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Social and spatial equity effects of non-motorised accessibility to retail

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ABSTRACT

The evaluation of social and spatial effects of how accessibility is distributed between individuals is key to studying equity issues in transportation. However, the establishment of minimum accessibility requirements and the identification of accessibility thresholds for population groups remain as key methodological barriers. This paper contributes to addressing these shortcomings by using Retail Mobility Environments as an analytical and geographical concept to identify advantageous and disadvantageous non-motorised accessibility to retail for different population groups. The city of Zaragoza, Spain provides the spatial laboratory for experimentation, and the study focuses on four target groups: the young employed, the young unemployed, seniors, and adults. The results reveal social and spatial inequalities in the distribution of non-motorised accessibility in Zaragoza, with marked negative effects on the young unemployed and adults. On the other hand, seniors and the young employed are the groups that benefit from the current setup. It is finally discussed on the capacity of the proposed methodology for exploring both social and spatial inequalities, for establishing minimum accessibility requirements, and for identifying accessibility thresholds according to different population groups. Furthermore, the convenience of linking equity issues to non-motorised accessibility is also highlighted.

1. Introduction

Accessibility approaches try to maximise the number of opportunities available to individuals and the means to reach such opportunities (Boisjoly & El-Geneidy, 2017; Currie & Stanley, 2008; van Wee, 2016). While theoretically sound, one limitation is the view of transport accessibility as an absolute measure with positive impacts, paying only limited attention to the fact that transport accessibility does not equally affect the full spectrum of the population (Arranz-López, Soria-Lara, Witlox, & Páez, 2018). For example, people's willingness to travel and choice of mode is affected by contingencies such as personal characteristics, the physical environment, and cultural norms. In other words, transport accessibility is essentially a relative issue (Grengs, 2014; Prins et al., 2014; Yang & Diez-Roux, 2012), which can be seen as "*the proportion of opportunities available to an individual with defined characteristics at a selected location, relative to an individual from a reference group at the same location*" (Páez et al., 2010a,b, p.3). Accordingly, variations in relative accessibility between socio-economic groups can result in social and spatial inequalities (Delbosc & Currie, 2011; Lucas, Bates, Moore, & Carrasco, 2016; Ricciardi, Xia, & Currie, 2015), being particularly relevant when considering non-motorised accessibility as universal transport mode.

The number of studies concerned with transport justice and equity has been increased in recent decades (Banister, 2018; Geurs, Boon, & Van Wee, 2009; Kenyon, 2003; Martens, 2015), focusing on the conceptualization of distributive justice and equity in transportation (Beyazit, 2011; Lucas, van Wee, & Maat, 2016; Martens, 2012). That has originated a growing lack of both conceptual clarity and diversity of themes impeding a meaningful cross-comparison between the findings of those studies on policymaking (Pereira, Schwanen, & Banister, 2016). Academics acknowledge that part of the challenge is methodological, being related to the difficulty to place accessibility issues at the core of the equity debate (Martens, Golub, & Robinson, 2012; van Wee and Geurs, 2011), especially when spatial and social effects of transport and land use policies must be captured. In this way, the study of relative accessibility, by comparing accessibility levels to major opportunities between socio-economic groups of population, can be a key method to gain insights into the abovementioned discussion. That approach will identify both places and popu-

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lation groups under situation of accessibility disadvantage -that is the multiples ways in which the location of different issues can enhance exclusion (e.g. opportunities, availability of transport modes, existing infrastructure, and individual willingness to reach those opportunities by using specific transport modes) (Lucas, 2012). However, methodological barriers still predominate such as: the establishment of minimum accessibility requirements and the identification of accessibility thresholds between population groups (Lucas, Bates, et al., 2016; Lucas, van Wee, & Maat, 2016; Pereira et al., 2016). If those methodological barriers persist, a lack of knowledge about the potential impacts of accessibility planning in social exclusion can remain, and as a result, the implementability of new daily practices will be very limited increasing the negative effects of accessibility inequalities between individuals. On the other hand, if those methodological issues are finally overcome, new planning criteria and guidelines can be used promoting a more customised accessibility planning process sensitive to the potential effects of social inequalities.

