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Does proximity matter in shopping behavior?☆

Rishi Verma [a,*], Giacomo Dalla Chiara [b], Anne Goodchild [b]

[a] Department of Industrial and Systems Engineering, University of Washington, Seattle, WA, United States
[b] Department of Civil Engineering, University of Washington, Seattle, WA, United States

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ABSTRACT

While e-commerce continues to grow as a proportion of retail sales, consumers still largely rely on vehicle travel to shop. At the same time, the "15-minute city" concept is gaining traction, suggesting that the livability and sustainability of urban areas will improve if essential goods and services are all located in close proximity to residential areas. However, little is known about how the proximity of commercial establishments to consumers affects their shopping behaviors, namely their choice of whether to shop online or in-person, and the mode of travel if the latter is chosen. In this study, we use data from a 2022 shopping behavior survey asking about consumers' most recent shopping events, whether they were performed online or in-person, the travel mode. Respondents' approximate home locations were also collected, allowing the research team to map nearby establishments. The collected data was used to estimate discrete choice models of shopping behaviors and test whether proximity to commercial establishments affects shoppers' choices. In particular, this study tests whether proximity to commercial establishments makes consumers more likely to shop in person (vs. online) and to travel by walking (vs. driving). Proximity to commercial establishments did not affect the likelihood of purchasing goods online, while it did affect the travel mode choice for in-person shopping travel for certain types of goods. Regression analysis indicates that each additional commercial establishment within a 0.5-mile radius increased the likelihood of walking by 23%for groceries and 17% for prepared meals. This did not apply to clothes shopping, which also had the highest rate of e-commerce at 62.4%. We observed that for in-person shopping, travel time was approximately 10 min for both walking and driving. In addition, we found that e-commerce made up 25.3% of all shopping activity and the majority (81%) of shopping travel involved driving.

1. Introduction

Travel for in-person shopping still makes up a significant amount of vehicle trips. According to the 2016 National Household Travel Survey (Hu, 2001); 41.2 % of personal vehicle trips are for shopping. At the same time, online platforms provide an increasingly wide array of goods and services for purchase through the Internet, which can be delivered directly to shoppers' homes via a fleet of last-mile delivery vehicles in a short time. In 2012, retail sales from online channels represented 5.4 % of total retail sales in the US, which has grown to 14.8 % in 2022, with many cities worldwide offering same-day deliveries at the consumers' doorsteps (Department of Commerce Census Bureau, 2012; U.S. Department of Commerce Census Bureau,. Quarterly Retail E-Commerce Sales - 3rd Quarter,

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* Corresponding author.
E-mail addresses: rverma32@uw.edu (R. Verma), giacomod@uw.edu (G.D. Chiara), annegood@uw.edu (A. Goodchild).

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2022). With the increased flexibility offered by e-commerce, consumers can buy goods from retailers regardless of location.

An emerging urban planning concept is the "15-minute city" (Moreno et al., 2021). The core tenet of this model is chrono-urbanism, suggesting that by increasing walkability and providing proximity to travel destinations such as work, stores, and entertainment, the need for vehicular travel is reduced, increasing the quality of life and reducing the negative externalities generated by car travel. By promoting walking and biking vs. driving, 15-minute cities positively impact the residents' mental and physical health, reducing car trips and related emissions and helping cities reach their climate goals. From an urban logistics standpoint, a 15-minute city is achieved by providing access to goods and services within a "15-minute" journey. Specifically, six "essential urban functions" must be fulfilled within this distance: living, working, shopping, and access to healthcare, education, and entertainment (C40, nd).

This study investigates the shopping component of a 15-minute city and the extent to which residents' behavior is linked with the urban environment. In particular, we address the following research question:

1.1. How does proximity to goods and services affect shopping behavior?

We define shopping behavior as the sequential choices between shopping online and in-person and, in the latter case, the shopping travel mode between walking, biking, or driving. We define proximity as the distance between consumers' residences and commercial establishments. Given an individual consumer, we consider three forms of proximity (Fig. 1). First, the minimum distance from a resident's home to the closest commercial establishment that supplies the category of product they wish to purchase. Second, we consider the travel time it takes to reach the destination based on their selected mode of transportation. Finally, we look at the number of commercial establishments within a given distance from a resident's home, for example, the number of supermarkets and convenience stores within 0.5 miles.

Understanding the relationship between proximity and shopping behavior is essential to planning livable and sustainable cities. We consider two hypotheses:

- An increase in proximity to commercial establishments increases the likelihood of walking and biking to nearby stores vs. driving
- An increase in proximity to commercial establishments reduces the likelihood of shopping online vs. in-person

The first hypothesis directly concerns the share of individual car trips taken for shopping and suggests that proximity reduces car dependency while reducing negative externalities of car travel. This includes traffic, accidents, emissions, and related economic, social, and health impacts. The second hypothesis impacts last-mile delivery trips, often performed by larger vehicles performing delivery routes, often within urban residential areas.

A shopping behavior questionnaire was developed to test these hypotheses. The anonymous survey asked respondents to report information about their latest shopping trip for a given kind of goods or service purchased, including whether they shopped in-person or online, their travel mode, and their travel time. Other explanatory variables were collected, including socioeconomic information, housing, and car and bike ownership. To compute proximity metrics, each respondent was asked to report the closest street intersection to their home address, which was then processed using Google Maps API to identify nearby commercial establishments and compute relevant proximity metrics. The survey was deployed in a case study area in West Seattle, a peninsula on the west side of downtown Seattle, WA. 919 responses were obtained. After calculating descriptive statistics of the observed shopping behaviors, the sample data was used to formulate and estimate random utility models of the choice between purchasing online, driving, and walking to a store, using the developed proximity metrics as explanatory variables, among others.

The following section reviews previous studies and literature relevant to our research question, identifies gaps in previous

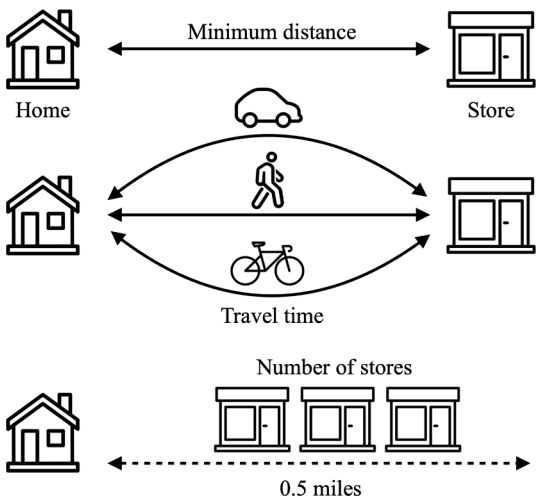

Fig. 1. Three measures of consumers' proximity to commercial establishments.

approaches, and outlines our contributions. The next sections describe our methodology for data collection and analysis and detail the sample gathered. Results from our statistical and regression analysis are then reported, followed by a discussion, summary of findings, and conclusion.

2. Relevant Literature

The choice of in-person versus online shopping is related to various factors, from income levels to attitudes toward online shopping platforms. A 2015 study in Indonesia analyzing how respondents chose between buying online vs. in-person concluded that the most influential factors relating to shopping choice were internet experience, internet access, and each respondent's disposition towards a particular form of shopping, with the remaining significant factors being demographic (Irawan and Wirza, 2015). One challenge in modeling shopping behaviors is that they are related to the types of goods and services in question: attitudes towards online shopping change whether the goods being purchased are household goods or fashion items. Empirical studies often look at shopping as a single overarching type of activity that describes all goods that a person or household purchases and use this as the basis for comparing in-person and online shopping. However, as Ding and Lu wrote, "the travel impacts of online shopping significantly differ by product types" (Ding and Lu, 2017). In reality for a consumer, in-person shopping frequency and the experience of using online platforms might vary greatly according to the types of goods and services being considered. Indeed, Dholakia found nuanced interactions with gender and the nature of the shopping destination (mall vs. supermarket) that would be lost if all types of shopping were considered equal. (Roy Dholakia, 1999). Nevertheless, in a review of e-commerce research, Rotem identified that most studies do not distinguish between classes of products, which can contribute to the obfuscation of mobility effects (Rotem-Mindali and Weltevreden, 2013). Dias et al. address this by explicitly differentiating behavior for different types of goods within their modeling of shopping choices (Dias et al., 2020).

With the advent of e-commerce, several studies have explored the relationship between online and in-person shopping. The standard hypotheses considered are substitution, where online shopping replaces an in-person shopping trip; complementarity, where online shopping encourages additional in-person travel; modification, where online shopping changes the patterns of shopping trips; or a neutral effect (Gould and Golob, 1998; Salomon, 1985); (Mokhtarian, 2002). These possible effects have repeatedly been used to frame the study of e-commerce and its relationship with in-person shopping.

