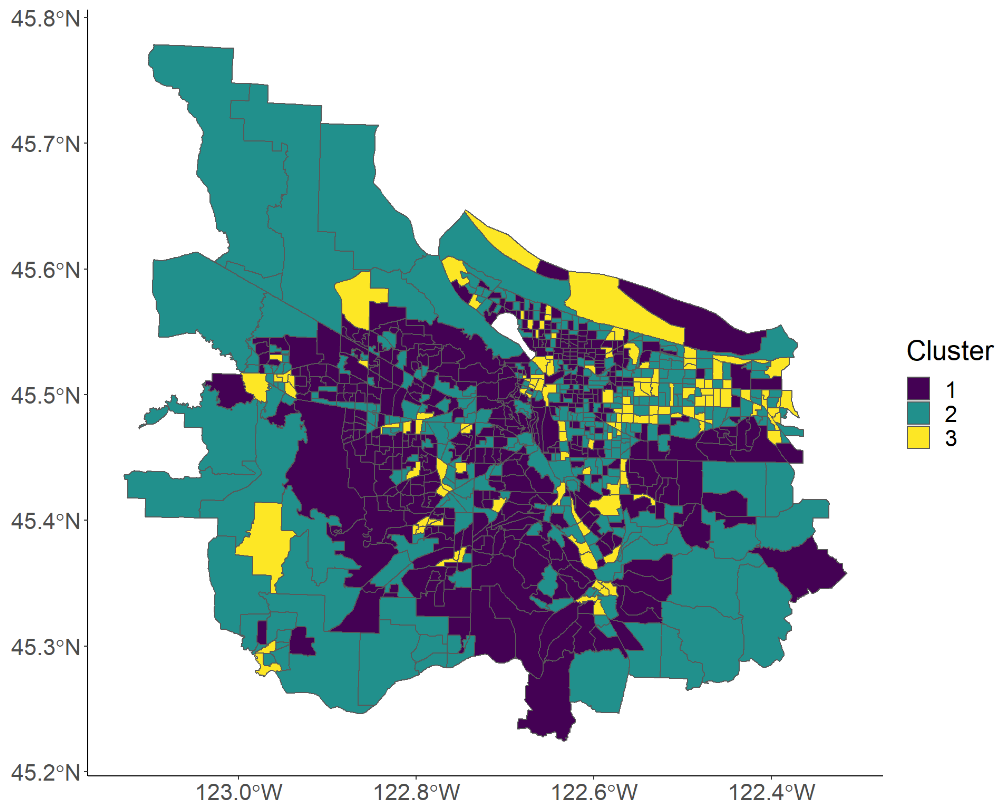

Figure 5: Internet and computer access cluster results.

Table 3 highlights the variables that most characterize the computer and internet access clusters and their values. Households in Cluster 1 were most likely to have access to a computer and broadband internet service. Households in Cluster 3 were least likely to have access to a computer or broadband service and were far more likely to have no access to internet at all relative to Cluster 1 or Cluster 2. Recalling the observation of the minor correlations with Clusters 1 and 3 in the Income category, these results suggest lower income populations have less access to computers and internet compared to higher income populations. Cluster 2 appeared most likely to have cell only based internet access, although the difference from Cluster 3 was very small. Considering much of the Cluster 2 area is located farther from the city center, this finding may be partially explained by service area limits for broadband internet, i.e., the option of broadband may not exist in outlying areas.

Table 3: Internet access cluster characteristics

Key Variables	Cluster 1 "High"	Cluster 2 "Medium"	Cluster 3 "Low"
% HH with Computer	97.9	93.4	82.3
% HH with Broadband	94.3	85.0	71.1
% HH with Cell Only	5.9	9.0	8.9
% HH without Internet	3.9	10.4	23.7
Size or Quantity			
Lockers	73.6	68.8	33.0
Population (Pop.)	834,530	594,030	216,101
Households (HH)	318,592	235,225	89,918
Area (Mi.2)	293.7	468.7	63.0
Densities			
Lockers per Sq.Mi.	0.25	0.15	0.52
Lockers per 1000 Pop.	0.09	0.12	0.15
Lockers per 1000 HH	0.23	0.29	0.37
Access by Mode as % Pop.			
Walking (0.25-0.5) Mi..	7.8-26.0	14.7-40.0	16.8-46.7
Biking (1.5-3.0 Mi.)	78.2-93.9	85.8-91.1	95.4-97.8
Driving (3.0-5.0 Mi.)	93.9-98.3	91.1-94.1	97.8-98.1