Based on these important issues, this paper seeks to evaluate the social and spatial effects of how non-motorised accessibility to retail is distributed between different population target groups. The city of Zaragoza, Spain was selected as a case study due to its stated policy objective to promote non-motorised accessibility to retail opportunities. At methodological level, the geographical and analytical concept of "Retail Mobility Environment" (RMEs) has been used as the basis for both the establishment of accessibility minimum requirements and the identification of accessibility thresholds. We analysed the social and spatial effects of accessibility, by comparing generic Retail Mobility Environments (RMEs) – homogenous geographical areas where retail activity and non-motorised accessibility are interrelated in a specific way, considering the city population as a whole – with relative RMEs – homogenous geographical areas where non-motorised accessibility to retail activity is affected by travel time thresholds for different population target groups. A total of four population groups were included in the study: the young employed, the young unemployed, adults, and seniors. Spatial variations between generic and relative RMEs for the city of Zaragoza resulted in the identification of "Disadvantageous Accessibility Places" and "Advantageous Accessibility Places" for each target population group. We also conducted a set of 26 semi-structured interviews with respondents from groups affected by "Disadvantageous Accessibility Places", to better understand the social and spatial effects of how non-motorised accessibility to retail is distributed in the case study.

The paper is structured as follows. Section 2 reviews the main theoretical streams in the literature. Section 3 focuses on describing the case study. Section 4 presents databases and the research design, while Section 5 details the results. Finally, Section 6 provides concluding remarks and points to future research topics.

2. Theoretical background

2.1. Social and spatial equity in transportation

It can be identified a growing number of studies aimed at studying the relationships between transport accessibility and social inequalities from several viewpoints. For example, Lucas et al. (2016b) proposed a method that combines ethics theories with accessibility-based analysis. They use the Lorenz curve to establish an accessibility threshold value, based on UK indicators, for avoiding social exclusion. Casas (2007) compared levels of accessibility between disabled and non-disabled groups, finding that the number of opportunities were lower for disabled groups than for non-disabled. It was also found that being young, having a driver license and a job, and living in an urban setting increased the number of reachable opportunities. Another example, carried out by Páez et al. (2010a,b), used accessibility as a deprivation indicator in the context of food deserts. They found that low-income households tended to have better accessibility in the city centre, but not in suburban areas. They also revealed that access to fast food was more egalitarian when household income was analysed. Guzman, Oviedo, and Rivera (2017) assessed levels of equity in accessibility to employment and education, signalling that low-income households had lower accessibility levels by both car and public transport when compared to high- and medium-income households. Other studies that evaluate accessibility to assess social equity issues can be consulted in Bocarejo and Oviedo (2012), Grengs (2012), and Lucas et al. (2016c).

Despite the prominent number of studies focused on addressing equity issues in transportation by using accessibility-based approaches, some gaps still remain at methodological level – fundamentally the need for establishing both minimum accessibility requirements and accessibility thresholds for target groups (Pereira et al., 2016; Van Wee and Geurs, 2011). The establishment of minimum accessibility requirements would facilitate the adoption of normative criteria in practice that can guarantee minimum accessibility standards for the whole population beyond individual habits, avoiding that people can be prevented to participate in the social, political, and economic life of their community. Furthermore, accessibility thresholds can provide policy-makers with insights into how much accessibility can be enough to satisfy the basic need for the widest spectrum of population (Bertolini, 2017). In this research, the use of the geographical and analytical concept of "Mobility Environments", and specifically "Retail Mobility Environments", is explored as an effective way to bridge the mentioned gaps.

2.2. Retail Mobility Environments

Retail Mobility Environments are derived from the planning concept of Mobility Environments, which refers to geographical areas where land use and transport are reciprocally interrelated in a specific way (Bertolini & Dijst, 2003; Soria-Lara, Valenzuela-Montes, & Pinho, 2015). While studies focusing on the use of mobility environments have been prominent in recent years, there is no common and codified operationalisation for identifying such environments (Bertolini, 2017). For example, Bertolini and le Clercq (2003) identified mobility environments in the context of Amsterdam by a combination of transport characteristics (e.g., speed, capacity) with land use characteristics (e.g., diversity, density). For Zandvliet and Dijst (2006), mobility environments are based on interrelating population characteristics (e.g., mean available income, percentage of residents aged 0–14, families with children) and the time that these groups spend to reach certain activities (e.g., work, shopping, leisure). Studies in Spain and Portugal focused on defining mobility environments as homogeneous geographical units where transport dotation and land use issues (e.g., density and diversity) are specifically interrelated, identifying places with a common mobility identity (e.g., proximity mobility environments vs long-distance mobility environments) (Silva, Reis, & Pinho, 2014; Soria-Lara, Aguilera-Benavente, & Arranz-López, 2016). One relevant example was carried out by (Arranz-López, Soria-Lara, López-Escolano, and Pueyo Campos (2017) who identified and mapped Retail Mobility Environments (RMEs). RMEs are geographical areas where policymaking can promote an effective interaction between retail activity and non-motorised accessibility, facilitating a policymaking process that support more compact city patterns.