A study using data from 1996 and 2001 shopping data collected in the Netherlands was also concerned with the impact of spatial variables on e-commerce, focusing particularly on urbanization (Farag et al., 2006). The researchers classified areas into five urbanization categories and used these as explanatory factors. In addition, they measured proximity based on the number of stores of a particular type within a 10 and 20-minute drive from the participants and used logistic regressions to determine the likelihood of purchasing three items online: travel tickets, CD/video/DVD, and clothing. The authors conclude that residence in both urban and suburban areas is positively linked with increased online shopping activity, though this effect is modified by the type of goods. These particular items were chosen due to the existence of online shopping platforms that sold them. However, a contemporary perspective could move from outdated products like CDs to the current state of e-commerce that allows for buying a variety of household products available from sites like Amazon. Furthermore, this paper does not look at specific purchases and whether they were in-person or online. Instead, the modeling framework proposed in this study analyses the likelihood of any online purchases. As a result, the proximity measures become largely irrelevant and insignificant in the model used in the Netherlands study. Similarly, the data did not include any in-person shopping trips, so the researchers could not analyze travel modes and patterns and how they interact with shopping choices.

Handy and Clifton looked at mode choice for shopping to identify strategies to reduce vehicle trips (Handy and Clifton, 2001). In particular, they examined the concept of "local shopping" by distributing surveys and conducting focus groups to assess how the distance from a participant's residence to the nearest store could affect their choice of whether to drive or walk to complete their trip. However, they identified that the nearest food store was not the chosen destination for grocery shopping for nearly two-thirds of residents. Through analysis of the focus group responses, the authors concluded that the availability of nearby alternatives combined with a resident's level of satisfaction with their nearest store were relevant factors in determining whether they would travel further. A primary takeaway from this study was that though more commercial establishments in closer proximity to participants' residences may not necessarily decrease vehicle dependency, having very few nearby options ensured that shopping would be done via vehicle trips. Handy et al. in 2005 suggests that even though differences in travel behavior can be largely explained by attitudes towards travel, there is support for a causal relationship between built environment and travel behavior, suggesting that strategies to change the built environment through development and land use policy may find success in changing behavior (Handy et al., 2005). However, this study was conducted before the rise of e-commerce giants such as Amazon, and the study did not consider online shopping as an alternative. A modern look at shopping behaviors from an e-commerce perspective could examine how online shopping for delivery may substitute for or complement these trips.

Furthermore, the nature of proximity of alternative stores within the "local" area may play a different role when online ordering for delivery is an option since residents will not necessarily need to visit specific businesses for their shopping needs. More recently, in 2017, Suel and Pollack used discrete choice models to model the choice between retail channel, shopping destination and travel mode, which included online activity. They found a substitution effect, where higher income groups may swap in-person shopping trips with online shopping for "larger basket" purchases that have a high number of items. Furthermore, their results indicate that this substitution effect is linked with driving trips over walking trips, due to the low frequency of large basket walking trips. Our study will use a similar approach of discrete choice models and investigating the complete picture of shopping alternatives, incorporating both travel mode and online shopping (Suel and Polak, 2017). Arranz-Lopez et al. in 2021 used this lens to also examine the separation between

different goods types, examining grocery and clothes shopping separately. They found that the frequency of buying groceries online was not relevant for predicting "perceived accessibility" (the distance one was willing to walk for in-person shopping), but the opposite was true for clothes shopping. As they point out, this indicates a need for more study on the interplay between products, travel, and online shopping (Arranz-López et al., 2022).

Ren and Kwan used an activity diary dataset to study e-commerce patterns in the Columbus Metropolitan area, seeking to investigate the role of geographic context on e-commerce behavior (Ren and Kwan, 2009). The diary collected information about internet usage over 2 days; the researchers additionally used street network data to look at measures of accessibility. A logistic regression model was fitted across all types of goods to examine the factors that led participants to engage in e-commerce during a typical week, in addition to Poisson and negative binomial models used to predict the number of online purchases. The authors found that in their particular sample, which heavily skewed white and vehicle owners, proximity to shopping opportunities did decrease e-commerce behavior but did so minimally; in fact, race had a far more significant effect. However, since this study is focused on the frequency of shopping, the authors do not position shopping in-person vs. online as mutually exclusive choices; furthermore, the goods type is considered homogeneous across the participants within a "non-daily" category. Colaço et al. included both Likert scale shopping preferences and number of shopping opportunities within 500 m in their study, using structural equation modeling to examine the interactions between online and in-store shopping preferences over different days of the week (weekdays vs weekends). Their findings were concentrated on the perception of shopping behavior and actual behavior, finding a strong link between the two. However, counting shopping opportunities did not lead to significant findings and moreover, the number of shopping opportunities available was quite high, since the study was based in a city center (average of over 80 shopping opportunities per person). In our more residential study area, limited shopping opportunities near residences may be a much stronger predictor depending on the goods (Colaço and Abreu e Silva, 2021). The aftermath of the COVID-19 pandemic was also found by Colaço to potentially accelerated a substitution of online shopping in place of in-person shopping, in a study conducted at the same time period that we will examine (Colaço and Silva, 2023). Diaz-Gutierrez et al. conducted an analysis of pandemic effects on shopping over Puget Sound, the greater surrounding region of our study area, asking about grocery and food shopping separately. They found that online shopping an substitute for grocery shopping, but online shopping can increase more than in-person shopping decreases, indicating that the substitution may not entirely replace in-person (Diaz-Gutierrez et al., 2023). So, while the immediate effects of the pandemic may have dissipated, its lingering effects may continue to affect how different goods are shopped for.

To summarize, the effects of proximity to brick-and-mortar retail and business locations on specific shopping choices need additional study in the modern era of e-commerce, particularly with regard to its interaction with travel behavior for different categories of goods types. More recent studies have found some effects of proximity, accessibility, and geographic context using historical data, but there is a research gap when it comes to fully understanding the substitution effect. When goods types are separated, and proximity to nearby establishments is considered, available travel modes must also be observed since historical studies have shown that considering this factor is a significant part of the decision process. We must look at the current state of e-commerce since buying products online is becoming easier and faster. In this study, we continue this area of contemporary research by using data from a cross-sectional survey collected during the summer of 2022, asking participants about their most recent shopping experience in one of four goods categories. We collected data on whether this experience was in-person or an online order for either pick-up or delivery, thereby directly measuring the shopping choices in contrast to one another. We asked respondents for their approximate home address, which we use to measure proximity both to the nearest relevant business and to count the total number of nearby alternatives within 0.5, 1.0, and 1.5 miles. Additionally, we asked in-person shoppers to report their travel mode and travel time to understand the necessary components of in-person shopping better. Using our collected data, we fitted random utility models to identify the effects of proximity on shopping travel behaviors.

Table 1
Survey Description.

Section	Variables
Part 1: Socioeconomic Factors	• General Demographics (Age, Gender, Race, education) • Socioeconomic status (Household composition, Income, employment) • Mobility disability
Part 2: Dwelling & Transportation	• Vehicle ownership • Access to micro-mobility (Bicycles, scooters, etc.) • Nearest intersection to the home address
Part 3: Delivery Behavior	• Residential package security (lockers, reception) • Usual behavior (frequency, delivery location)
Part 4: Most Recent Shopping Activity	One goods type was randomly assigned (among groceries, household supplies, restaurant food, and clothing items) to each surveyor, reporting: • Time of most recent shopping activity • Quantity purchased • Shopping choice (in-person/pick-up/delivery) • If shopped in-person or pick-up: transport mode and travel time • If shopped for delivery: delivery location • Whether trip-chaining occurred

3. Methods

3.1. Survey Design

A shopping behaviors survey questionnaire was designed and tested. The survey was intended to be completed online in under 5 min and anonymously. The survey contained four main sections (see Table 1, full survey in Appendix A). The first section asked about respondents' demographic and socioeconomic characteristics, including age, gender, income, household composition, and whether the participant had a disability that "limited physical activity." The second section asked about transportation access, including vehicle and bicycle access. Participants were also asked to report the closest street intersection to their home address. While keeping the survey anonymous, the nearest intersection was considered precise enough to be used to compute proximity metrics. The third section asked about habitual shopping behavior, in particular, whether and how often the respondents purchased through e-commerce channels and habitual delivery locations. Finally, the fourth section asked questions about respondents' most recent completed shopping experience related to one of four goods categories, randomly selected among groceries, household supplies, restaurant food, and clothing items. Participants were asked whether they shopped in-person, whether they had placed a delivery order, or whether they had placed a pick-up/take-out order, in addition to the timing of their most recent shopping experience. For delivery orders, the order must have been delivered to be considered complete. Participants who had shopped in-person or placed pick-up orders were asked about their travel time and travel mode to and from their destination.

