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Research paper

# Comparing walking accessibility variations between groceries and other retail activities for seniors

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ABSTRACT

This paper aims to compare walking accessibility levels between groceries and other types of retail for seniors, examining whether patterns are uniform (or not). The city of Granada, Spain served as case study. First, a questionnaire was administered with persons older than 55 years, assessing their willingness to reach different types of retail opportunities on foot. A total of 202 valid responses were obtained (171 face-to-face and 31 online): 56% women, average age 69 years old, 20% living alone, and average monthly family income between €1000-€2000. Second, the K-modes clustering algorithm was used to identify four seniors sub-groups: "non-motorized seniors between 65 and 75", "motorized seniors between 65 and 75", "non-motorized seniors older than 75", and "motorized seniors younger than 65". The variables used were: age, car availability, household income, and household composition. Third, by using the Kruskal-Wallis and Mann-Whitney tests (p-level $<0.05$), a comparison of time-willingness functions to walk to retail was made between seniors sub-groups. The results revealed that walking accessibility to groceries are not significantly different among those sub-groups, while the accessibility levels to weekly retail are significantly lower for the "motorized seniors younger than 65" for time-willingness slots of 20–30 min. R software was used for statistical analysis.

## 1. Introduction

The wide access to the Internet is leading an increase of e-grocery shopping, triggering potential threatens for physical stores. While the rate of online groceries purchases is expected to have a rapid growth in upcoming years (González, 2017), there are some population groups with a null or negligible experience with the Internet and e-shopping (Hussain, Ross, & Bednar, 2018, pp. 199–212). The group of seniors is a case in point, considering physical grocery shopping as a social experience integrated in their daily habits. In this respect, physical accessibility to groceries can be crucial for seniors to participate in the social life of their respective communities (Lucas, van Wee, & Maat, 2016).

Under this context, an accessibility planning approach has gained prominence among academics, professionals, and institutions as a key aspect in achieving sustainable planning outcomes at city and regional levels. The shift toward accessibility planning approaches originated in a vast body of academic literature focused on developing the following conceptual and practical innovations: how to estimate accessibility to major destinations, how to map it, how to increase knowledge transfer to practitioners, and how to identify the main effects of accessibility (Arranz-López, Soria-Lara, López-Escolano, & Pueyo-Campos, 2017a; Arranz-López, Soria-Lara, López-Escolano, & Pueyo Campos, 2017b; Geurs & van Wee, 2004; van Wee, 2016; Arranz-López, Soria-Lara, & Pueyo-Campos, 2019).

Accessibility is usually seen as the relationship between the availability of opportunities in a given location and the supply of transportation services to reach them (Bocarejo & Oviedo, 2012), traditionally applied as an absolute variable that equally impacts the full population spectrum. However, people have different perceptions of accessibility levels and as a matter of preference or constraint, different individuals display varying levels of willingness to travel in order to reach opportunities. The result is that accessibility becomes a relative concept that can lead to biased outcomes when considered an absolute parameter of welfare and sustainability (Moniruzzaman, Páez, Nurul Habib, & Morency, 2013; Morency, Paez, Roorda, Mercado, & Farber, 2011; Sultana, Salon, & Kuby, 2017). For this study, relative accessibility is considered as "the proportion of opportunities available to an individual with defined characteristics at a selected location, relative to

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an individual from a reference group at the same location" (Páez, Gertes Mercado, Farber, Morency, & Roorda, 2010a).

There is a growing number of studies paying attention to how accessibility to major locations can vary depending on socio-economic population groups. Most of consulted studies are focused on the north-American, Canadian, and North-European contexts, but all of them have applicable findings to the case study of this research. A significant example is the studies focused on "food deserts", analysing accessibility variations associated with ethnicity (Gordon et al., 2011; Ma et al., 2018), socio-economic status (Hendrickson, Smith, & Eikenberry, 2006), and property prices (Helbich, Schadenberg, Hagenauer, & Poelman, 2017). However, the age of individuals has received limited attention as key variable to understand accessibility variations to food stores. Furthermore, the growing ageing population rates in developed countries have spurred concerns regarding seniors' travel patterns and accessibility to other major locations. For example, Ricciardi, Xia, and Currie (2015) explore accessibility levels to public transport systems in the context of Perth, Australia, comparing seniors, low-income populations, populations without car availability, and the rest of the population. The findings reveal that the biggest accessibility differences are found in the seniors group, showing the lowest accessibility level to public transport systems. Similarly, Delbosc and Currie (2011) also analyze accessibility to bus stops in Melbourne, Australia, finding that the low-income population has the lowest accessibility levels followed by seniors. Páez, Nurul, and Morency (2013) demonstrate that car accessibility figures for major destinations are higher for seniors than those observed for other groups in the city of Montreal, Canada. Also in Montreal, Páez, Mercado, Farber, Morency, and Roorda (2010b) find that seniors' accessibility to health care facilities is significantly lower in suburban areas than in the city center, compared to other population groups in the same location.

While most of the consulted studies focused on the comparison of motorized accessibility levels between seniors and other socio-economic groups, there is a significant research gap related to improving the knowledge about how non-motorized accessibility to groceries can vary between senior citizens (older than 55 years for this research) (Böcker, van Amen, & Helbich, 2017; Cao, Mokhtarian, & Handy, 2010; Hess, 2012; Negron-Poblete, Séguin, & Apparicio, 2016). That is the need for a more in-depth understanding on how and to what extent are seniors able to reach groceries on foot, and the impact of that for policymaking. First, seniors citizens are more dependent than others of public and non-motorized transport modes for covering daily needs (Páez et al., 2010b). Second, despite the considerably growth of e-shopping rates providing an alternative to physical mobility (Kenyon, 2010), it has been demonstrated how the e-shopping rates for older people are very low or non-existent in some contexts (Olsson, Samuelsson, & Viscovi, 2019). Accordingly, improving walking accessibility is seen as essential for achieving decarbonized, livable, and socially inclusive cities (Givoni and Banister, 2013; Tight, 2016; Vale, Saraiva, & Pereira, 2015). The former is even more relevant when considering the UN projections that anticipate 66% of the world's population to live in cities by 2035, with urban populations that have a two-thirds share of persons older than 55 years in developed countries (United Nations, 2014).

Despite the growing interest in the topic, the abovementioned knowledge gap remains. Some reasons underline that. On the one hand, seniors are frequently analyzed in accessibility studies as a homogenous group to be compared with other socio-economic groups (e.g., youngsters and adults). However, some studies have found significant differences within the senior cohort regarding travel behavior and capacity to access certain locations (Alsnih & Hensher, 2003; Hildebrand, 2003). These differences could be amplified even further by the anticipated growth of the senior population at city level. On the other hand, even though it is well-known that the willingness of the senior population to reach retail locations on foot diverges significantly from the willingness of other population groups, it remains a largely unexplored topic in the academic literature (Arranz-López, Soria-Lara, Witlox, & Páez, 2018; Negron-Poblete et al., 2016). Finally, although at least one-third of daily travel among the senior population is on foot (Talavera & Valenzuela, 2017) and despite the well-documented difficulties faced in accessing motorized transport modes (private or collective) (Böcker et al., 2017), studies on walking accessibility that specifically focus on seniors are limited.