The flexibility of mobility environments and RMEs approaches – generic enough to cover the full spectrum of the population while being sensitive enough to the specific conditions of different population groups (Bertolini, 2017; Silva, 2013; Soria-Lara et al., 2015; Talavera et al., 2014) – provides a good methodological fit with the goals of this research, i.e. the establishment of minimum accessibility requirements and the identification of non-motorised accessibility thresholds to retail.

3. The Zaragoza case study

Zaragoza is a medium-size city (700,000 inhabitants) located in north-eastern Spain (Fig. 1). The city has undergone significant changes over the last 15 years driven by the transformation of both the transportation system and the retail landscape.

The transport system of Zaragoza offers 43 bus lines covering the whole city, a north-south LRT line, a public bike-share system with 130 stops, and a recent electric scooter service offered by a private company. Related to the private mobility, 94% of population use their car for daily mobility while only 6% a motorbike. From the non-motorised accessibility side, there have been a small decrease of walking trips in the last ten years (4.6%), but a significant increase of trips by bicycle (2%) have taken place (Ayuntamiento de Zaragoza, 2018). Moreover, some significant changes have been incorporated at the city level, such as the pedestrianisation of streets with high retail density, the urban renewal of some parts of the historic centre, and the extension of bicycle lanes through the main city roadways.

From the retail side, 1186 small-sized stores have disappeared in favour of medium and large-sized retail areas (e.g., supermarkets, mall centres). Nonetheless, the non-motorised trips still predominate to cover daily retail population needs (12% of the trips), when compared to car trips (3.6%). Also, the development of mall centres has resulted in both less retail zones in the newer urban neighbourhoods (e.g., *Parque Venecia*, *Valdespartera*, *Miralbueno*) and the disappearance of many small shops within traditional built-up areas (e.g. San José neighbourhood). To face this situation, the local government is implementing policy packages for increasing non-motorised accessibility (walking and cycling) to traditional retail across the city. Some examples are large investments to revitalise small and distributed retail (mainly food markets) in the heart of all traditional neighbourhoods, the modernization of some commercial places (e.g. culinary markets), as well as specific temporary events for marketing (e.g. street markets and advertising campaign in surrounding locations of revitalised neighbourhoods) to improve sales volumes of small shops. Those local policies have markedly improved non-motorised accessibility to retail across the entire city and provide a good basis for evaluating the research questions of this paper.

Fig. 1 shows the current retail distribution in Zaragoza. Daily retail which mainly includes food stores, (e.g. supermarkets, groceries) is located across the city, but with a weak presence in the newest neighbourhoods mainly located in the south and west (e.g. neighbourhoods such as Valdespartera and Parque Venecia). Weekly retail which includes health and body care (e.g. gym, convenience store); leisure (e.g. cinema, bars); and fashion (e.g. clothes, accessories) is mainly located in the city centre, but also in some traditional neighbourhoods such as Actur and Delicias, where a big shopping centre, and important commercial streets are located. Incidental retail which includes stationary stores (e.g. office supplies, bookstore); household goods (e.g. furniture, DIY stores); technology stores (e.g. computer stores, mobile phone); and other retail (e.g. travel agency, car dealership) follow similar distribution patterns than weekly retail does.

4. Data and methods

This research compares generic RMEs (estimated for the full spectrum of population) and relative RMEs (estimated for different socio-economic groups) as the basis to evaluate the social and spatial effects of how non-motorised accessibility to retail is distributed in the case study. It follows a three-stage research design (see Fig. 2): (i) data gathering; (ii) estimation of generic and relative RMEs; and (iii) evaluation of social and spatial effects.

4.1. Data gathering

The main data source was a questionnaire (n = 530) that collected information about the socio-economic characteristics of the population[1] and time-willingness to walk and bicycle to daily, weekly, and incidental retail locations in Zaragoza. Responses were codified in 5-, 10-, 15-, 20-, 30-, 45- and 60-min time-willingness intervals. Variations in time-willingness would represent individual attitudes for reaching retail locations, affected by contingencies such as personal characteristics, physical environment, and cultural norms. The last part of the questionnaire explored the reasons behind these contingencies (e.g. walking is healthier). The questionnaire was administered from April to June 2016, both online (460 responses) and face-to-face (70 responses). Face-to-face interviews were especially relevant for obtaining responses from the elderly population. The sample was significant at 95% confidence interval, with a bias of 5%.