3.2. Study Area

The survey was distributed to a study area to gather responses. The study area consisted of the West Seattle peninsula, an area of the city of Seattle, in Washington State, located on a peninsula west of the Duwamish Waterway. All travel mode choices, including walking, public transit, bicycling, and driving, are easily accessible to residents in West Seattle, presenting an opportunity to study travel behaviors in addition to studying proximity. The study area is subdivided into ten neighborhoods: Alki, Delridge, Fairmount Park, Fauntleroy, Gatewood, Genesee, Industrial District West, North Admiral, Seaview, and South Park. Within the study area, there are also two terminal ports, the T-5 and T-115, located on the peninsula's east coast. The land area is 14.5 square miles. Land use is mostly residential at 86.2 %, with 10 % industrial and the remaining commercial or public. In 2019, a total of 99,072 people lived in WS, distributed over a total of 28,759 buildings (about 3.5 people per building). The population density is 6,857 people per square mile. Population density by neighborhood is shown in Fig. 2, and we note that the northwest part of the peninsula is the most densely populated.

The area of West Seattle was chosen for convenience in the survey distribution. Due to the closure of one of the main bridges connecting the peninsula's north side to the Seattle industrial and downtown districts, the City of Seattle performed outreach to keep

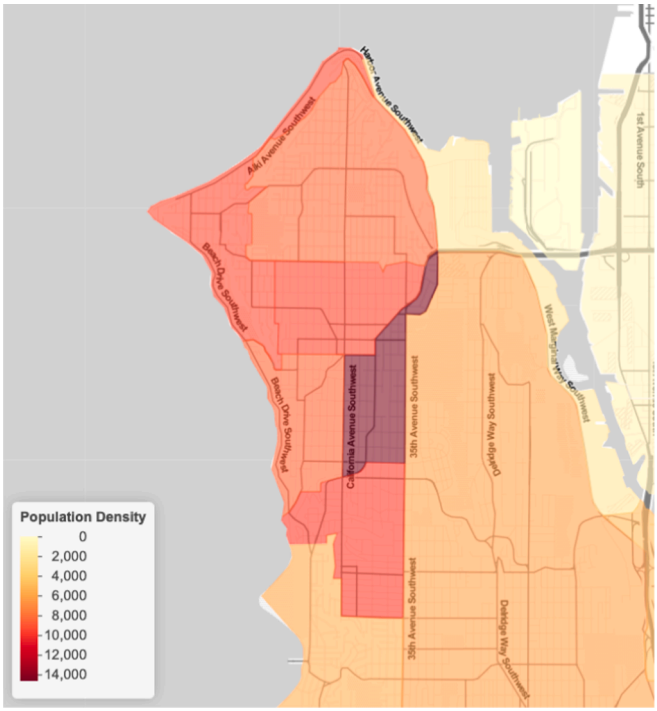

Fig. 2. Population density by neighborhood in the study area.

West Seattle residents informed on the bridge constructions and reopening schedule. We were able to use several media channels operated by the City of Seattle, including newsletters, social media posts, and contacts with local blogs and community associations, to advertise the survey and maximize the number of responses.

3.3. Survey Distribution

The survey was deployed from 20 May to 18 August 2022 (91 days), using the JotForm Platform. The primary distribution channels were the Seattle Department of Transportation (SDOT) newsletter, which has approximately 10,000 recipients, and the "Flip Your Trip" newsletter (a program that provides trip planning assistance to WS residents), which has approximately 8,000 recipients. In addition, the research team made social media posts and distributed the survey on the West Seattle Blog and West Seattle Transport Coalition. Participants were offered the chance to win a $50 gift card at the end of the survey if they provided their contact information and mailing address; this information was only used for identity verification and not as part of any analysis.

3.4. Choice Model Estimation

Three multinomial random utility models were estimated using the sample data obtained from the survey to identify factors influencing shopping behavior. Each model concerns the shopping behavior for a different category of goods. These discrete choice models were estimated using the Biogeme package for Python (Bierlaire, 2020). The universal choice set consisted of three alternatives:

- Walking to a desired commercial establishment
- Driving to a commercial establishment (available only to those with a driver's license or able to access a vehicle in the household)
- Delivery order placed and completed (Any order that resulted in home delivery, including local delivery, ship-from-store services, and parcel delivery)

This choice set was drawn from the survey responses, where participants were asked about their most recently completed shopping experience in one of the four goods categories: groceries, household supplies, clothes, and restaurant food. For delivery orders, this requires that the delivery was completed and not in-transit at the time of reporting. Mixed shopping experiences, where some goods were purchased in-person and others online for either pick-up or delivery as part of the same shopping session, were categorized based on which experience was most recently completed as reported by the survey participants. Pick-up orders were consolidated into in-

Table 2
Sample Distribution.

Socioeconomic variables	Percentage of population		
	Seattle	West Seattle	Sample
Race			
White	65.8 %	68.7 %	84.3 %
Black or African-American	7.1 %	8.3 %	2.05 %
American Indian and Alaska Native	0.5 %	0.37 %	1.1 %
Asian	16.3 %	9.5 %	5.6 %
Native Hawaiian and Other Pacific Islanders	0.3 %	0.53 %	0.16 %
Two or More Races / Other	7.6 %	9.12 %	4.3 %
Hispanic or Latino	7.1 %	9.87 %	2.5 %
Age			
18–24 years	10.3 %	5.5 %	0.9 %
25–44 years	40.1 %	36.6 %	28.2 %
45–54 years	12.2 %	13.7 %	21.7 %
55–64 years	10.3 %	12.5 %	22.0 %
65–74 years	7.6 %	8.0 %	19.7 %
75 years and over	4.9 %	5.3 %	7.5 %
Gender Identity			
Male	50.6 %	49.2 %	30.2 %
Female	49.4 %	50.8 %	68.4 %
Gender Not Listed/None of these			1.4 %
Education Level			
Less than a bachelor's degree	35.0 %	43.8 %	19.02 %
Bachelor's degree or higher	65 %	56.4 %	80.1 %
Annual Household Income			
Less than $49,000 ("Low")	26.50 %	26.03 %	12.00 %
$50,000 to $149,000 ("Medium")	43.00 %	43.40 %	50.40 %
$150,000 or more ("High")	30.50 %	30.55 %	37.70 %

person shopping in the choice models, since both forms require travel to and from a business. As a result, the alternatives "Walking" and "Driving" refer to survey participants who shopped in-person, and those who placed an online order, and then traveled to the business to pick up their goods. This form of online shopping does not fall into the category of "substitution" as earlier discussed; rather, under "modification", where the shopping behavior has been changed but and in-person trip has not been eliminated. The analysis of shopping travel in Tables 4, 5, and 6 below each consider the entire set of shopping travel data collected, including both the travel for in-person shopping and for pick-up orders.

Additionally, while biking and public transit were also considered in different model formulations, there were not enough respondents who chose those shopping travel modes, and they were therefore dropped from the universal choice set.

We controlled for several demographic factors that were collected: Age, Education Level, Disability Status, Number of Children, Gender, Income Level, and Employment Status. Additionally, we control for two factors relating to how often consumers shop: the timing of the most recent shopping trip, and their reported frequency of shopping. Finally, we have factors relating to proximity. First, the Haversine distance between a shopper's residence and the nearest business that can supply the goods for which they are shopping. Additionally, the number of businesses within a 0.5-mile, 1-mile, and 1.5-mile radius that can supply these goods.

The first model we estimated combines the goods categories of groceries and household supplies. Our second and third models were estimated for restaurant food and clothing items, respectively. Previous iterations of our choice modeling approach used goods type as an explanatory variable and kept groceries and household supplies separate. However, the results from these early models showed such significant differences between the behaviors for different goods types that we chose to create separate models instead to look closer at the effects of proximity. We combined groceries and household supplies in the final model for three reasons. First, to increase our sample size for walking and delivery and avoid overfitting the model. Second, these categories were the only pairing that did not show significant differences in behavior in our early models (See full model results in Appendix B). Third, we also observed that both groceries and household supplies can be purchased from the same set of businesses, namely supermarkets and convenience stores. Accordingly, for the "distance to nearby businesses" proximity factor in this category, we included both "supermarkets" and "supermarkets & convenience stores.".