Computer and internet access have been linked to income, and low access households may be considered a disadvantaged group from an equity standpoint. The percentage of households without internet access is highest in Cluster 3, at more than twice the percentage of the next highest cluster (23.7% vs. 10.4% for Cluster 2 and 3.9% for Cluster 1). Cluster 3 generally has lower access to computers and internet services overall, relative to Clusters 1 and 2. However, Cluster 3 appears to have the highest average concentration of lockers for all three measurement units, particularly with respect to area. Cluster 3 may have greater access to the parcel lockers as the percentage of its population within nearly all buffer distance ranges is greater than the percentages for Cluster 1 or Cluster 2. This is a positive finding with regard to equity.

6.3 TRANSPORTATION AND BUILT ENVIRONMENT

The spatial distribution of the transportation and built environment category clusters is displayed in Figure 6. The map shows the majority of Cluster 3 is in the center of the study area, which generally corresponds to the downtown and inner eastside areas of Portland. Cluster 2 areas are more dispersed around the region but seem to be located near major transportation routes. Cluster 1 contains the most land area, consisting of most of the outlying regions and generally surrounding the areas assigned to Clusters 2 and 3.

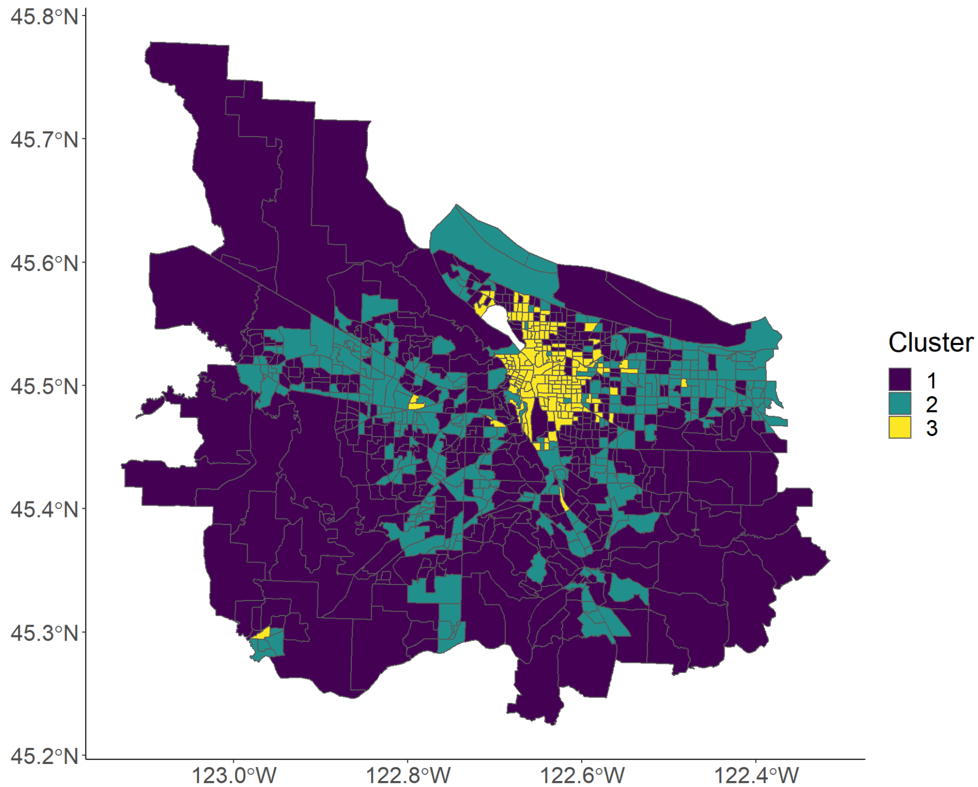

Figure 6: Transportation cluster results.

Several variables related to commute mode choice, housing unit type, and population density were selected for display in Table 4 to quantify the primary characteristics of each cluster. These variables generally showed the most variance among clusters. Housing unit types and population density were included in this category as a representation of the built environment, which has been shown to influence transportation choices (Cervero, 2002). When combining transport and housing variables it is difficult to both succinctly and accurately label the clusters, nonetheless a non-numerical "intuitive" description is added under each cluster.

Cluster 1 is characterized by a lower likelihood of walking or taking public transit to work, relative to the other two clusters. Single detached housing was much more likely in Cluster 1 at almost twice the percentages of Cluster 2 or Cluster 3. Correspondingly, multi-unit housing was least likely in Cluster 1. Furthermore, population density was lowest in Cluster 1 relative to Clusters 2 and 3. These findings align with the spatial distribution of the clusters shown in Figure 6, whereby Cluster 1 dominates the areas furthest from the population dense city center.