In parallel, we collected spatial databases from several data sources, including retail locations digitisation from databases developed by the Spanish Ministry of Economy in 2015. It was cross-checked with information from telephone directory listings and retail corporate websites. The final list included 3025 retail locations, which were classified in daily, weekly, and incidental retail. Both a bicycle lane network, from Zaragoza City Council open data website, and a street network, from the Spanish National Centre of Geographic Information, were used for accessibility calculations. Finally, a 100 m × 100 m grid from the European Environment Agency was used as base map to integrate all data and to process the analysis.

4.2. Estimation of generic and relative RMEs

The identification of both generic and relative RMEs involved three steps (a detailed methodological description can be found in Arranz-López et al., 2017): (i) definition of accessibility zones, using the combination of three indicators (walking accessibility and bicycling accessibility through gravity-based models, and betweenness) (Table 1); (ii) definition of retail zones, also using the combination of three indicators (retail density, retail diversity, retail contiguity) (see Table 1); (iii) identification of RMEs, by combining the mean values of the aggregated results from both accessibility and retail zones by using an axis-based scheme (Fig. 3). The combination of indicators during the stages (i) and (ii) was made by using multi-criteria analysis (Analytic Hierarchy Process) (Saaty, 1990). To do that, participants were asked to prioritise by peer-comparison which indicators were more relevant when they travelled to retail by using non-motorised modes. This resulted in specific weights to combine separately accessibility zones indicators and retail zones indicators. In total, four types of RMEs were identified (see Fig. 3):

I. ***Short-distance environments***: characterised by high values for both non-motorised accessibility and retail activity, resulting in lively places where motorised modes are not essential, and walking/cycling is sufficient for covering retail needs.
II. ***Non-motorised environments***: characterised by high values for non-motorised accessibility and low values for retail activity, resulting in places where non-motorised modes are predominant.

[1] The collected variables were age, gender, employment status, educational level, children, monthly household income, and household car and/or bicycle availability.

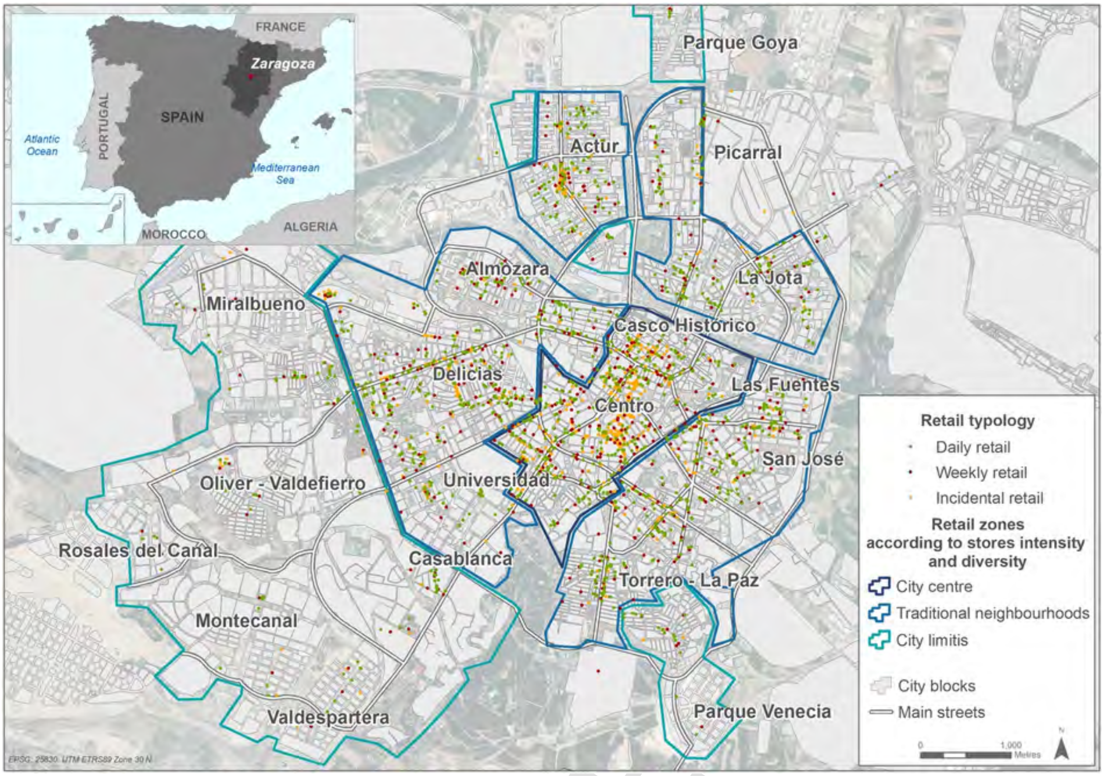

Fig. 1. Location map of Zaragoza.