4. Data description

A sample of 919 responses was obtained, corresponding with approximately 1 % of the study area population. Table 2 shows the distribution of the main socioeconomic variables for the sample (sample of respondents), the population of West Seattle, and the

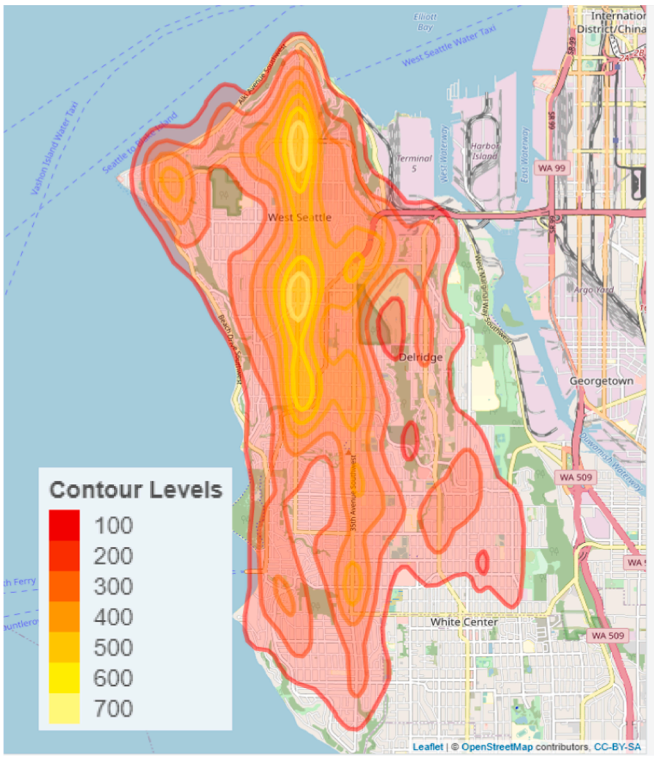

Fig. 3. Geographic distribution of survey respondents. Areas highlighted in yellow have a higher density of respondents than areas in orange and red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

population of the Seattle metropolitan region (U.S. Census Bureau. Selected Characteristics of the Total and Native Populations in the United States., 2020; Census Bureau, 2020). Overall, the demographics of West Seattle are quite similar to that of the Seattle metropolitan region, with the most significant differences being a lower proportion of Asian residents and lower proportions of higher education in West Seattle. Across other demographic and socioeconomic factors including race, age, gender, and income, the population of West Seattle is within 5 % of greater Seattle. Given these demographics, we believe that West Seattle is an appropriate representation of the population of the greater Seattle area. Each goods category has a similar number of responses: 264 respondents were asked about "Groceries", 231 were asked about "Household Supplies", 197 were asked about "Restaurant Food", and 227 were asked about "Clothes". 881 participants reported having shopped in one of our categories within the last three months, and these responses were selected for further analysis. 90 responses were also damaged by a glitch in the survey platform's data storage system, leading to some missing fields. A bigger proportion of participants in our sample identified as White, aged over 45, female, and had a bachelor's degree or higher than the populations of Seattle and West Seattle. Empirical results are not weighted to keep consistency with the inferential model; we note the potential for bias as a result.

We used the Google Maps geocoding API (Geocode and Developer Guide, 2022) and R (R Core Team) to query the approximate latitude and longitude coordinates of the intersections near participants' residences. In addition, the number of establishments in each good was within specific distances from each participant and was collected using the Google Maps Places API (Places and Developer Guide, 2022). These were decided to be 0.5 miles, 1 mile, and 1.5 miles as reasonable but significantly separated distances that each could be comfortably walked or driven.

Fig. 3 shows the geographic distribution of survey participants as a heatmap with contour lines; higher densities of participants are indicated by smaller yellow bounded regions. Though our survey was distributed to West Seattle residents there were a small number of participants from outside the study area. Furthermore, some participants chose not to provide their approximate location. The data from these responses were still analyzed for uncovering patterns in shopping trends, but it has been filtered out for geospatial analysis. In total, there were 868 out of 919 responses that provided location information.

5. Results

5.1. Empirical results

In-person vs. *Online Shopping*. We observe from Table 3 that 61.3 % of the most recent shopping activity was done in-person, while 25.3 % took the form of online orders with home delivery. A further 13.4 % of most recent shopping fell into the pick-up category, where the shopper places an order online but travels to pick it up. Since pick-up orders still require visiting the establishment, we combine this with in-person rates to get 74.7 % of the most recent shopping experiences across the four goods categories involved in travel. Breaking down by goods type, significant differences in shopping behavior can be observed. First, groceries and household supplies are primarily purchased in-person, with respectively 92.7 % and 80.5 % of respondents reporting traveling to purchase these goods. Online shopping for household supplies is more popular than groceries, with approximately 20 % of respondents choosing to buy online. For groceries, delivery options are typically same-day orders from a supermarket, and goods are typically perishable. As a result, the ease of online shopping does not apply as strongly for this good, as shoppers will need to coordinate their time around receiving their order to ensure that perishable items are stored safely. In contrast, though household supplies can be bundled with grocery orders, their non-perishable nature makes them suitable for orders that do not require immediate attention once delivered. Online delivery is strongest for clothes shoppers both across all goods categories and within the clothes category at 62.4 % of most recent shopping activity. Pick-up orders and in-person shopping are both minimal, combining for a total of 25.3 % of most recent experiences involving travel. Restaurant food is slightly different from the other categories: in-person refers to in-person dining, a rate which is found to be 34 %. Pick-up orders were observed to be dominant in this category at 50.5 %, leading to an overall rate of 84.2 % of participants whose most recent experience with a restaurant involved travel.

Shopping Travel Mode choice. Across the four goods categories, we find that driving is the dominant mode of choice, with 81 % of shopping travel occurring using a personal vehicle. We note that 96 % of survey participants also reported having access to a vehicle. Walking is the second most preferred mode choice, though a distant one, with only 13 % of total participants choosing to walk. Walking was most popular for groceries, though still only at 14.4 %. 52 % of participants reported having access to a bicycle, yet only 2.3 % of trips were made by bicycle. Use of public transit was similarly minimal at 3.3 %. Mode choice does not appear to vary significantly across goods type; indeed, a chi-square test with 9 degrees of freedom conducted over walking, driving, cycling, and public transit and the four goods categories yielded a p-value of $0.422 > 0.05$, leading us to fail to reject the null hypothesis that choice of shopping travel

Table 3
Shopping Choice and Most Recent Experience by Goods Category.

Shopping Choice	Goods Type				Total
	Groceries	Household Supplies	Restaurant Food	Clothes	
% In-Person	233 (89.3 %)	171 (75.7 %)	62 (33.7 %)	74 (35.2 %)	540 (61.3 %)
% Pick-up	9 (3.4 %)	11 (4.9 %)	93 (50.5 %)	5 (2.4 %)	118 (13.4 %)
% Delivery	19 (7.3 %)	44 (19.5 %)	29 (15.8 %)	131 (62.4 %)	223 (25.3 %)

Table 4
Shopping Travel Choice and Trip Chaining by Goods Type.

Travel mode		Goods Type				Total
		Groceries	Household Supplies	Restaurant Food	Clothes	
Bicycle	*Shopping*	5 (2.3 %)	3 (1.8 %)	3 (1.9 %)	3 (4.3 %)	14 (2.3 %)
	Trip-Chaining	1 (20 %)	2 (66.6 %)	/	3 (100 %)	6 (54.5 %)
Personal Vehicle	*Shopping*	173 (80.5 %)	142 (85 %)	121 (77.7 %)	59 (84.3 %)	495 (81.3 %)
	Trip-Chaining	74 (42.8 %)	91 (64.1 %)	/	35 (59.3 %)	200 (53.4 %)
Public Transit	*Shopping*	6 (2.8 %)	4 (2.4 %)	6 (3.8 %)	4 (5.7 %)	20 (3.3 %)
	Trip-Chaining	4 (66.6 %)	3 (75 %)	/	3 (75 %)	10 (71.4 %)
Walking	*Shopping*	31 (14.4 %)	19 (10.8 %)	26 (16.7 %)	4 (5.7 %)	80 (13.1 %)
	Trip-Chaining	11 (35.5 %)	8 (42.1 %)	/	2 (50 %)	21 (38.9 %)
Total	*Shopping*	215 (100 %)	168 (100 %)	156 (100 %)	70 (100 %)	609 (100 %)
	Trip-Chaining	90 (41.9 %)	104 (61.9 %)	/	43 (61.4 %)	237 (52.3 %)

is linked with goods type. Also included in Table 4 are trip-chaining rates by goods type and travel mode. Trip-chaining refers to visiting multiple places on a single shopping or errand trip; for example, visiting a supermarket followed by a laundromat. In this study, in-person shoppers for groceries, household supplies, and clothes were asked about whether they trip-chained. In-person restaurant diners were not asked. Results show that overall, over 50 % of shoppers trip-chained, especially in the categories of household supplies and clothes, where over 60 % trip-chained. Trip-chaining was also most common with personal vehicles in each category. High rates of trip-chaining can imply that even if a shopper were to replace one of the stops with an online delivery order, they may still take a vehicle trip to visit the other locations.

Travel Time. Table 5 shows the respondents' reported time spent traveling to their shopping destination. Shopping travel time seems to follow two trends. First, walking time is remarkably consistent across goods categories, averaging between 10 and 13 min for each goods type, and the average across all goods categories is also in this range. We investigate this observation with a Welch one-way ANOVA over travel time for walking. The p-value is 0.77, which is easily greater than the significance level of 0.05 and leads us to fail to reject the null hypothesis that walking travel time is linked with goods type. Shoppers preferred a travel time averaging close to 10 min when walking to their destination. For shoppers who chose to drive, we can see a similar trend across three categories: groceries, household supplies, and restaurant food. The average travel time in each case is between 9 and 12 min. However, shopping for clothing differs, with an average travel time of 27.2 min. Using a Welch one-way ANOVA over travel time, we find a significant p-value of $2.06 \times 10^{-12} < 0.05$, justifying additional tests between each pair of goods. Using Games-Howell nonparametric comparison for unequal variances, we find significant differences between the following groups at the 0.05 significance level: Groceries-Clothing (2.4×10^{-12}), Food-Clothing (4.2×10^{-8}), and Household Supplies-Clothing (2.14×10^{-8}), aligning with our observation. However, no significant differences were found between driving travel time across the other six pairings of goods. Looking at the totals, we still see that the average driving time is 11.19 min across all goods types, even though the category of clothes differs, which may be due to the comparatively low number of people who drove for clothes shopping compared with the other categories. Finally, we can observe that public transit takes the longest average time in each category and that no clear pattern emerges for bicycling, though this is likely due to the low number of observations.