The main characteristics of Cluster 2 are a tendency toward commuting by carpool, but not by bicycle, relative to the other clusters. Cluster 2 also had the lowest average percentage of workers working from home. Although the overall percentage of mobile houses is low in all clusters, it is more than twice as high in Cluster 2 as in Cluster 1, the median cluster, and almost ten times higher than in Cluster 3.

Table 4: Transportation and BE cluster characteristics

Key Variables	Cluster 1 "Drive alone – single housing"	Cluster 2 "Drive alone – multi-unit"	Cluster 3 "Transit/active – multi-unit"
% Workers Drove Alone*	72.4	68.3	45.6
% Workers Carpooled*	8.3	11.8	5.3
% Workers Public Transit*	5.4	8.8	17.3
% Workers Bicycled*	2.3	1.4	10.9
% Workers Walked*	1.9	3.4	10.7
% Workers Work from Home*	8.8	5.1	8.9
% Housing as Single Detached	86.1	39.9	44.5
% Housing as Multi-unit	8.9	47.0	50.8
% Housing as Mobile	1.9	3.9	0.4
Population Density (per mi.^{2})	4948	6675	11922
Size or Quantity			
Lockers	72.7	70.6	32.2
Population (Pop.)	794,218	623,453	226,990
Households (HH)	289,326	247,956	106,453
Area (Mi.2)	656.3	144.6	24.6
Densities			
Lockers per Sq.Mi.	0.11	0.49	1.31
Lockers per 1000 Pop.	0.09	0.11	0.14
Lockers per 1000 HH	0.25	0.28	0.30
Access by Mode as % Pop.			
Walking (0.25-0.5) Mi..	6.2-21.4	12.6-36.9	26.9-68.3
Biking (1.5-3.0 Mi.)	74.2-88.3	89.0-98.0	98.0-98.8
Driving (3.0-5.0 Mi.)	88.3-94.5	98.0-98.8	98.8-100

*Aged 16 years or older

Cluster 3, primarily located in the central region of the city, is characterized by an appreciable increase in population density relative the rest of the study area. Thus, it should not be surprising that rates of public transit or active travel modes (walking or bicycling) of commuting to work far outpaced rates elsewhere in the study area. The average expected number of lockers per square mile is highest in Cluster 3 and lowest in Cluster 1 which tends to be more rural and has the lowest population density. Cluster 3 also has a greater expected number of lockers per population and per household, on average, although the differences between clusters are less significant. The estimated percentage of the population in Cluster 3 within walking distance to an

Amazon locker is nearly twice that of Cluster 2 and more than three times the percentage in Cluster 1. Moreover, almost all of Cluster 3 is within 1.5 miles of an Amazon locker. As expected, the percentage of Cluster 1 within the buffer zones is lowest for all three mode choices.

6.4 NON-INCOME DEMOGRAPHICS

Di Ciommo and Shiftan (2017) acknowledge age, educational level, and employment status are related to income and car ownership. Youth and elderly who are non-drivers are more reliant on public transportation and those with language barriers may be less likely to hold a driver's license and have trouble navigating public transit. Additionally, race or ethnicity is frequently considered in equity analyses as minorities often have lower relative incomes (Di Ciommo & Shiftan, 2017). Figure 7 displays a map of the non-income category cluster results. The map shows most of the outlying areas and a strip through the center of the study region, west of the downtown area, belong to Cluster 1.