To bridge the research gap described, this paper compares whether and to what extent walking accessibility is similar between groceries and other retail types for seniors, as well as seeks to identify time-willingness thresholds that indicate significant shifts in walking accessibility. The city of Granada in Spain was chosen as the location for the case study, due to the fact that it is a compact city with a high share of ageing population and retail locations that are widely dispersed across the city, which reduces travel distances. A questionnaire regarding willingness to reach groceries, weekly, and incidental retail locations on foot was elaborated and administered via face-to-face interviews and online with participants older than 55 years. Then, a k-modes clustering method was implemented, distinguishing four distinct socio-economic sub-groups: "non-motorized seniors between 65 and 75", "motorized seniors between 65 and 75", "non-motorized seniors older than 75", and "motorized seniors younger than 65". It was followed by a statistical comparison of time-willingness decay functions to reach retail locations on foot for each identified sub-group. Finally, walking accessibility to retail activity was estimated and mapped using a gravity-based model.

The remainder of the paper is organized as follows: Section 2 presents the case study. Section 3 covers the research design, while Section 4 summarizes the main obtained results. Finally, Section 5 closes the paper with some concluding remarks, including reflections on future research directions.

## 2. The case of Granada, Spain

Granada is a medium-size city with 232,770 inhabitants, located in southern Spain (see Fig. 1). The city experienced a strong increase in its senior population during the last decades. Specifically, the demographic cohort of persons older than 55 years grew by 20,000 individuals in the last 20 years, totaling 34.5% of the entire population in 2018. Projections indicate a continuous increase, anticipated to reach 40% by 2031 (Instituto Nacional de Estadística, 2016). The described increase of senior population is mainly related to the decrease in the birth rate, as migratory flows seems to be balanced between the different groups of population in Granada.

The spatial distribution of seniors across Granada is not homogenous (Fig. 1). All the historical neighborhoods located in the city center, such as *Pajaritos*, *San Francisco Javier*, *Bobadilla*, *Fígares*, *Plaza de Toros*, *Campo Verde*, *Camino de Ronda*, and *Centro-Sagrario* show rates of senior population higher than 35%. However, in the city's periphery, such as *Rey Badis*, *Almanjayar*, *La Cruz*, *Camino de los Neveros*, and *Lancha del Genil*, the highest rate of senior is 19%.

Regarding transportation issues, short distances between population and destinations predominate across the city, providing a good local environment for non-motorized transport modes. Non-motorized trips represent 54% of all journeys (Ayuntamiento de Granada, 2013). However, the share of shopping motorized trips is growing and is especially high for trips between Granada proper and the surrounding municipalities in the Granada Metropolitan Area (approx. 80%). This is mainly due to the peripheral location of the main shopping centers, which attract large volumes of motorized traffic. In total, shopping trips are almost 38% of all trips in Granada (Ayuntamiento de Granada, 2013). Spatially, the density of retail activity decreases from the city center to the periphery. The areas of maximum concentration of retail activity are along the axis formed by the neighborhoods *Centro*, *Ronda*, and *Zaidín*. The places with the lowest retail density are the newest residential neighborhoods located in the north and south of Granada, where an important number of motorized shopping trips are originated, either to the city center or to the surrounding shopping centers.

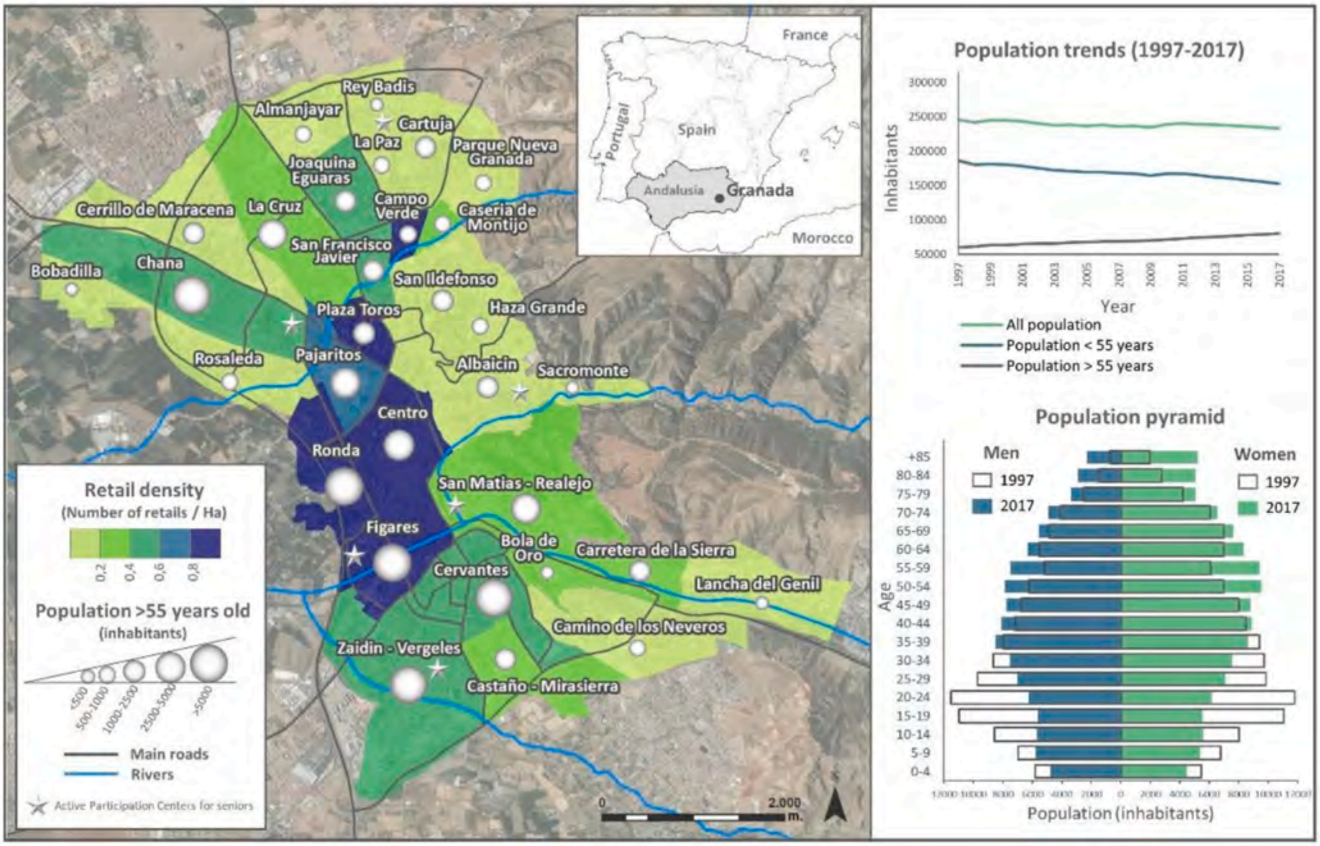


**Fig. 1.** Location, demographic data, and retail information for the city of Granada.

## 3. Research design

This research followed a three-stage approach (Fig. 2): (i) data gathering; (ii) cluster analysis of seniors and comparison of time-willingness decay functions; and (iii) calculation and mapping of relative walking accessibility.

### 3.1. Data gathering

The main data source was a questionnaire conducted with respondents older than 55 (see Appendix I). The official age of retirement in Spain is 65 years old, but people older than 55 years old could start their retirement according to special conditions, as well as reducing their weekly working hours. In total, 171 questionnaires were administered via face-to-face interviews, by visiting active participation centers for seniors, places frequented by seniors for various activities related to socialization and leisure. Active participation centers specifically refer to a type of local buildings where seniors can complete several activities related to entertainment, such as: paintings, crafts, etc. The research team visited 6 active participation centers, distributed equally across the city of Granada (Fig. 1). By using a snowballing approach, the questionnaire was also disseminated online, obtaining a total of 31 responses. In total, 202 valid questionnaires were processed. All respondents received and signed a specific consent, informing about the expected exploitation of the obtained results and the ethical issue for this study. Face-to-face interviews were especially relevant as the target population has limited access to online resources and a high rate of digital illiteracy. The respondents' profiles between face-to-face and online participants were analyzed and compared to identify potential bias in the sample. However, no significant differences were found between those two groups of respondents. It is worth to noting that the difficulties to respond the questionnaire by seniors was firstly analyzed in a pilot test to distil the most appropriate types of questions. A total of 10 seniors were engaged during the pilot test.