Proximity to commercial establishments. Using the Google Maps API and the collected approximate locations as described above, we found the number of nearby businesses to each shopper that offered the asked-about goods type. We used this approach to search for the number of businesses within 0.5 miles, 1.0 miles, and 1.5 miles of each shopper using Haversine distance based on latitude and longitude coordinates. The summarized results are shown below in Table 6. In this analysis, we simplified the concept of "shopping choice" to 3 alternatives: In-person shopping via Walking, In-person shopping via Driving, and Online shopping for Delivery. By doing this we combined pick-up orders in-person, as both involve travel to the business.

We first observe the totals in each category. By far the most accessible good is restaurant food, with the highest average number in each of the three radii. Grocery stores are lowest in frequency in each radius, but there are still over 7 grocery stores within 1.5 miles of the average shopper; furthermore, there were at least two grocery stores within 1.5 miles of 99 % of grocery shoppers. Similarly, across each of the other categories, we see that goods are generally accessible within the region, as each good has multiple relevant establishments within the 1-mile and 1.5-mile radius. Across groceries, household supplies, and restaurant food, the respondents who walked had a higher average number of businesses located within a half mile of their residence than those who drove or ordered delivery. This observation lines up with what we previously observed about walking travel time: shoppers on average tend to walk around 10 min to their destinations, and at a comfortable pace of 3 miles per hour, this corresponds to an approximate distance of 0.5 miles. Though the number of establishments with a 0.5 radius varies based on goods type, this suggests that there may be a correlation between there being more establishments within this distance and shoppers choosing to walk.

Table 5
Travel Time by Mode and Goods Type.

Travel mode		Reported Travel time (minutes)				
		Groceries	Household Supplies	Restaurant Food	Clothes	Total
Bicycle	*Mean*	5	15	24.3	13.67	13.71
	[Min,	(U.S. Department of Commerce Census Bureau,. Quarterly Retail E-Commerce Sales - 3rd Quarter, 2022; Handy and Clifton, 2001)	(Dias et al., 2020; Colaço and Abreu e Silva, 2021)	[3, 65]	(Irawan and Wirza, 2015; Colaço and Abreu e Silva, 2021)	[3, 65]
	max*]*			35.2		
	SD [a]	4.7	5			16.0
					7.1	
Personal	*Mean*	9.2	11.5	11.75	27.24	12.63
Vehicle	*[Min,*	[2, 45]	[2, 60]	[2, 75]	[4, 90]	[2,90]
	max*]*	6.5	9.2	9.5	17.0	11.2
	SD					
Public	*Mean*	14.7	25	22.5	27.75	21.7
Transit	*[Min,*	(C40, nd; Weng et al., 2019)	(Colaço and Abreu e Silva, 2021; Weng et al., 2019)	[5, 50]	[10, 60]	[5,60]
	max*]*	9.2		17.0	22.5	14.2
	SD		5.8			
Walking	*Mean*	10.6	10.3	10	12.5	10.2
	[Min,	[3, 40]	(Department of Commerce Census Bureau, 2012; Colaço and Abreu e Silva, 2021)	(Hu, 2001; Colaço and Abreu e Silva, 2021)	(Dias et al., 2020; Colaço and Abreu e Silva, 2021)	[1, 40]
	max*]*	8.2				
	SD		5.5	5.2	5.0	6.6

[a] SD = Standard Deviation

Table 6
Number of commercial establishments within 0.5, 1.0, and 1.5 miles of respondents' home addresses, by shopping travel mode choice.

Mode Choice		Number of Businesses Within each Radius											
		Groceries			Household supplies			Food			Clothes		
		0.5mi	1mi	1.5mi	0.5mi	1mi	1.5mi	0.5mi	1mi	1.5mi	0.5mi	1mi	1.5mi
Walking	*Mean*	2.13	4.72	7.83	4.24	10.17	19.80	14.1	28.3	48.6	1.31	4.31	9.77
	SD	1.93	2.28	1.82	3.60	4.97	5.12	7.67	8.30	9.43	2.40	4.85	3.81
Driving	*Mean*	0.93	3.50	7.15	2.79	9.23	18.5	6.89	22.9	42.7	1.88	4.84	9.32
	SD	1.36	2.72	2.69	3.16	5.19	5.53	6.03	11.4	12.1	3.12	4.68	4.05
Delivery	*Mean*	1.11	3.83	7.61	3.55	9.65	20.75	7.19	22.9	45.5	1.62	5.45	10.18
	SD	1.68	2.28	2.03	3.39	4.90	4.42	5.42	9.21	12.9	2.77	4.34	3.46
Totals	*Mean*	1.22	3.79	7.34	3.13	9.46	19.1	8.03	23.7	44.0	1.68	5.20	9.91
	SD	1.60	2.64	2.47	3.30	5.10	5.33	6.70	10.8	12.0	2.84	4.47	3.66

5.2. Modeling Results

Coefficient estimates and significance are shown in Table 7. For all three models, the base choice was set as "Driving", so this alternative does not have an intercept. The regression coefficients for the variables entered under Delivery can be interpreted as an increase (if positive) or decrease (if negative) in the log-odds of a shopper having chosen Delivery over Driving or Walking based on an increase in the variable, and this is analogously true for variables entered for Walking. Looking at the demographic factors, there are not many consistent effects across the estimated models. We highlight that having a mobility-related disability is positively linked with the Delivery of groceries and household supplies, which supports the idea that delivery services can make goods more accessible for mobility-impaired individuals (Saphores and Xu, 2021). We see some links between higher education level and positive links with Delivery and Walking, as well as higher incomes and Delivery, and negative links with being employed and Driving. Interactions between employment, education, and income were tested but not found to be significant in any of the three models.

For our proximity factors, we find that having a higher number of supermarkets and convenience stores within 0.5 miles of a shopper's residence is positively linked and significant for choosing Walking over Driving or Delivery. We see a similar result in restaurant food, where the coefficient for Walking is also positive and significant at the 0.05 level. This suggests that proximity does make a difference in one sense: having more options nearby can support walking for in-person shopping for some goods. We did not find the distance to the nearest business (MinDistance) to be significant in any of the three models, implying the ability to choose between multiple easily accessible stores affects behavior more than access to a single option. Furthermore, we found that the positive link found at the 0.5-mile distance is lost at the 1.0-mile and 1.5-mile distances and is not seen at all for clothes shopping. We can conclude then that this positive link between more options and Walking is truly only seen at a 10-minute walking distance as supported by our previous observations.

6. Discussion

New trends in consumer shopping have been studied from the perspective of e-commerce and the impacts it can have on behavior, while studies on proximity have assumed that alternatives consist of different retail locations. Reviewing studies on shopping behavior, we found evidence of the impacts of online shopping replacing in-person shopping, but only one paper estimated how the availability of goods nearby relates to whether this substitution occurs (Suel and Polak, 2017). However, the availability of goods in stores varies based on the type of goods, and people shop for different kinds of goods with different behaviors. Similarly, the choice to shop in-person vs online is linked with accessibility to the internet and transportation options, but we found that studies in e-commerce primarily considered the former (internet, smartphones, etc.) over investigating vehicle access, driving times, and walking distances. This paper fills in this research gap by directly relating each respondent's decision to shop in-person vs online with their residential proximity to retail locations. When in-person shopping was selected, we further asked about travel modes and times. Additionally, behavior was collected across multiple types of goods, enabling comparison of differing levels of proximity and availability across the same sample population. To create a proximity analysis, we scraped Google Maps to find establishments in our study area, found the approximate distance from each respondent to the available in-store locations and identified their closest option in each case. The number of establishments between three different radii: 0.5, 1.0, and 1.5 miles, was also calculated to create a measure of variety in nearby options.

We note that the Haversine distance was used to measure the distance from participants' approximate home residences to various commercial establishments. This allowed us to find establishments that geographically fit within the described radii, and to directly compare the driving vs walking alternatives for the nearest possible location. Furthermore, the Haversine distance could be consistently and efficiently applied across our dataset, and can be easily compared against other studies using locations at similar distances

Table 7
Choice Model Results Summary Table.