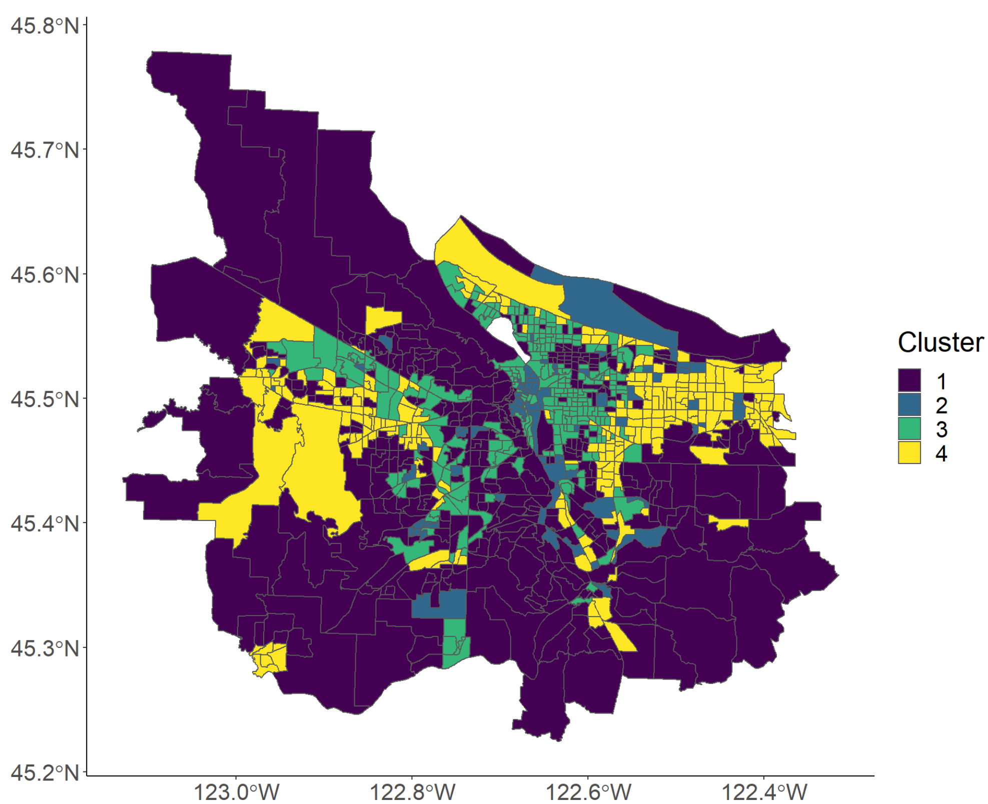

Figure 7: Non-Income Demographic cluster results.

Cluster 2 is comprised of fewer block groups overall and appears to be dispersed among the central and eastern portions of the study area. Block groups immediately east of the downtown area appear to be predominantly of Cluster 3. Cluster 3 appears slightly more scattered in the western half of the study area but seems to follow primary transportation routes. Cluster 4 block groups tend to be farther from the city center than those of Cluster 3.

This category contained the largest number of variables and only those in which higher variances were observed between clusters were selected for display in Table 5. Cluster 1 is characterized by a much higher rate of owner-occupied housing. The housing units were less likely to have only one occupant, but more likely to have four occupants compared to the other clusters. Compared to Clusters 2 and 3, Cluster 1 was generally more likely to have multiple occupants in a housing unit. The percent of the population who were age 0-9 or 10-7 was also greater in Cluster 1 than Cluster 2 or 3, but not greater than Cluster 4. In the adult age groups, Cluster 1 had the largest percentage of 45–64-year-olds but the smallest percentage of 18–29-year-olds on average. This combination of age groups may indicate a high prevalence of families with children. Moving to race and origin, Cluster 1 had the lowest percentages of Black or African American and Hispanic or Latin-American in the population relative to all other clusters. The population in Cluster 1 also tended to be more educated, with the lowest rate of non-high school graduates and higher rates of bachelor's and graduate or professional degrees. However, the differences in these rates compared to Cluster 3 were small. When many variables are present it is difficult to both succinctly and accurately label the clusters, nonetheless a non-numerical "intuitive" description is added for each cluster.

A higher percentage of housing units with only one occupant was a prominent characteristic of Cluster 2. These block groups also tended to have the lowest rates of housing with three or more occupants compared to all other block groups. Additionally, Cluster 2 had the lowest percentage of the population aged 0-9 years but the highest percentage aged 65 or older, on average. There is a noticeably lower percentage of the population in the work force, and a higher percentage was indicated to have not worked in the past 12 months. These results seem to point to the presence of a higher percentage of retired persons in these block groups.