The questionnaire was structured in three parts. The first consisted of 10 questions focused on demographic and socio-economic characteristics of the target group, such as gender, age, neighborhood, household size and type (e.g., living alone), monthly household income, household car availability, education level, employment status, and physical disabilities. Responses based on gender, car availability, living alone, driving license, and physical disabilities were coded as binary variables. The other variables were classified into intervals.

The second part of the questionnaire asked seniors to report their time-willingness to walk to groceries, weekly, and incidental retail locations.[1] Given the purpose of this research, groceries, weekly, and incidental retail were considered generically, and the name/brand of the retailer was not specified. An example of such questions was "*Independently of the neighborhood where you are currently living, how much time are you willing to spend to reach groceries/weekly/incidental retail stores on foot?*" The responses were codified in the following minute intervals: 5 or less, 10, 15, 20, 30, 45, 60, and more than 60.

The third part of the questionnaire listed other issues related to the preferred transport means, how frequently respondents go shopping,

[1] Groceries included food shop, butcher, charcuterie, greengrocer, bakery, fishmonger, and supermarket. Weekly retail included bazar, drugstore, perfumery, pharmacy, Do-it-yourself store, copy shop, tobacconist, herbalist, houseware store, stationery shop, hairdresser, barbershop, clothing store, and shoe store. Incidental retail included travel agency, car/motorcycle/bicycle rental, pet shop, comic store, car dealership, sports shop, electronics/IT shop, florist, garden store, jeweller, toy store, bookshop, furniture store, music store, optician's shop, orthopaedic services, gift shop, souvenir shop, videogame store.

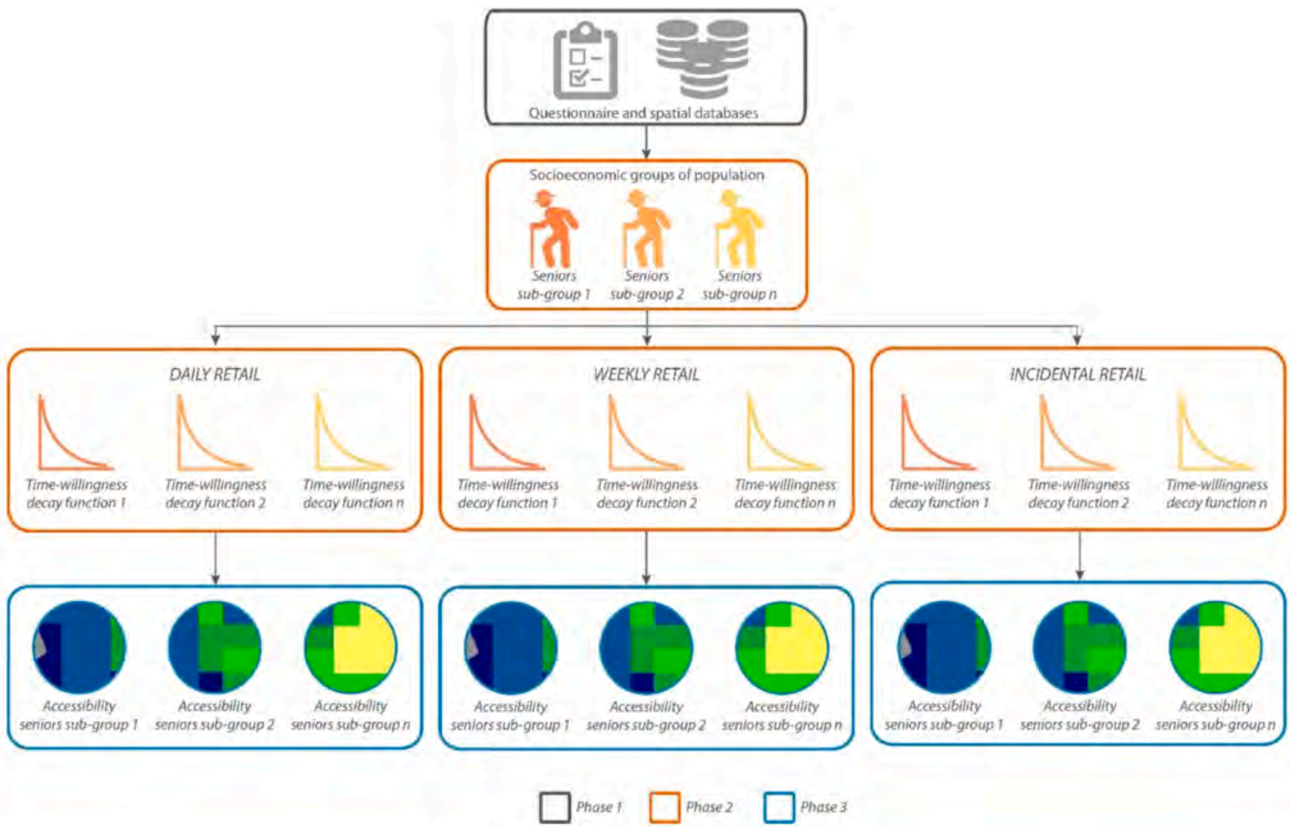


**Fig. 2.** Methodological scheme.

retail store preferences (e.g., small stores vs. shopping center), the quality of the pedestrian infrastructure, the reasons for going shopping on foot and the frequency they did e-shop. Responses based on the quality of the pedestrian infrastructure and the reasons for going shopping on foot were scored according to a five-point Likert scale. The e-shopping frequency was coded as a binary variable, and the other variables were classified into intervals.

Additionally, the spatial databases required for calculating accessibility indicators were collected and manually digitized. A grid from the European Environment Agency was used as a spatial basis to represent accessibility values. The grid was adapted from the original 1 km × 1 km scale to a 100 m × 100 m cell size. Furthermore, the street network from the Spanish National Center of Geographic Information was used to calculate distances between origins and destinations. Origins and destinations referred to the centroid of each 100 m × 100 m cell size, and the origin-destination matrix was calculated for the full spectrum of cells providing an estimation of potential accessibility in a given place. Retail locations were manually digitized from a database developed by the Andalusia Regional Government and cross-checked with Google Maps and Open Street Maps, yielding a total of 2929 retail locations.

### 3.2. Cluster analysis and comparison of time-willingness decay functions

Clustering techniques were employed to group seniors into homogeneous socio-economic sub-groups. These sub-groups were the basis for both analyzing time-willingness decay functions and conducting accessibility analysis. By using the klaR library of the R statistical computing environment (Weish et al., 2005), a k-modes algorithm was run due to the categorical nature of the data involved. During the process, special attention was paid to the choice of the variables that would characterize these sub-groups as well as the optimal number of sub-groups.