Variables	Goods Type (Model variations)		
	Groceries/Household supplies Estimate	Restaurant Food Estimate	Clothes Estimate
Mode Constants			
Drive (base)	0.0	0.0	0.0
Delivery	−2.23*	−1.29	1.87
Walk	−3.89***	−0.354	−0.551
Age			
Drive (base)	0.0	0.0	0.0
Delivery	−0.012	−0.013	0.00112
Walk	1.33×10^{-3}	−0.057	−0.00037
Children (# of)			
Drive (base)	0.0	0.0	0.0
Delivery	0.13	−0.28	−0.118
Walk	−0.38*	−0.55	0.342
Disability			
Drive (base)	0.0	0.0	0.0
Delivery	1.23**	1.2	−0.708
Walk	−0.631	0.27	−0.765
Education Level: 1 = Bachelor's degree or higher			
Drive (base)			
Delivery	0.0	0.0	0.0
Walk	0.14	−0.36	1.12**
	1.64	0.14	2.07
Employment: 1 = Employed			
Drive (base)	0.0	0.0	0.0
Delivery	0.60	1.19	0.13
Walk	0.51	−1.63**	−0.495
Gender: 1 = Male			
Drive (base)	0.0	0.0	0.0
Delivery	−0.42	−0.70	0.0706
Walk	0.88***	−0.32	−0.956
High Income: 1 = $150,000 or more			
Drive (base)	0.0	0.0	0.0
Delivery	0.53	0.46	−0.0999
Walk	−0.43	0.91	−0.85
Low Income: 1 = Less than $49,000			
Drive (base)	0.0	0.0	0.0
Delivery	−0.21	0.256	−1.31**
Walk	0.21	−0.97	−9.96***
Min Distance			
Drive (base)	0.0	0.0	0.0
Delivery	1.8×10^{-4}	3.7×10^{-4}	−0.000504
Walk	1.1×10^{-4}	2.0×10^{-4}	0.000178
Supermarkets + Convenience stores within 0.5 miles		/	/
Drive (base)	0.0		
Delivery	0.08		
Walk	0.22***		
Restaurants within 0.5 miles	/		/
Drive (base)		0.0	
Delivery		1.8×10^{-3}	
Walk		0.167***	
Clothes stores within 0.5 miles	/	/	
Drive (base)			0.0
Delivery			−0.118
Walk			−0.105
Supermarkets within 0.5 miles		/	/
Drive (base)	0.0		
Delivery	−0.127		
Walk	−0.02		
Sample Size	437	165	191
Initial LL	−316.82	−109.62	−138.84
Final LL	−316.58	−109.37	−138.69
Rho-Square for init. model	0.000739	0.00232	0.00107

Significance levels: *** < 0.01, ** < 0.05, *< 0.1.

In a sample of 919 recent shopping experiences in Seattle we found:

1. Proximity to nearby businesses increased odds of walking for in-person shopping in 3 out of 4 goods types
2. Increased options within 0.5-mile radius increased odds of walking by 23% for groceries and supplies, and 17% for restaurants
3. E-commerce comprised 25.3% of shopping activity
4. 81% of shopping travel was conducted via personal vehicle
5. Average walking time between 10-12 minutes across all goods

Fig. 4. Summary of findings.

apart. However, for both walking and driving the Haversine distance does not take the built infrastructure into account, namely roads and sidewalks. There are city-maintained sidewalks on both sides of each street throughout our entire study area, and geographic barriers are limited to small city parks. Furthermore, our study area is comprised of grid-pattern streets in a consistent size and arrangement. As a result of the consistent environment built in our study area, we did not find issues with the travel distances given by the Haversine distance in our study, though we acknowledge the limitation presented as it does not specify the true distance covered while traveling in a city. We also note the context of the timing of our study, conducted from May through August of 2022. At that point in time, consumers had been dealing with the effects of the COVID-19 pandemic for just over years. Though vaccines had widespread availability and the State of Washington's indoor mask mandate was lifted in March 2022 after consistent decreases in COVID-19 cases, residual effects likely carried on. Consumers may have had a stronger preference for no-contact shopping, including delivery and pick-up, possible due to caution, or even familiarity with the systems of online shopping across multiple goods.

We analyzed the behaviors with descriptive statistics to identify dominant trends. Our results show that in-person shopping via vehicle travel was the most common choice across three goods: groceries, household supplies, and restaurants, but that online shopping was the most common choice for clothing items. When considering proximity, we found that the groceries, the goods for which in-person shopping was at its highest, actually had the least number of stores nearby. However, large chain grocery stores were found to be within 1.5 miles of nearly all respondents. In contrast, though respondents were in closer proximity to clothing stores than grocery stores, the average distance to larger retailers was over 4 miles, with the majority of nearby shops being small boutiques or consignment shops. Driving was also found to be the dominant travel choice for shopping, comprising 81 % of most recent in-person trips, though 96 % of respondents reported having access to a car. For three of our goods categories, we found that the average driving time was between 9–12 min. Furthermore, for each of these categories, in-person shopping was the most frequent choice for the most recent shopping experience, and the majority of shoppers drove to the business. However, for our fourth category of clothes, we found not only that average driving time was more than double, but in-person was not the majority choice for clothes shopping; rather, e-commerce made up 62 % of participants' most recent clothes shopping experience. We conclude that a combination of the type of good and the travel time to a desired retailer or establishment may affect the choice of shopping behavior.

We fit multiple discrete choice models on shopping behavior across walking, driving, and delivery over the goods categories of restaurant food, clothing items, and the combination of groceries and household supplies. As the number of establishments within a small radius of 0.5 miles (within a 10-minute walk at a 3mph pace) increased, we found significant increases in the odds of choosing walking for in-person shopping over driving and delivery in the goods categories of groceries/shopping and restaurant food. However, this effect was not present at larger radii of 1 mile and 1.5 miles, and the minimum distance to an establishment was never significant. Though modest, the correlation between the availability of more options and shopping behavior is displayed here and aligns with our finding of an average reported walking travel time of 10 min. Fig. 4 summarizes our main findings.

What do these results indicate for the development of the 15-minute city? The 15-minute city model would place the needs of residents within a short distance from their homes via either walking, bicycling, or public transit. Weng et. al notes that "needs" vary between different kinds of residents, and indeed our study only looks at shopping as one out of the six "essential urban functions" (C40, nd; Weng et al., 2019). Nevertheless, our results have implications for how consumers may behave in an environment where establishments are located within close proximity to their homes. Of principal importance is the question: would residents still use vehicles to travel to further away establishments, use e-commerce platforms to place delivery orders, or take advantage of local shopping options? First, we note that the minimum distance to an establishment was never a significant variable in our choice model. However, for certain kinds of goods (namely, groceries/household supplies, and restaurant food), increased options within a proximity of 0.5

miles were linked with increases in the odds of walking trips of 23 % and 17 % respectively. The trends we identified lean closer to a "10-minute city". Since our travel times were reported rather than measured, however, this value is likely imprecise.

This suggests that indeed for some types of activities, residents may utilize the local options available in a 15-minute city. However, this excludes clothing items. We note that while the products from supermarkets may be to a certain extent interchangeable between stores, (for example, that milk of equivalent quality may be purchased from a variety of locations), preferences for clothing items can be significantly more specific and unique, considering sizing, brands, retailers, and design, which may be driving this behavior. We also observed that within a 0.5-mile radius, participants were on average closer to a higher number of clothing stores than grocery and convenience stores, and yet in-person shopping was at a minimum for clothing. Our results imply that even in a planned 15-minute city, there may always be some preference for ordering specific items online, or for driving to a specific retailer even if there are closer establishments. Further investigation into what kinds of goods and activities produce these behaviors could clarify precisely how they should be accounted for in planning a 15-minute city.

Our survey produced a higher-than-expected result of 25.3 % of shopping activity taking the form of delivery orders, up from the 14.5 % found by the U.S. Census Bureau in 2022. Although our study only looked at certain goods, this may be a worrying result for local economies. Local shopping has the benefit of keeping economic activity within communities since local businesses are more likely to employ local residents, utilize local services and procure supplies from other local businesses, and pay local taxes. Delivery orders, especially those from national e-commerce platforms, may not give these economic benefits. 96 % of survey respondents also reported having access to a vehicle, and 81 % of all shopping travel was conducted via personal vehicle. The convenience of driving may present itself as a default choice for many consumers, from which tailpipe emissions can have a negative environmental impact.

The phenomenon known as residential self-selection may also impact behavior here, as we observe that for groceries, household supplies, and restaurants those who chose walking had more options in a 0.5 mile radius than those who drive. Residents could initially choose where to live based on an set of factors such as distance to work, shopping opportunities, and their preferred mode of transportation e.g., walking, driving, bicycling, or using public transit. Their location choice could then influence their corresponding travel behavior; for example, choosing to live next to a bicycle trail may encourage usage of a bicycle. This can culminate in a feedback loop where the preferred transportation method becomes a default one, and the resident chooses to either stay in the area, or move to an area with a similar transportation environment based on these strengthened preferences. The transportation environment and residential environment influence each other, creating an endogeneity problem in assigning cause (van Wee and Cao, 2022).