Table 5: Non-Income cluster characteristics

Key Variables	Cluster 1 "Educated middle-aged homeowners"	Cluster 2 "Older, less workers"	Cluster 3 "Educated, younger workers"	Cluster 4 "Young, Hispanic, Latin-American"
% Housing Occupied by Owner	82.3	40.6	45.4	51.9
% Housing with 1 Occupant	19.9	54.1	33.9	25.2
% Housing with 2 Occupants	38.7	31.2	37.2	29.8
% Housing with 3 Occupants	16.8	6.9	14.9	16.8
% Housing with 4 Occupants	17.0	5.0	9.9	13.9
% Housing with 5 Occupants	5.1	1.9	2.8	8.1
% Housing with 6 Occupants	1.6	0.4	0.9	3.9
% Housing with 7+ Occupants	0.8	0.6	0.4	2.3
% Population Age 0-9	11.5	5.2	9.4	14.3
% Population Age 10-17	10.4	4.5	5.7	10.5
% Population Age 18-29	10.6	15.3	22.5	17.4
% Population Age 30-44	19.9	19.0	30.8	24.1
% Population Age 45-54	31.3	26.3	21.9	23.0
% Population Age 65+	16.3	29.9	9.8	10.8
% Pop. Black/African Am.	1.4	4.7	4.8	4.9
% Pop. Hispanic/Latin-American	5.7	8.2	8.8	23.9
% Pop. Limited English Ability	1.3	3.8	1.7	8.6
% Pop. < High School Degree*	3.9	8.0	4.7	17.0
% Pop. Bachelor's Degree*	31.4	24.2	32.8	16.6
% Pop. Graduate/Prof. Degree*	22.0	16.6	21.0	6.9
% Population in Labor Force**	66.8	51.3	76.8	67.6
% Population Did Not Work**	29.8	44.9	20.6	30.4
Size or Quantity				
Lockers	51.7	20.4	53.6	49.7
Population (Pop.)	644,447	100,009	409,093	491,112
Households (HH)	238,510	53,774	180,754	170,697
Area (Mi.2)	588.6	33.4	72.6	130.8
Densities				
Lockers per Sq.Mi.	0.09	0.61	0.74	0.38
Lockers per 1000 Pop.	0.08	0.20	0.13	0.10
Lockers per 1000 HH	0.22	0.38	0.30	0.29
Access by Mode as % Pop.				
Walking (0.25-0.5) Mi..	4.3-17.4	19.7-48.5	19.6-51.1	12.5-37.8
Biking (1.5-3.0 Mi.)	67.5-86.3	96.0-99.7	96.5-100.0	90.1-96.0
Driving (3.0-5.0 Mi.)	86.3-93.6	99.7-100.0	100.0-100.0	96.0-97.4

*Aged 25 years or older; **Aged 16 years or older

Cluster 3 appears to have higher percentages of 18-29-year-olds and 30-44-year-olds relative to all other clusters. The population in these block groups also tend to be more educated, with higher rates of bachelor's and graduate or professional degrees than Cluster 2 or Cluster 4. Also, on average, the percentage of the population in the workforce was highest for Cluster 3 while the percent of the population that did not work was the lowest compared to all other Clusters. Together, these characteristics may indicate a higher presence of younger working adults.

In Cluster 4, a few characteristics are quite pronounced. For example, the percentage of housing units with five, six, or seven or more occupants is much higher relative to the other clusters. In addition, the percentages of the population with Hispanic or Latin-American origins, limited English speaking abilities, or attaining less than a high school (or equivalent) degree are significantly higher compared to the other clusters. On average, the population in Cluster 4 has the lowest rates of bachelor's and graduate or professional degrees and the highest percentages of children aged 0-9 years and 10-17 years. These characteristics seem to indicate a higher prevalence of larger families and population of Hispanic or Latin-American origin.

Cluster 3 is shown having the highest average locker density with respect to area, but Cluster 2 has the highest average density with respect to both population and households. The lowest average locker densities for all three measurement units exist in Cluster 1. Cluster 2 is characterized by a couple of factors that may contribute to transportation disadvantage, including greater percentages of people aged 65 or older or those who do not work as compared to the other clusters. Cluster 4 exhibits a greater number of demographic qualities that may contribute to transportation disadvantages. Cluster 4 has the highest percentage of young children (aged 0-9 years), and much higher percentages of people with Hispanic or Latin-American origin or with limited English language abilities. This cluster also demonstrated the lowest education levels on average, with the highest proportion of people with less than a high school degree (and the lowest proportions of people with bachelor's or graduate degrees). For this equity category, it appears that Cluster 4 should be prioritized.

Regarding percentages of the population in each cluster within the walking, biking, and driving locker buffers, the lowest percentages are observed in Cluster 1 for all modes, followed by

Cluster 4. Cluster 2 and Cluster 3 demonstrate the highest population percentages within the locker buffers, reaching almost 100% within a 3-mile radius. It appears that the distribution of Amazon lockers in Cluster 4 is not on par with the distribution in Cluster 2 or Cluster 3. Additional focus should be given to Cluster 4 with when considering locations for new locker facilities if locker access equity is a policy goal.