Regarding the choice of variables for the clustering process, Pearson correlation coefficients ($p < 0.05$ level) were calculated for the different socio-demographic variables, in order to identify the relationships between them, discarding the most-correlated variables. The calculation revealed that age, monthly household income, household car availability, and living alone were the least-correlated variables and, therefore, the most suitable for the clustering analysis. The choice of optimal number of sub-groups was based on the gap-statistic method, which compares intra-cluster variance. It yielded the optimal number of sub-groups (a total of 4 sub-groups), which was then tested via an error bar analysis (confidence interval of 95%).

Time-willingness decay functions to reach groceries, weekly, and incidental retail were empirically obtained for each socio-economic sub-group from the questionnaire, yielding a total of 12 walking time-willingness decay functions. Those time-willingness functions usually adopt a negative exponential form (Fig. 3). Despite other types of distance-decay functions have been explored for the research (Martínez & Viegas, 2013), the use of negative exponential functions is adopted as they facilitate a better estimation of shorter trips associated to non-motorized modes (Iacono, Krizek, & El-Geneidy, 2010). The time-willingness functions were statistically compared for each retail type to identify time-willingness thresholds between the socio-economic sub-groups via the following process (Fig. 3):

(i) In the first step, a comparison of the absolute time-willingness values in minutes between sub-groups was carried out, using the non-parametric Kruskal-Wallis test. Significant differences at $p < 0.05$ level indicated that at least one socio-economic sub-group had a significantly different time-willingness decay function for any time-willingness slot.
(ii) If no significant differences were found during the first step, the second step consisted of the systematic comparison of the time-willingness percentile values between sub-groups. This allowed for the identification of statistically valid differences between sub-groups for specific time-willingness slots.

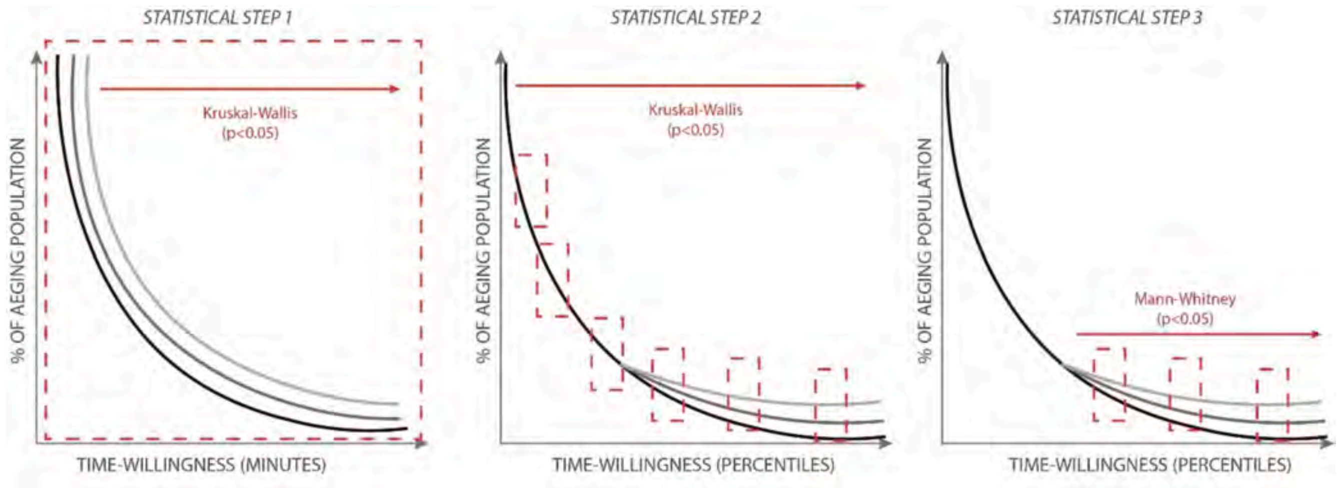


**Fig. 3.** Theoretical representation of comparison between time-willingness decay functions.

(iii) Finally, the non-parametric Mann-Whitney *U* test was used to analyze pairs of time-willingness decay functions for those cases where differences at $p < 0.05$ level were obtained for the Kruskal-Wallis test during steps one or two.

### 3.3. Calculation and mapping of relative accessibility

Accessibility to retail locations for each socio-economic sub-group was calculated by using a gravity-based model (Equation (1)), meaning that access indicators are based on the distance between origins and destinations, weighted by both the availability of retail stores at the destination and the time-willingness decay functions of each sub-group. Accessibility was separately calculated for groceries, weekly, and incidental retail.

$$A_i = \Sigma_{j \neq i} E_j e^{-\beta X_{ij}} \quad (1)$$

$A_i$ is the accessibility for zone $i$; $E_j$ is the number of stores at destination $j$; $X_{ij}$ is the distance between origins and destinations along the street network; and $\beta$ is the parameter of the time-willingness decay function. As mentioned in Section 3.2, those time-willingness decay functions adopt an exponential for in equation (1), since they facilitate a better estimation of shorter trips associated to non-motorized modes (Iacono et al., 2010).

### 3.4. Research design limitations

It is here discussed the main limitations of the research design above described. Regarding sample characteristics, participation centers for seniors were systematically visited to collect face-to-face responses. This data gathering strategy was implemented due to the difficulties found to randomly contact to senior across the streets or in groceries stores. That recruitment process has originated a self-selection bias, since only participants related to the goal of the research took part in the survey process, making the determination of causation more difficult. The self-selection bias also came due to seniors visiting such active participation centers can be more willing to participate in the study because of their particular social perceptions, socio-economic status, and motivations in comparison with seniors do not visit participation centers. For example, seniors visiting participation centers could give special relevance to social interaction within their respective communities, while seniors not frequently visiting participation centers could be less socially proactive. In the context of this research, the described issue may overestimate the walking time-willingness analyzed, as seniors frequently visiting participation centers could be more active to cover their respective needs on foot.

Other part of the sample was obtained by using online questionnaires. That strategy for data gathering was used due to the simplicity of the process. Nevertheless, it is necessary to mention that a non-random sampling process does not guarantee the right representativeness of the sample in the context of the case study (Szolnoki & Hoffmann, 2013). That is seen as a minor problem for the analysis carried out, as online responses covered a total of 15% of the total responses.

Another limitation is related to the study of different types of shopping trips. While it is well-reported how shopping behavior (e.g. buying in hypermarkets or small stores) can affect to covering longer and shorter trips (Reutterer & Teller, 2009), that issue has not been specifically addressed in this study. Nevertheless, the estimated time-willingness average to reach groceries on foot seems to be linked to short trips for daily purchases (e.g. greengrocers, bakeries, butcher shop). Further research on time-willingness thresholds could incorporate the different types of shopping trips, extending the identification of those thresholds not only for different socio-economic groups between seniors, but also according to types of shopping trips.

## 4. Results

### 4.1. Clustering and distance-decay analysis

The population sample included a higher number of women (56%) than men, and the average age of respondents was 69 years old. In total, 79% reported to be retired, while 83% of participants indicated that they had some type of motorized vehicle. The largest share of respondents reported monthly family income between EUR 1000 and EUR 2,000, while 20% of respondents declared to live alone (mostly women).

Regarding transport mode choices, 88% visit groceries on foot. The ratio was lower for reaching both weekly (66%) and incidental retail destinations (44%). Finally, it is worth mentioning that 75% of participants did not buy online groceries ever, which indicates the relevance of walking to groceries for the case study. Table 1 summarizes the main socio-economics characteristics and the expressed mobility habits.