Pedestrian infrastructure such as sidewalks, frequent crossings, decreased speed limits in residential areas, and public spaces may be necessary to promote walking over driving for shopping trips, but this should not be misconstrued as being sufficient. Due to the above-described endogeneity issue, it is possible that increasing the number of stores in neighborhoods will not change behaviors and will only be noticed who already prefer walking. However, we believe that the close proximity of within 0.5 miles provides an incentive for this desired of fewer vehicle trips and fewer online orders by increasing speed and practicality. For many residents it may be ultimately faster to walk down the street to a convenience store than to drive and park, or indeed to place a delivery order that could take hours or days to arrive. Some types of pedestrian infrastructure can enhance this effect. For example, pedestrian signal crossings that are not linked to traffic signals can simultaneously slow down traffic, increase safety for and awareness of pedestrians, and remind driving residents about the availability of safe pedestrian infrastructure in their neighborhood.

Our study found minimal usage of public transit for shopping travel at only 3.3 % of total trips made. We have similar findings for bicycle travel at only 2.3 % of shopping travel usage. At such a low level of usage our data does not reveal what existing factors promote or dampen the use of these modes of travel for shopping. However, we can recommend some policies that have potential for increasing usage. The e-bike and in particular the e-cargo bike has been rising in popularity in recent years as an alternative for vehicle trips. Especially in urban areas, cargo e-bikes can provide greater efficiency than vehicles by taking advantage of bicycle paths and having better access to parking, in addition to being significantly less expensive. Cargo e-bikes can vary in size and shape, from simply yet sturdy designed bicycles with modular saddlebag and box attachments for rear racks to "Bakfiets" with large baskets mounted behind the front wheel large enough for small children to ride in. 48 out of 50 U.S. states have updated their laws to recognize e-bikes, making them better known and establishing their use to the public. Cities can go further by implementing purchasing rebate programs, like those that have been successfully used in Denver, Colorado to subsidize the adoption of e-bikes and provide increased subsidies for cargo e-bikes and for income-qualified residents, with 71 % of respondents reporting that the used their gas vehicles less often after purchasing an e-bike (Denver's, 2022). At the same time as promoting the adoption of bicycles, cities can make additional investments in infrastructure with wider bicycle lanes and connected networks. Much like pedestrian infrastructure though, this will likely not be sufficient to transform consumers' approach to shopping and further study into bicycling for shopping will be necessary in order to better understand what factors could encourage usage.

Finally, we look at the implications for ecommerce and home delivery. With higher than projected rates of home delivery activity, there may be associated higher levels of negative externalities caused by ecommerce. Money spent at large ecommerce retailers does

not benefit the local economy and may cause local brick-and-mortar stores to lose business. However, there is growing awareness of "local ecommerce" where small businesses create online storefronts to sell products specifically to a local market. When implemented, a local e-commerce platform can provide the convenience of online shopping without the associated large-scale supply chain. High levels of ecommerce and delivery activity can also result in increased emissions from delivery vehicles, greater risk of injury from heavy vehicles in residential areas, and increased traffic congestion. However, our results suggest a way for communities to address these concerns: prioritizing the saturation and distribution of physical grocery and convenience stores in neighborhoods, as these were linked with increases in walking trips. Even when not planning specifically for a 15-minute city, increased local shopping options for these goods types may increase the amount of shopping taking place at local businesses in addition to replacing vehicle trips with walking. City planners interested in this kind of change can pursue strategies toward increasing the number of small corner stores in residential neighborhoods. Regulation on how developed land can be used is governed by zoning codes, which vary by location. In West Seattle specifically, the zoning model is suburbanized, not allowing commercial usage of land in housing zones. Since over 80 % of the land is zoned for exclusively residential use (apart from commercial establishments that may be "grandfathered" in), by design this pushes an automobile-dependent community (Feit, 2023). Amending zoning codes to allow for mixed-use in residential areas, specifically permitting ground-level corner and convenience stores may be an appropriate strategy to increase local shopping activity, a strategy which could be generalized and adapted to the zoning policies of different areas (Kraft, 2021).

7. Conclusions

How does proximity affect travel for shopping? We found that a consumer's proximity to a single establishment does not significantly affect the odds of online shopping. In other words, given the sample data collected, the likelihood of shopping online is unaffected by whether a consumer lives in proximity to commercial establishments or not. However, we do see a positive relationship between in-person shopping via walking and proximity to commercial establishments. Our choice model found that having more shopping options within this 10–13-minute range (approximated as 0.5 miles) was positively correlated with selecting walking over driving or delivery for multiple types of goods, increasing the odds of walking for shopping by 23 % for groceries and household supplies and 17 % for restaurants. Cities may have different goals when it comes to consumer shopping: reducing vehicle dependence, increasing spending in the local economy, decreasing emissions, and increasing accessibility. The question of whether a particular product is better bought in-person versus online is not an obvious one and begs the question of "better" for whom. However, our finding that more options nearby is associated with increased odds of 10-minute short-distance walking trips over driving or online shopping suggests that local city retail can continue to be a part of a diverse shopping ecosystem when consumers have access to the goods they need.

CRediT authorship contribution statement

Rishi Verma: Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Giacomo Dalla Chiara:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anne Goodchild:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contributions

The authors confirm their contribution to the paper as follows: study conception and design: Anne Goodchild, Giacomo Dalla Chiara, Rishi Verma; data collection: Rishi Verma, Giacomo Dalla Chiara; analysis and interpretation of results: Rishi Verma, Giacomo Dalla Chiara; draft manuscript preparation: Rishi Verma, Giacomo Dalla Chiara; supervision, review, editing: Giacomo Dalla Chiara, Anne Goodchild. All authors reviewed the results and approved the final version of the manuscript.

Appendix A. – Survey questionnaire

Instructions are written in italics
[Skip Logic is bolded and bracketed]

Section 1: Demographic Questions

1. What is your Gender Identity?
   - o Male
   - o Female
   - o Gender(s) not listed here/None of these

2. What is your expected household income in 2022, before taxes?
   - o Less than $24,999
   - o $25,000 to $49,000
   - o $50,000 to $99,999
   - o $100,000 to $149,000
   - o $150,000 to $199,999
   - o $200,000 or more

3. What is your Age?
   _____

4. Do you have a disability that limits physical activities? (Walking or use of mobility device,carrying, lifting, etc.)
   - o Yes
   - o No

5. What is your Race and/or Ethnicity?
   - o American Indian or Alaska Native
   - o Asian or Asian American
   - o Black or African American
   - o Hispanic or Latino/a/x
   - o Middle Eastern or North African
   - o Native Hawaiian or Pacific
   - o Islander
   - o Race or ethnicity not listed here *(please tell us more)* _____
   - o White

6. What is your Employment status?
   - Employed part or full-time
   - Full-time Student
   - Unemployed & looking
   - Unemployed & not looking
   - Retired

7. What is the highest level of education you have completed?
   - o Primary School or lower
   - o High School Diploma/GED
   - o Community college/Associates degree/post-secondary certificate
   - o Bachelor's degree
   - o Graduate degree

8. How many children (below 18 years old) live in your household?

____

9. How many people in total (including children) live in your household?

____

10. Do you own a smartphone?
- Yes
- No

Section 2: Home/Transportation questions

2.1 Do you have a driver's license?
Please answer NO if your license is expired or otherwise invalid
- Yes
- No

2.2 Do you/does someone in your household own a vehicle for personal use?
- Yes
- No **[Skip to 2.5]**

2.3 Is this an electric vehicle?
- Yes
- No

2.4 What type of vehicle do you use most often?
Select all that apply
- Sedan/coupe/hatchback/compact car
- Pickup Truck
- SUV
- Minivan
- Station Wagon
- Other *(please specify):* _____

2.5 Do you own a…
Select all that apply
- Bicycle (including bike share)
- Electric Bicycle (including bike share)
- Cargo Bicycle (including bike share)
- Electric Cargo Bicycle (including bike share)
- Electric Scooter (including scooter share)
- Electric Unicycle/Personal Transporter
- Other *(please specify):* _____

2.6 What is your home address OR the nearest intersection to your home?
(Example: "15th Ave and 50th St". If you'd prefer, you can also enter a nearby bus stop or landmark- we will use this to calculate distances to various stores)

_____

Section 3: Package Delivery Questions

The following questions ask about packages that are too large to fit in a mailbox.

3.1 Does your residence have a package locker or other way for carriers to securely deliver packages?

- Yes, a locker
- Yes, a reception area/building manager
- No

3.2 How do you usually receive packages?
Select all that apply

- I receive on my doorstep
- I receive them from a reception area/lobby
- I receive them from a package locker in my building
- I pick them up from a store/ nearby package locker
- I meet the driver outside my building
- I ship it somewhere else (like my office)

3.3 Have you ever experienced package theft?
This is when a package is stolen after being delivered to the doorstep

- Yes
- No

3.4 How worried are you about theft if a package is left outside your building unattended?

- 5 (Very worried)
- 4
- 3 (Neutral)
- 2
- 1 (Not at all worried)

3.5 How often per month do you receive packages for delivery? (Including subscription services like Dollar Shave Club, Hello Fresh etc.)