7. DISCUSSION

Mail and package distribution are considered a basic service. Access to basic goods, services, and activities is a key component in accessibility-based transportation equity evaluations (Litman, 2002). In the postal service literature, the concept of universal service for post and packages has been frequently discussed (Cohen et al., 1993; Cremer et al., 2000; De Donder et al., 2002). Universal postal service includes accessibility for all, quality of service, and reasonableness of rates, with an overall goal of avoiding major access differences via differential pricing and product offerings that create conditions that result in a "market failure". In the transportation literature the term market failure implies a situation when a minimum level of accessibility or mobility that should be available to all is not met (Button, 2005). The idea of avoiding market failure in transportation has many similarities with the concept of universal postal service.

Regarding locker accessibility, a market failure can be defined as situations where locker locations respond solely to customer demand and purchasing power with no coverage of populations that *need* affordable and/or convenient locker access. Amazon is a private, profit-seeking entity, and the placement of lockers responds to customer demands and the company's overall competitive strategy, and these goals may not necessarily match the allocation of lockers based on equity or need considerations. It should be the role of policy makers and transportation agencies to analyze whether policies or the allocation of resources to improve locker accessibility based on need and/or equity considerations are justified.

Parcel policies should also take into account that there are four basic types of parcel locker systems depending on carrier and public access characteristics: a) Open or common carrier parcel locker systems which can be utilized by different logistics operators or e-commerce companies and may be run by an external non-profit entity like a city or metropolitan agency. These lockers are usually located in public spaces and can be utilized by any potential customer. b) Closed locker systems which are operated and managed by one business, stakeholder, or consortium. In closed systems, only the owner or operator typically utilizes the locker (rival companies do not have access). These lockers are located on private property owned by the owner of the locker or through access granted via a contract (e.g., Amazon lockers located at convenience stores) but they can be utilized by any potential customer. The third class of locker system c) is usually located inside multi-unit residential apartment units. This third type of system is usually located indoor and run by the building or property manager and can be utilized by different carriers or logistic operators. However, they have restricted (no public) access since only residents or property owners can utilize the indoor lockers. In cases a) and b) public access is not restricted. Finally, case d) is a closed system with restricted customer access that could be utilized in some business settings. The discussion and focus of this research is on cases a) and b) where there is unrestricted public access, though at the moment only type b) is available in Portland and type a) could be promoted by policy makers where needed.

The equity spatial analysis presented in this research has direct policy implications since it can guide the placement of incentives to locate additional (open) lockers in urban areas, for example installing *supplementary* common carrier (open) public parcel lockers in transit stations where they are needed the most to fill an equity or accessibility gap (Keeling et al., 2021). Common carrier lockers could then serve public agencies' accessibility and equity goals, facilitating deliveries for those who are transportation disadvantaged or time poor.

Policy makers could also use the proposed methodology to monitor the ongoing installation of lockers across the urban area. In Poland, the capital Warsaw with 600 lockers (Wilczek, 2021), has a much higher density of lockers per capita than Portland, almost 4.5 times more lockers per capita. Based on Warsaw's figures, it is likely that more lockers will be installed in the future in the Portland metropolitan region. Given the dramatic growth of e-commerce the locker market is not yet mature.

8. CONCLUSIONS

E-commerce is growing rapidly, and it is critical that different populations have access to efficient and environmentally friendly last mile delivery options like automated lockers. This research presents a novel approach utilizing cluster analysis to evaluate locker distribution accessibility and equity metrics. Overall, a large percentage of the population can access Amazon lockers because they tend to be located in convenience or other small format retail stores, close to arterial roads, on land zoned for mixed-use commercial and residential, and in areas of higher population and employment density. In terms of accessibility by mode, lockers are accessible by automobile for the vast majority of the population in the Portland metropolitan region. The share of the population that can access lockers by walking is significantly smaller and this may present a challenge for non-driver populations.

Regarding equity, clusters in the income and computer and internet access categories appear to have equitable access to parcel lockers. However, the data suggests that there is less access to parcel lockers for Hispanics, people with low education levels, or people who have limited English language abilities. Black and African Americans did not clearly fall into one cluster, but this may be due to the relatively low number of Black and African Americans in the Portland metropolitan area.