From the sample, a total of four socio-economic sub-groups were identified using the k-modes algorithm. Error bar plots served to analyze the variability of the individuals' between sub-groups with a 95% interval confidence, as well as to describe their composition according to age, motorized vehicle availability, monthly household income, and household type (Fig. 4). Sub-group 1, labelled as "non-motorized seniors between 67 and 75", included persons 65–75 years old; most of them do not have a motorized vehicle at home; their average monthly household income was between EUR 1000 and EUR 2,000, and most did not live alone. Sub-group 2, labelled as "motorized seniors between 65 and 75",

**Table 1**
Socio-economics characteristics and mobility habits.

| Socio-economic characteristics | N | % | Mobility habits to retail | N | % |
|---|---|---|---|---|---|
| **Gender** | | | **Transport mode to groceries** | | |
| Male | 88 | 44 | On foot | 177 | 88 |
| Female | 114 | 56 | Car | 19 | 9 |
| | | | Public transport | 2 | 1 |
| **Age** | | | Bicycle | 4 | 2 |
| 55–65 | 72 | 36 | | | |
| 65–75 | 63 | 31 | **Transport mode to weekly retail** | | |
| >75 | 67 | 33 | On foot | 134 | 66 |
| | | | Car | 35 | 17 |
| **Vehicle availability** | | | Public transport | 31 | 15 |
| Car | 142 | 70 | Bicycle | 2 | 1 |
| Motorcycle | 25 | 12 | | | |
| Bicycle | 15 | 7 | **Transport mode to incidental retail** | | |
| Neither | 58 | 29 | On foot | 89 | 44 |
| | | | Car | 60 | 30 |
| **Driving license** | | | Public transport | 51 | 25 |
| Yes | 120 | 59 | Bicycle | 2 | 1 |
| No | 82 | 41 | | | |
| | | | **Frequency visiting groceries** | | |
| **Employment status** | | | Quite often | 124 | 61 |
| Employed | 38 | 19 | Frequently | 64 | 32 |
| Unemployed | 38 | 19 | Occasionally | 5 | 3 |
| Retired | 126 | 62 | Rarely | 2 | 1 |
| | | | Never | 7 | 3 |
| **Household income (EUR)** | | | | | |
| <1000 | 41 | 20 | **Frequency visiting weekly retail** | | |
| 1000–2000 | 73 | 36 | Quite often | 12 | 6 |
| 2000–3000 | 39 | 19 | Frequently | 37 | 18 |
| 3000–5000 | 21 | 10 | Occasionally | 70 | 35 |
| >5000 | 4 | 2 | Rarely | 72 | 36 |
| | | | Never | 11 | 5 |
| **Living alone** | | | | | |
| Yes | 46 | 23 | **Frequency visiting incidental retail** | | |
| No | 156 | 77 | Quite often | 4 | 2 |
| | | | Frequently | 6 | 3 |
| **Physical limitation or illness** | | | Occasionally | 21 | 10 |
| Yes | 52 | 26 | Rarely | 152 | 75 |
| No | 150 | 74 | Never | 19 | 10 |
| | | | | | |
| | | | **Online groceries shopping** | | |
| | | | At least once | 51 | 25 |
| | | | Never | 151 | 75 |

included persons 65–75 years old, with access to a motorized vehicle in the house (usually a car), with a high monthly household income (EUR 3000–5000), and usually not living alone. Sub-group 3 was labelled as “non-motorized seniors older than 75”: older than 75 years old, without access to a motorized vehicle at home, with low monthly household income (under EUR 1000), and most of them were living alone. Sub-group 4 was labelled as “motorized seniors younger than 65”; their age range was 55–65 years old; they had access to a motorized vehicle at home, had medium-high monthly household income (EUR 2000–3000), and rarely lived alone.

For each socio-economic sub-group, the time-willingness decay functions for walking to groceries, weekly, and incidental retail were empirically obtained by using the questionnaire described in the methodological section. After analyzing the absolute values of the time-willingness decay functions via the Kruskal-Wallis test, significant differences at p-level 0.05 were not found for any type of retail (groceries, weekly, or incidental). This means that no significant differences were identified when the full range of time-willingness decay functions was studied. Accordingly, percentiles of time-willingness for walking were then analyzed by using the Kruskal-Wallis test, to facilitate the identification of significant time-willingness differences for specific time slots. For both groceries and incidental retail, significant differences were not found for any time slot (Table 2, Table 4 and Fig. 5).

For groceries, the time-willingness decay functions were very similar for all four population sub-groups. In all cases, participants were not willing to walk more than 15 min to reach groceries locations, as it was generally assumed by participants that grocery stores should be located very close to residential areas. Proximity to groceries was especially relevant for the “non-motorized seniors between 65 and 75” sub-group (Sub-group 1); 94% were willing to walk only up to 10 min. Most respondents from all four socio-economic sub-groups declared that they usually reached groceries on foot. All sub-groups preferred small, local stores for groceries, followed by medium-sized stores (e.g., supermarkets). Seniors felt that it was more convenient to patronize retail stores located in their own neighborhood, where they also know the shopkeeper personally. No differences were identified between socio-economic sub-groups in this regard.

For incidental retail, no differences were found for any particular time slot. Most respondents stated that they are willing to walk up to 30 min to reach incidental retail destinations. The average time-willingness was higher than for other retail types, because of the infrequent visits to these stores. Some differences between socio-economic sub-groups were noted according to mode choice. On the one hand, “non-motorized seniors between 65 and 75” (Sub-group 1) and “non-motorized seniors older than 75” (Sub-group 3) preferred to reach incidental retail on foot and by public transport, as they tended to visit small and medium-sized stores, dispersed throughout the city. On the other hand, “motorized seniors between 65 and 75” (Sub-group 2) and “motorized seniors younger than 65” (Sub-group 4) preferred to use their private vehicles to reach bigger shopping centers, where incidental retail is concentrated in a single place. Nevertheless, the average walking times to incidental retail were similar for all sub-groups, irrespective of the mentioned differences regarding mode choice preferences.

Unlike for groceries and incidental retail, the analysis of time-willingness by percentiles showed significant differences for the case of weekly retail. The results showed statistical differences for the time-willingness slots of 20–30 min and 60 min (Table 3 and Fig. 5), indicating that at least one socio-economic sub-group had a walking time-willingness decay function that was significantly different from the ones for other sub-groups.

The results of the Mann-Whitney test, used to identify significant differences between pairs of time-willingness decay functions for weekly retail, are shown in Table 5. The time-willingness decay function for “motorized seniors younger than 65” (Sub-group 4) was significantly different from the values for other sub-groups for the 20–30-min slot (Table 5 and Fig. 5). This is especially relevant if one considers that 40% of respondents expressed willingness to walk to weekly retail within this time slot. On the other hand, for the 60-min slot, the distance decay function for “motorized seniors between 65 and 75” (Sub-group 2) is significantly different from the values for other sub-groups (Table 5 and Fig. 5).

“Motorized seniors younger than 65” (Sub-group 4) expressed lowest willingness to walk to weekly retail. In particular, the share of sub-group 4 respondents willing to walk more than 20 min to reach weekly retail was very small compared to the value among other sub-groups. This suggests that in cases where it takes more than 20 min to walk to a weekly retail location, the “motorized seniors younger than 65” would opt for personal motorized transport modes. The finding can be explained by the socio-economic characteristics of sub-group 4: they are mostly employed and have family responsibilities and, therefore, operate under tighter travel time restrictions that other senior sub-groups. In addition, “motorized seniors younger than 65” patronized weekly retail locations more frequently than the other sub-groups, implying the need for policies that facilitate non-motorized access for this population sub-group to weekly retail locations.

### 4.2. *Mapping relative accessibility*

A gravity-based model was used to illustrate spatially accessibility to weekly retail, due to the identified statistically valid differences (Fig. 6).