_____

Section 4: Groceries

The following questions ask about groceries bought from a grocery store, for example: fresh produce, milk, eggs, etc. bought from Safeway. Food items bought from a convenience store, for example: snacks from 7-11 are not included in the term "groceries"

4.1 In the past 3 months, how often have you bought groceries (either in-store or online)?
Please only answer for yourself rather than for your household. If someone else in your household other than you always buys groceries, please answer "I did not buy groceries in the last 3 months".

- More than 2 times per week
- 1-2 times per week
- 1-2 times per month
- Less than once per month
- I did not buy groceries in the last 3 months **[Skip to Section 5]**

The following questions will ask about the most recent time you bought groceries.

4.2 When was the *most recent time* you bought groceries?

Please only answer for yourself rather than for your household

- In the past week
- 1-2 weeks ago
- 3-4 weeks ago
- More than 1 month ago

4.3 How much/many groceries did you buy?

- A few items
- About 1 full grocery bag
- About 2 full grocery bags
- About 3-5 full grocery bags
- More than 5 full grocery bags

4.4 Did you buy groceries in-person or online?

- In person
- Online for pickup
- Online for delivery **[Skip to 4.8]**

4.5 What form of transportation did you take to and from the store?

- Personal Vehicle (driven by yourself or others)
- Public Transit (e.g. King County Metro bus)
- Walking or use of mobility device (e.g. wheelchair, mobility Scooter (including scooter share))
- Ridehail (e.g. Uber/Lyft) or taxi
- Bicycle (including bike share)
- Scooter (including scooter share)
- Other:

4.6 How many minutes did it take you to reach the store?

_____

4.7 Did you buy items from other stores as part of the same trip?

- Yes
- No

4.8 If you did order for delivery, where were your groceries delivered?

- On my doorstep
- To a reception area/building manager
- To a package locker in my building
- To a store/nearby package locker
- Met the driver outside my building
- Other: ____

Section 5: Household supplies

The following questions ask about household supplies: cleaning products, trash bags, laundry detergent, toothpaste etc.

5.1 In the past 3 months, how often have you bought household supplies?

Please only answer for yourself rather than for your household. If someone else in your household other than you always buys household supplies, please answer "I did not buy household supplies in the last 3 months".

- More than 2 times per week

- 1-2 times per week
- 1-2 times per month
- Less than once per month
- I did not buy household supplies in the last 3 months **[Skip to Section 6]**

The following questions will ask about the most recent time you bought household supplies.

5.2 When was the *most recent time* you bought household supplies?
Please only answer for yourself rather than for your household.

- In the past week
- 1-2 weeks ago
- 3-4 weeks ago
- More than 1 month ago

5.3 How much/many household supplies did you buy?

- A few items
- About full grocery bag
- About 2 full grocery bags
- About 3-5 full grocery bags
- More than 2 full grocery bags

5.4 Did you buy household supplies in-person or online?

- In person
- Online for pickup
- Online for delivery **[Skip to 5.8]**

5.5 What form of transportation did you take to and from the store?

- Personal Vehicle (driven by yourself or others)
- Public Transit (e.g. King County Metro bus)
- Walking or use of mobility device (e.g. wheelchair, mobility Scooter (including scooter share))
- Ridehail (e.g. Uber/Lyft) or taxi
- Bicycle (including bike share)
- Scooter (including scooter share)
- Other:

5.6 How many minutes did it take you to reach the store?

_____

5.7 Did you buy items from other stores as part of the same trip?

- Yes
- No

5.8 If you did order for delivery, where was your package delivered?

- On my doorstep
- To a reception area/building manager
- To a package locker in my building
- To a store/nearby package locker
- Met the driver outside my building
- Other:____

Section 6: Restaurant Food

The following questions ask about restaurant food. This includes any meal prepared by someone in food service/from a food establishment that you traveled to from home, or ordered for delivery to your home. Please do not include restaurant food that you ordered/traveled to from work or from any location other than home.

6.1 In the past 3 months, how often have you bought restaurant food?
Please only answer for yourself rather than for your household. If someone else in your household other than you always buys restaurant food, please answer "I did not buy restaurant food in the last 3 months".

- More than 2 times per week
- 1-2 times per week
- 1-2 times per month
- Less than once per month
- I did not buy prepared food in the last 3 months **[Skip to Section 7]**

The following questions will ask about the most recent time you bought food from a restaurant

6.2 When was the *most recent time* you bought restaurant food?
Please only answer for yourself rather than for your household

- In the past week
- 1-2 weeks ago
- 3-4 weeks ago
- More than 1 month ago

6.3 Did you order for in-person dining, take-out, or delivery? (If delivery, skip to 6.6)

- In-person dining
- Take-out
- Delivery **[Skip to 6.6]**

6.4 What form of transportation did you take to and from the restaurant?

- Personal Vehicle (driven by yourself or others)
- Public Transit (e.g. King County Metro bus)
- Walking or use of mobility device (e.g. wheelchair, mobility Scooter (including scooter share))
- Ridehail (e.g. Uber/Lyft) or taxi
- Bicycle (including bike share)
- Scooter (including scooter share)
- Other:

6.5 How many minutes did it take you to reach the store?

_____

6.6 Where was your food delivered?

- On my doorstep
- To a reception area/building manager
- To a package locker in my building
- To a store/nearby package locker
- Met the driver outside my building
- Other:____

Section 7: Clothes

The following questions ask about clothing items. This includes any clothes, footwear, outerwear, underwear, etc.

7.1 In the past 3 months, how often have you bought clothing items for yourself/for yourself or someone in your household?
Please only answer for yourself rather than for your household. If someone else in your household other than you always buys clothing items, please answer "I did not buy clothing items in the last 3 months".

- More than 2 times per week
- 1-2 times per week
- 1-2 times per month
- Less than once per month
- I did not buy clothes in the last 3 months **[Skip to Section 8]**

The following questions will ask about the most recent time you bought clothing items.

7.2 When was the *most recent time* you bought clothing items?
Please only answer for yourself rather than for your household.

- In the past week
- 1-2 weeks ago
- 3-4 weeks ago
- More than 1 month ago

7.3 How much clothing did you buy?

- 1-2 items
- 3-5 items
- 6-10 items
- More than 10 items

7.4 Did you buy clothing items in-person or online?

- In person
- Online for pickup
- Online for delivery **[Skip to 7.8]**

7.5 What form of transportation did you take to and from the store?

- Personal Vehicle (driven by yourself or others)
- Public Transit (e.g. King County Metro bus)
- Walking or use of mobility device (e.g. wheelchair, mobility Scooter (including scooter share))
- Ridehail (e.g. Uber/Lyft) or taxi
- Bicycle (including bike share)
- Scooter (including scooter share)
- Other:

7.6 How many minutes did it take you to reach the store?

_____

7.7 Did you buy items from other stores as part of the same trip?

- Yes
- No

7.8 If you did order for delivery, where was your package delivered?

- **On my doorstep**
- **To a reception area/building manager**
- **To a package locker in my building**
- **To a store/nearby package locker**
- **Met the driver outside my building**
- **Other:____**

Appendix B. – Grocery and household supplies results

Variables	Goods Type (Model variations)	
	Groceries Estimate	Household supplies Estimate
Mode Constants*Drive (base)DeliveryWalk*	0.0−2.75−3.85***	0.0−2.08−4.33**
Age*Drive (base)DeliveryWalk*	0.0−0.0185−0.00282	0.0−0.00768−0.000363
Children (# of)*Drive (base)DeliveryWalk*	0.00.197−0.192	0.00.0755−0.958**
Disability*Drive (base)DeliveryWalk*	0.02.91***−0.348	0.00.682−8.46***
Education Level: 1 = Bachelor's degree or higher*Drive (base)DeliveryWalk*	0.00.1661.59**	0.00.1532.01**
Employment: 1 = Employed*Drive (base)DeliveryWalk*	0.01.460.593	0.00.4090.784
Gender: 1 = Male*Drive (base)DeliveryWalk*	0.0−1.191.01	0.00.01340.973*
High Income: 1 = $150,000 or more*Drive (base)DeliveryWalk*	0.01.02−0.211	0.00.181−1.14
Low Income: 1 = Less than $49,000*Drive (base)DeliveryWalk*	0.0−9.18***0.901	0.00.125−0.593
Min Distance*Drive (base)DeliveryWalk*	0.02.9 x 10^{-4}2.4 x 10^{-4}	0.01.9 x 10^{-4}2.6 x 10^{-4}
Supermarkets + Convenience storeswithin 0.5 miles*Drive (base)DeliveryWalk*	0.00.08690.11	0.00.1830.512***
Supermarkets within 0.5 miles*Drive (base)DeliveryWalk*	0.00.06320.237**	0.0−0.2820.794**
Sample Size		
Initial LL		
Final LL		
Rho-Square for init. model		

Significance levels: *** < 0.01, ** < 0.05, *< 0.1.

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