Ancillary benefits of additional locker locations could also include a reduction in delivery vehicle miles traveled as well as reduced energy consumption and emissions. More policy implications can be found by increasing the spatial resolution, e.g., an inspection of the bottom ten block groups when ranked in order of highest to lowest number of lockers per population and per households revealed nine of them belong to the low-income cluster. Another policy implication is that equity metrics differ widely based on the units utilized, for example lockers per area, per population, or per household. Suburban low-density areas have the lowest levels of lockers per area or population, but tend to be inhabited by educated, higher income homeowners. Hispanics tend to be in more dense areas in terms of population but with lower density of lockers per population when compared to similarly dense areas. Given the larger size of Hispanic households the equity metrics are sharper when considering equity metrics per population instead of per household.

The equity spatial analysis presented in this research has direct policy implications since it can guide monitoring of the parcel locker system as well as the placement of resources or common carrier public parcel lockers where they are needed the most to fill an equity or accessibility gap or reduce a potential market failure. Policy makers and public agencies could use the proposed methodology to monitor locker accessibility and equity goals and recognize potential market failures. In this research parcel locker systems are classified into four basic types depending on carrier and public access characteristics. Policy makers should also monitor how locker type evolves over time, since closed or restricted locker systems do not bring the same advantages in terms of sustainability or equity respectively.

This research also introduces the concept of market failure in the parcel locker market. Lower income and underserved populations engage less in e-commerce and home deliveries, and it is possible that in addition to income barriers, there are other barriers like accessibility to affordable and conveniently located lockers that may accentuate e-commerce inequities. This is an issue that so far has not received enough attention in the parcel locker literature.

Lack of access to essential services such as food has given rise to concepts like food deserts. Similarly, lack of access to e-commerce and efficient last mile delivery systems can be studied in future research efforts as ancillary services to bridge the digital divide and barriers that impede access to new products and services. The traditional concept of accessibility can be broadened to include access to parcel lockers, i.e. adding access to lockers to expand the concept of home based accessibility for e-commerce products and services first introduced by Figliozzi and Unnikrishnan (2021). This is relevant as governments foster e-commerce access, for example to provide touchless and safe deliveries during the COVID-19 crisis and beyond, avoiding or reducing social contact in stores or with home delivery personnel.

The main ideas and methods utilized in this research are likely transferable to other urban areas but not the specific findings associated to the spatial distribution of lockers and population characteristics. Future research efforts are recommended in cities or regions with a different spatial or sociodemographic composition.

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APPENDIX

Table A. 1: Descriptive statistics for all ACS variables.

Income Variables:	Min	15th Perc	Median	85th Perc	Max	Mean	St. Dev
Median Housing Unit Value (Million $)	0.01	0.25	0.36	0.53	0.99	0.39	0.15
Average HH Income (Million $)	0.01	0.06	0.09	0.13	0.36	0.10	0.04
Median HH Income (Million $)	0.01	0.05	0.07	0.11	0.23	0.08	0.03
Per Capita Income (Million $)	0.01	0.02	0.04	0.05	0.12	0.04	0.02

Computer and Internet Access Variables:	Min	15th Perc	Median	85th Perc	Max	Mean	St. Dev
% HH with Computer	0.62	0.88	0.96	1.00	1.00	0.94	0.06
% HH with Internet (All Sub. Types)	0.29	0.79	0.90	0.96	1.00	0.88	0.09
% HH with Broadband Sub.	0.29	0.79	0.90	0.96	1.00	0.88	0.09
% HH with Dial-up Only Sub.	0.00	0.00	0.00	0.01	0.10	0.00	0.01
% HH with Cell Only Sub.	0.00	0.02	0.06	0.13	0.39	0.07	0.06
% HH with Satellite Only Sub.	0.00	0.00	0.00	0.01	0.22	0.01	0.01
% HH with Other Internet Only Sub.	0.00	0.00	0.00	0.00	0.08	0.00	0.01
% HH with Internet (No Sub.)	0.00	0.00	0.02	0.06	0.44	0.03	0.04
% HH without Internet	0.00	0.02	0.07	0.17	0.56	0.09	0.08