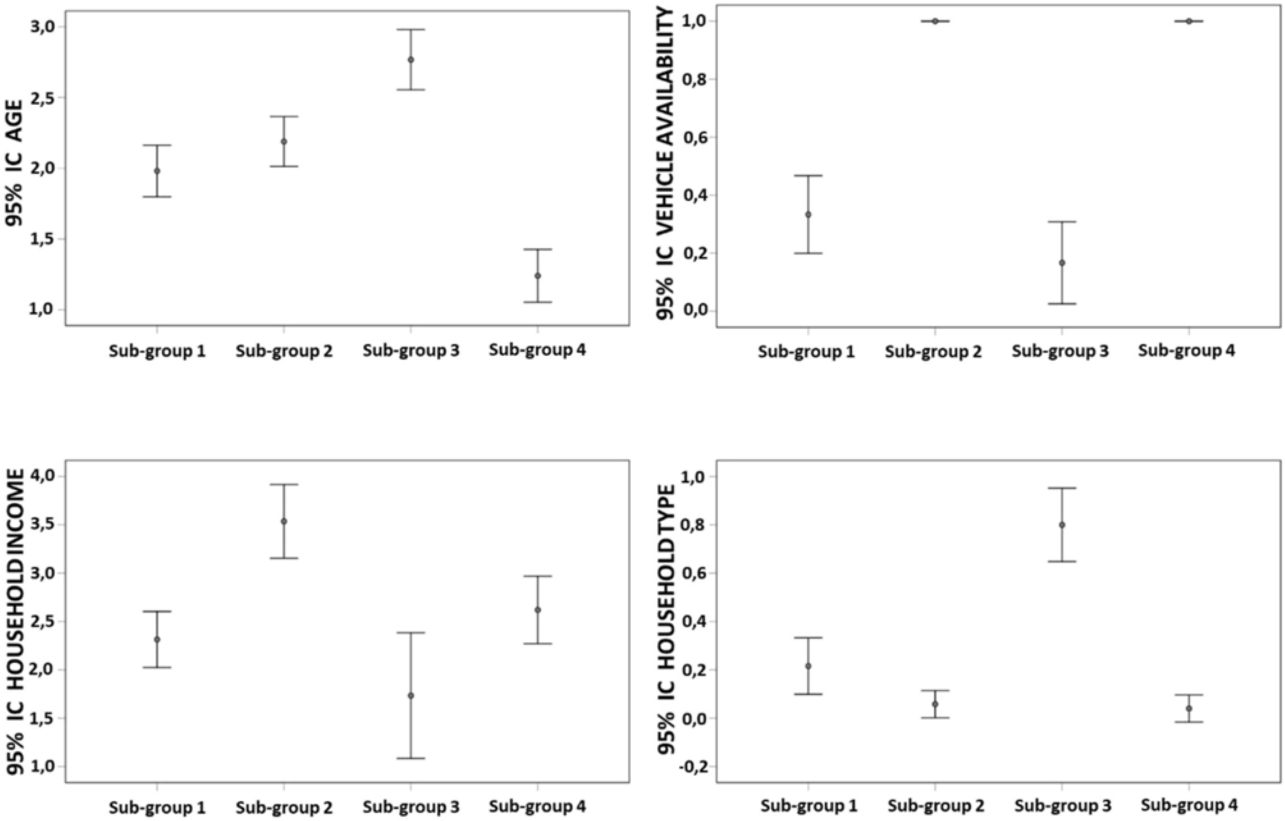


**Fig. 4.** 95% IC error bars by sub-group and socio-economic variable.

The results show the potential neighborhoods with higher motorized share for accessing weekly retail, i.e., areas that could benefit from the implementation of policies that foster a transition toward increasing walking accessibility levels to weekly retail.

As noted, the reduced willingness to walk to weekly retail by the "motorized seniors younger than 65" sub-group resulted in a loss of accessibility to weekly retail throughout the city for that sub-group. This limitation is particularly relevant in the city center, which houses a smaller share of the "motorized seniors younger than 65" population. However, weekly retail locations are heavily represented is the city center, resulting in a stronger increase of motorized trips into the area by "motorized seniors younger than 65". The described situation is especially severe in the following neighborhoods: *San Francisco Javier*, *Pajaritos*, *Ronda*, *Cervantes*, *Zaidín-Vergeles*, and *Castaño-Mirasierra*.

Spatial analysis also identified places with low levels of walking accessibility to weekly retail for all four socio-economic sub-groups, specifically in the central-eastern zone of the historic districts of *San Ildefonso*, *Haza Grande*, *Albaicín*, *Sacromonte*, and *San Matías-Realejo*. All of these neighborhoods are important tourist destinations and incidental retail orientated towards tourist predominates. However, accessibility

**Table 2**
Kruskal-Wallis test for walking time-willingness percentiles to *groceries*.

| Percentile | Walking time-willingness to groceries (minutes) | p-value |
|---|---|---|
| 5th | 5 | 0.754 |
| 10th | 10 | 0.475 |
| 15th | | |
| 20th | | |
| 25th | | |
| 30th | | |
| 35th | 15 | 0.943 |
| 40th | | |
| 45th | | |
| 50th | | |
| 55th | | |
| 60th | 20 | 0.224 |
| 65th | | |
| 70th | | |
| 75th | | |
| 80th | 30 | 0.136 |
| 85th | | |
| 90th | 45 | 0.946 |
| 95th | 60 | 0.280 |

p-value indicates differences of time willingness between seniors sub-groups.

**Table 3**
Kruskal-Wallis test for walking time-willingness percentiles to weekly retail.

| Percentile | Walking time-willingness to weekly retail (minutes) | p-value |
|---|---|---|
| 5th | 5 | 0.232 |
| 10th | 10 | 0.222 |
| 15th | 15 | 0.180 |
| 20th | | |
| 25th | | |
| 30th | 20 | **0.032**[a] |
| 35th | | |
| 40th | | |
| 45th | 30 | **0.013**[a] |
| 50th | | |
| 55th | | |
| 60th | | |
| 65th | | |
| 70th | | |
| 75th | 45 | 0.069 |
| 80th | | |
| 85th | | |
| 90th | 60 | **0.029**[a] |
| 95th | | |

p-value indicates differences of time willingness between seniors sub-groups.

[a] It refers to significant differences of time willingness between seniors sub-groups at p-level$<$0.05.

**Table 4**
Kruskal-Wallis test for walking time-willingness percentiles to incidental retail.

| Percentile | Walking time-willingness to incidental retail (minutes) | p-value |
|---|---|---|
| 5th | 5 | 0.426 |
| 10th | 10 | 0.470 |
| 15th | | |
| 20th | 15 | 0.206 |
| 25th | | |
| 30th | 20 | 0.363 |
| 35th | | |
| 40th | | |
| 45th | 30 | 0.173 |
| 50th | | |
| 55th | | |
| 60th | | |
| 65th | | |
| 70th | | |
| 75th | | |
| 80th | 45 | 0.513 |
| 85th | | |
| 90th | 60 | 0.324 |
| 95th | | |

p-value indicates differences of time willingness between seniors sub-groups.

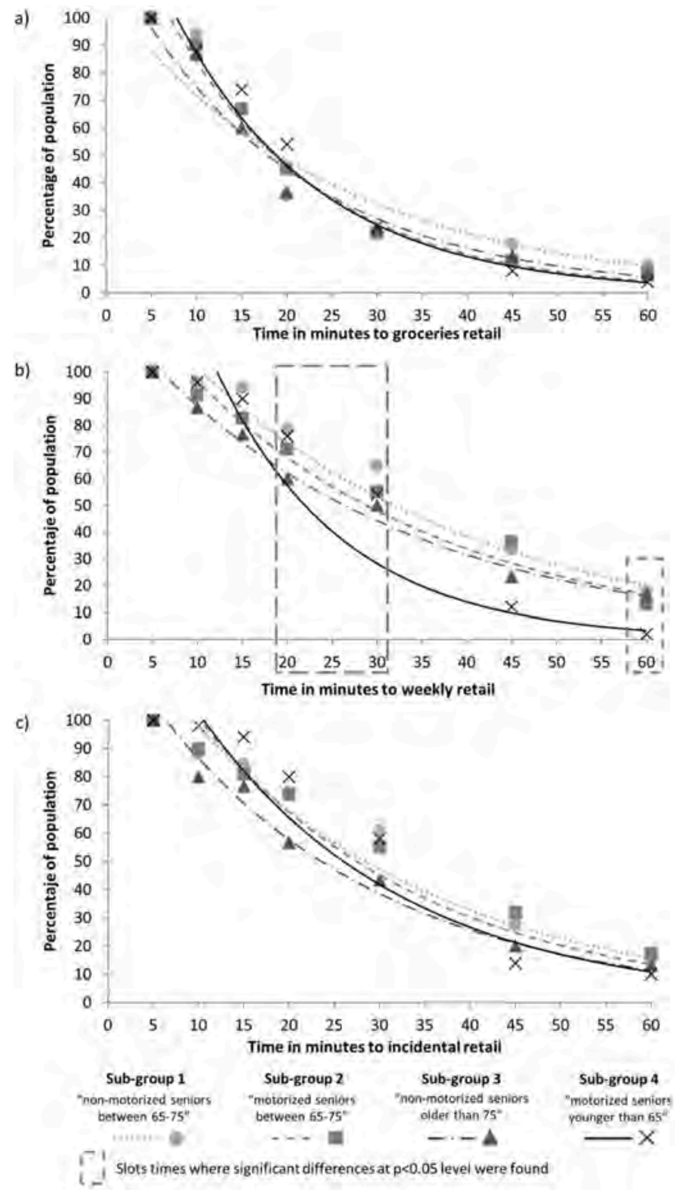


**Fig. 5.** Time-willingness decay functions for groceries (a), weekly (b), and incidental (c) retail.

levels to weekly retail are also low in other residential neighborhoods, such as *Genil, Chana*, and *Realejo.* In these cases, the situation poses an additional challenge to policymakers because of the high ratio of seniors, resulting in a higher likelihood of weekly retail trips into the city center. Policies that facilitate the location of weekly retail in the mentioned neighborhoods as well as the provision of pedestrian infrastructure to the city center would reduce traffic congestion in the city center.

## 5. Conclusions

The paper explored the following research questions: *to what extent is walking accessibility similar between groceries and other types of retail for seniors?* and *Are there time-willingness thresholds that could trigger significant shifts in walking accessibility to such retail types within this population group?* The obtained results conclude that walking accessibility is significantly different for weekly retail between the four studied senior sub-groups, while it is quite similar for both groceries and incidental retail. In particular, a walking time-willingness threshold for the 20–30-min time slot was identified for the “motorized seniors younger than 65” sub-group, indicating significantly lower willingness to walk to this type of retail on foot within this time slot. In summary, three tiers of findings and reflections have been identified:

- *Accessibility planning in the ageing city.* The research revealed a strong preference among seniors to reach different types of retail on foot in Granada, especially for “motorized seniors between 65 and 75”, “non-motorized seniors between 65 and 75”, and “non-motorized seniors older than 75”. A total of 88% of participants declared that they walk to grocery stores; 66% walk to weekly retail and 44% to incidental retail. These results diverge from other studies that highlighted high dependence on motorized accessibility to major locations among seniors (Ricciardi et al., 2015). On the contrary, it presents a strong basis for sustainable transport planning to secure the desired impacts in the mid-term, assuming that around 40% of the population in the south of Spain will be over 65 years old by then (Soria-Lara and Banister, 2017). For this reason, future urban designs should facilitate walking for seniors (fundamentally for persons over 65 years old), by removing obstacles, stairs, and any other physical barriers that impede walking. Mapping these physical barriers and designing policies to overcome them are key for fostering an effective transition toward low-carbon mobility in the city of Granada.
- *Geographies that matter.* As seen in previous studies, seniors located in peripheries of cities are at a relative disadvantage compared to seniors living in city centers (Páez et al., 2010b; Weber & Kwan, 2003). This finding also holds true for walking accessibility to retail, as evidenced by our case study. On the one hand, the “motorized seniors younger than 65” sub-group is a dominant share of the overall senior population in these locations, and they are also the sub-group with the lowest willingness to walk to retail. On the other hand, peripheries have a poor dotation of retail activities (especially weekly retail), which fosters motorized trips between these neighborhoods and the city center. Representative examples in Granada are the neighborhoods of *Chana* and *Zaidin.* The implementation of policies that encourage location of new retail opportunities in peripheries could help address this problem (e.g., via reduced taxes), in combination with policies that restrict motorized vehicles access to the city center.
- *Relevance of small and traditional retail.* As demonstrated, groceries shopping trips are doing frequently or quite often, especially for the older seniors, and most socio-economic sub-groups declared their preferences to patronize traditional stores. Furthermore, the preference to reach retail on foot was strongly related to the presence of

**Table 5**
Mann-Whitney *U* test for walking time percentiles to weekly retail (p-value).

| | 20 min (30th to 40th percentile) | | | 30 min (45th to 70th percentile) | | | 60 min (90th to 95th percentile) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sub-group 2 | Sub-group 3 | Sub-group 4 | Sub-group 2 | Sub-group 3 | Sub-group 4 | Sub-group 2 | Sub-group 3 | Sub-group 4 |
| Sub-group 1 | 0.881 | 0.958 | **0.012**[a] | 0.704 | 1.000 | **0.012**[a] | **0.011**[a] | 0.877 | 0.414 |
| Sub-group 2 | | 0.821 | **0.008**[a] | | 0.834 | **0.001**[a] | | **0.012**[a] | **0.003**[a] |
| Sub-group 3 | | | 0.051 | | | 0.054 | | | 0.480 |

p-value indicates differences of time willingness between pairs of seniors sub-groups.
[a] It refers to significant differences of time willingness between pairs of seniors sub-groups at p-level<0.05.

small stores across the city. "Motorized seniors younger than 65" were the exception, preferring to use their private vehicles to travel to large shopping centers for weekly retail in the peripheries of the city. In this respect, legal regulations that protect small and traditional stores could be introduced, to strengthen their important role as key destinations for non-motorized trips in Granada. In this respect, the e-commerce boom is also an emerging threat, but its impact on the time-willingness of seniors to walk to retail seems to be small.