Transportation-BE Variables:	Min	15th Perc	Median	85th Perc	Max	Mean	St. Dev
% Workers Drove Alone*	0.06	0.52	0.68	0.80	0.98	0.66	0.14
% Workers Carpooled*	0.00	0.03	0.08	0.15	0.64	0.09	0.06
% Workers Public Transit*	0.00	0.01	0.07	0.16	0.59	0.09	0.08
% Workers Bicycled*	0.00	0.00	0.01	0.09	0.32	0.04	0.05
% Workers Walked*	0.00	0.00	0.02	0.08	0.55	0.04	0.07
% Workers Work from Home*	0.00	0.02	0.07	0.13	0.35	0.08	0.05
% Workers Other Trans.*	0.00	0.00	0.00	0.02	0.21	0.01	0.02
% Workers Taxi*	0.00	0.00	0.00	0.00	0.17	0.00	0.01
% Workers Motorcycle*	0.00	0.00	0.00	0.01	0.07	0.00	0.01
% Housing as Single Detached	0.00	0.28	0.69	0.95	1.00	0.63	0.29
% Housing as Single Attached	0.00	0.00	0.03	0.11	0.45	0.05	0.07
% Housing as Multi-unit	0.00	0.00	0.23	0.61	1.00	0.29	0.28
% Housing as Mobile	0.00	0.00	0.00	0.03	0.81	0.02	0.07
Population Density (Thous. per mi.2)	0.03	2.72	6.03	10.30	59.92	6.79	5.28

Non-income Demographic Variables:	Min	15th Perc	Median	85th Perc	Max	Mean	St. Dev

% Housing Occupied	0.69	0.90	0.96	1.00	1.00	0.95	0.05
% Housing Occupied by Owner	0.00	0.33	0.65	0.88	1.00	0.61	0.25
% Housing with 1 Occupant	0.00	0.15	0.25	0.40	0.98	0.28	0.14
% Housing with 2 Occupants	0.00	0.25	0.35	0.45	0.71	0.35	0.10
% Housing with 3 Occupants	0.00	0.08	0.15	0.23	0.45	0.16	0.07
% Housing with 4 Occupants	0.00	0.05	0.13	0.21	0.61	0.13	0.08
% Housing with 5 Occupants	0.00	0.00	0.04	0.10	0.34	0.05	0.05
% Housing with 6 Occupants	0.00	0.00	0.00	0.04	0.28	0.02	0.03
% Housing with 7+ Occupants	0.00	0.00	0.00	0.03	0.22	0.01	0.02
Median Rooms Owner-Occupied	1.80	5.37	6.30	7.60	10.00	6.45	1.19
Median Rooms Renter-Occupied	1.40	3.40	4.30	5.60	10.00	4.44	1.17
% Population Age 0-9	0.00	0.06	0.11	0.16	0.31	0.11	0.05
% Population Age 10-17	0.00	0.04	0.08	0.14	0.30	0.09	0.05
% Population Age 18-29	0.00	0.08	0.15	0.24	0.88	0.16	0.09
% Population Age 30-44	0.02	0.16	0.23	0.32	0.54	0.24	0.08
% Population Age 45-54	0.03	0.19	0.26	0.34	0.61	0.26	0.08
% Population Age 65+	0.00	0.07	0.13	0.21	0.81	0.14	0.09
% Population White	0.32	0.68	0.82	0.92	1.00	0.80	0.12
% Population Black/African American	0.00	0.00	0.01	0.08	0.39	0.04	0.06
% Population Asian	0.00	0.01	0.04	0.13	0.63	0.07	0.08
% Population White Hispanic/Latino	0.00	0.01	0.05	0.13	0.64	0.07	0.09
% Population Hispanic/Latino	0.00	0.02	0.08	0.20	0.75	0.11	0.12
% Population Other Race	0.00	0.00	0.01	0.06	0.50	0.03	0.06
% Population Multi-Race	0.00	0.01	0.04	0.09	0.28	0.05	0.04
% Population Limited English Ability	0.00	0.00	0.01	0.07	0.30	0.04	0.05
% Population Less than High School Deg.*	0.00	0.01	0.05	0.16	0.46	0.08	0.08
% Population High School Deg./GED*	0.00	0.07	0.17	0.28	0.62	0.17	0.10
% Population Associate's Deg./Some College*	0.03	0.19	0.30	0.40	0.59	0.30	0.10
% Population Bachelor’s Deg.*	0.00	0.15	0.27	0.39	0.58	0.27	0.11
% Population Graduate/Professional Deg.*	0.00	0.05	0.15	0.30	0.65	0.17	0.12
% Population in Labor Force**	0.20	0.59	0.69	0.79	0.96	0.69	0.10
% Population in Armed Forces**	0.00	0.00	0.00	0.00	0.05	0.00	0.00
% Population Full-time Worker**	0.08	0.35	0.45	0.53	0.79	0.44	0.09
% Population Part-time Worker**	0.06	0.21	0.27	0.34	0.69	0.27	0.07
% Population Did Not Work**	0.04	0.19	0.28	0.37	0.77	0.28	0.10

*Aged 25 years or older; **Aged 16 years or older