The obtained findings also open new research horizons, for example, comparing how relevant is the size of the city for the time-willingness of seniors to walk to retail, and analyzing how e-commerce affects walking accessibility. Furthermore, the use of living labs for implementing

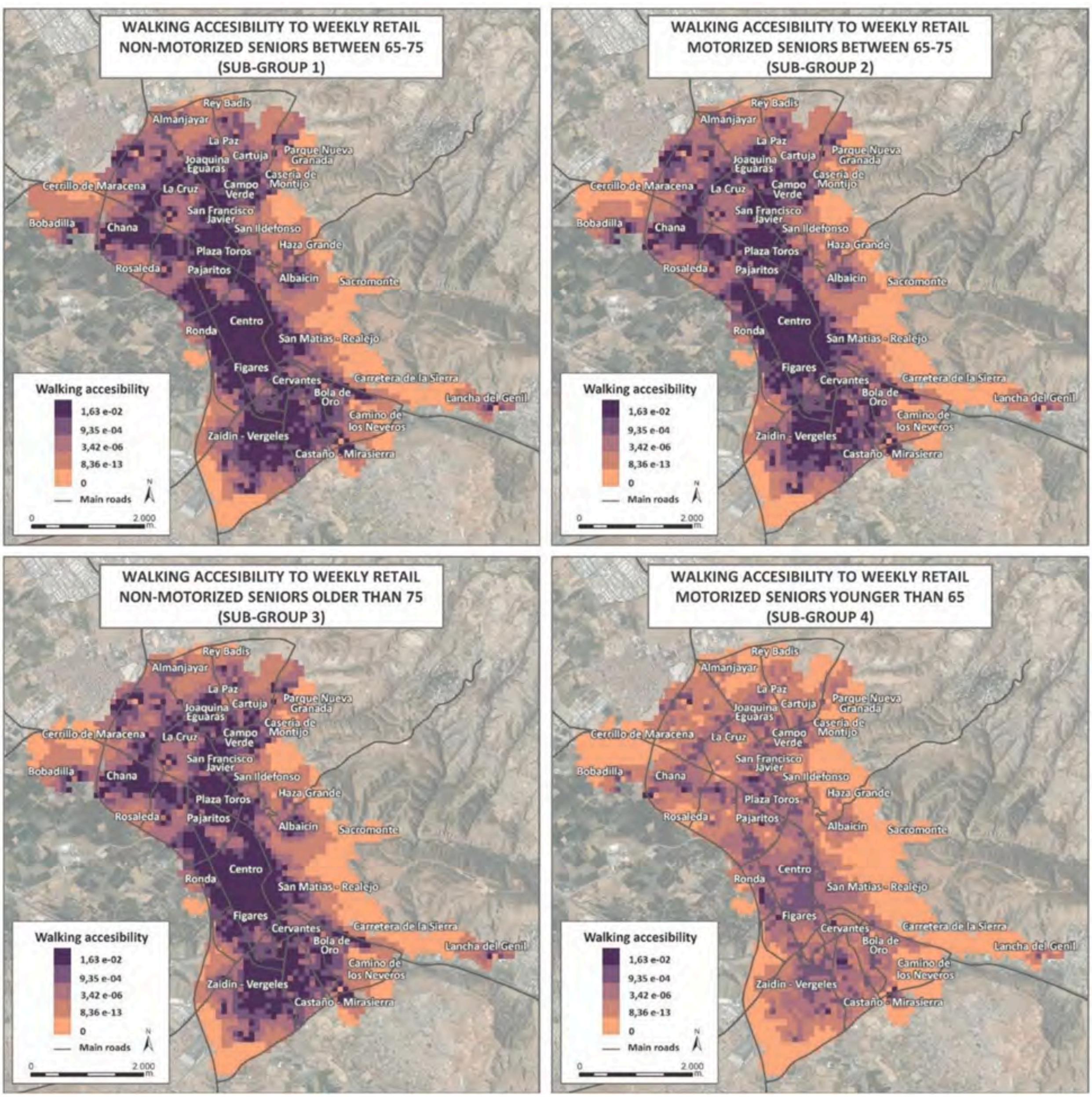

**Fig. 6.** Walking accessibility to weekly retail for the four seniors sub-groups.

tracking systems can be another important source of knowledge on walking accessibility for seniors and what to do to foster it.

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**Appendix 1**

This appendix contains the survey used during the data gathering process. That must be considered that the survey is a translation into English from the original in Spanish.

*Demographic and socioeconomic issues*

1. How old are you?
   o # years old
2. Please, indicate your gender
   o Male
   o Female
3. What is your educational level?
   o No studies
   o Basic
   o Secondary
   o Bachelor
   o University
4. What is your current employment status?
   o Part time employee
   o Full-time employee
   o Unemployed
   o Retired
5. What is your household income after taxes per month?
   o <1.000
   o 1.000–1.999
   o 2.000–2.999
   o 3.000–5.000
   o >5.000
6. What is your household composition?
   o Single
   o Single +1 child
   o Single +2 or more children
   o Couple
   o Couple +1 child
   o Couple +2 or more children
7. Are there older people living with you?
   o Yes
   o No
8. Indicate the availability of vehicles in your household (multiple answer)
   o No vehicles
   o Car
   o Motorcycle
   o Bicycle
9. Do you have a driving license?
   o Yes
   o No
10. Do you have any physical limitation or illness that prevents you from walking?
    o Yes
    o No

*Walking time-willingness*

11. Independently of the neighborhood where you are currently living, how much time are you willing to spend to reach groceries on foot?
    o Less than 5 min
    o 5–10 min
    o 10–15 min
    o 15–20 min
    o 20–30 min
    o 30–45 min
    o 45–60 min
    o More than 60 min
12. Independently of the neighborhood where you are currently living, how much time are you willing to spend to reach weekly retail (e.g., clothing store, bazar, drugstore) on foot?
    o Less than 5 min
    o 5–10 min
    o 10–15 min
    o 15–20 min
    o 20–30 min
    o 30–45 min
    o 45–60 min
    o More than 60 min
13. Independently of the neighborhood where you are currently living, how much time are you willing to spend to reach incidental retail (e.g., bookshop, furniture store, jeweller) on foot?
    o Less than 5 min
    o 5–10 min
    o 10–15 min
    o 15–20 min
    o 20–30 min
    o 30–45 min
    o 45–60 min
    o More than 60 min

*Mobility habits to reach retail*

14. How do you usually reach groceries?
    o On foot
    o By car
    o By public transport
    o By bicycle
15. How do you usually reach weekly retail (e.g., clothing store, bazar, drugstore)?
    o On foot
    o By car
    o By public transport
    o By bicycle
16. How do you usually reach incidental retail (e.g., bookshop, furniture store, jeweller)?
    o On foot
    o By car
    o By public transport
    o By bicycle
17. How often do you go to groceries?
    o Quite often
    o Frequently
    o Occasionally
    o Rarely
    o Never
18. How often do you go to weekly retail (e.g., clothing store, bazar, drugstore)?
    o Quite often

o Frequently
o Occasionally
o Rarely
o Never

19. How often do you go to incidental retail (e.g., bookshop, furniture store, jeweller)?
  o Quite often
  o Frequently
  o Occasionally
  o Rarely
  o Never
20. What type of grocery store do you prefer?
  o Small store/local store
  o Medium store
  o Shopping center
21. What type of weekly retail store do you prefer?
  o Small store/local store
  o Medium store
  o Shopping center
22. What type of incidental retail store do you prefer?
  o Small store/local store
  o Medium store
  o Shopping center
23. Have you ever bought online?
  o Never
  o At least once
24. Rate, from 1 to 5, the following aspects of the pedestrian infrastructure of your neighborhood (e.g. pedestrian crossings, sidewalks, benches, parks)
  o Security
  o Quantity
  o Adaptation for people with disabilities/reduced mobility
25. Rate, from 1 to 5, the reasons why you go shopping on foot.
  o It is cheaper
  o I am environmentally conscious
  o It is a way to interact with people
  o It is healthy
  o The distances are affordable
  o It is a safe city
  o It is faster

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