III. ***Motorised environments***: characterised by low values for non-motorised accessibility and high values for retail activity, resulting in places with a substantial number of retail stores, and motorised transport has an advantage over non-motorised modes.

IV. ***Long-distance environments***: characterised by low values for both non-motorised accessibility and retail activity, resulting in more remote places where non-motorised modes are not effectives means of transport and, therefore, motorised transport is essential for covering shopping activities.

On the one hand, the identification of generic RMEs is based on estimating gravity-based indicators (Table 1) for non-motorised accessibility (walking and bicycling), by using a single distance decay function to reach retail locations for the entire population sample (n = 530). No attention is paid to the specific circumstances of segments of the population. Considering that generic RMEs represent the current levels of non-motorised accessibility to retail for all individuals in Zaragoza, such generic RMEs were considered as the baseline or minimum requirement to identify non-motorised accessibility variations that can result in advantageous or disadvantageous non-motorised places.

On the other hand, the relative RMEs' distinctiveness lies in estimating gravity-based indicators (Table 1) for non-motorised accessibility (walking and bicycling) by using distance decay functions customised for different target groups of the population. Moreover, the relative distance decay functions were based on identifying time-willingness thresholds for reaching retail by non-motorised modes for different population groups.

The population groups were identified according to the socio-economic variables listed in Section 4.1 by using clustering techniques. First, a bivariate analysis between the socio-economic attributes was carried out, in order to estimate the tentative potential of each variable to define clusters. During the process, it was seen that age, employment status, car availability, and bicycle availability all showed the lowest correlations. Accordingly, these variables were used for the clustering process by using the k-modes algorithm due to the categorical characteristics of the data involved. Finally, four clusters were taken for this study (interval of confidence of 95%) based on the silhouette coefficient of 0.54, which meant that the clusters presented a reasonable inner-structure. Cluster #1, called *the young employed*, was formed by the population between 19 and 44 years of age, employed and with access to a car. Cluster #2, called *the young unemployed*, comprised the population between 19 and 44 years of age, unemployed, and with access to a car and bicycle. Cluster #3, called *seniors*, was composed by the population of persons older than 65 years, retired and with access to a car. Cluster #4, called *adults*, consisted of the population between 45 and 64 years of age, employed, while access to a car and bicycle is unclear.

Using declarations on time-willingness to reach retail by non-motorised modes (Section 4.1), we applied Kruskal-Wallis and Mann Whitney *U* tests to compare time-willingness to reach retail between population groups and established time-willingness thresholds when significant differences were found between the analysed groups ($p < 0.05$ level). First, statistical differences were found for walking time-willingness between socio-economic groups from 15 to 25 min for daily retail, from 20 to 30 min for weekly retail, and from 30 min upwards for incidental retail (Fig. 4). Second, cycling time-willingness between socio-economic groups showed statistical differences for all time-willingness intervals. By assessing distance decay functions from the statistically significant time slots, we obtained relative non-motorised accessibility (walking and bicycling) measures, which were further applied to identify relative RMEs (a detailed methodological description can be found in Arranz-López et al., 2018).

4.3. Evaluation of equity and spatial effects

To evaluate equity and spatial effects of how non-motorised accessibility is distributed between individuals in Zaragoza, the spatial

Fig. 2. Methodological scheme.

distribution of generic and relative RMEs was systematically compared. That resulted in the identification of "Disadvantageous Accessibility Places" (DAPs) and "Advantageous Accessibility Places" (AAPs). For each target group, DAPs would be considered as *locations with reduced non-motorised accessibility levels to retail activities of need/interest compared to generic RMEs*. On the other hand, AAPs would indicate the opposite, i.e. *locations with favourable non-motorised accessibility levels to retail activities of need/interest compared to generic RMEs*. Both DAPs and AAPs can be created by multiple causes, such as demographic characteristics, physical disabilities, car ownership, and/or income levels.

Since variations between generic and relative RMEs are only due to the variability of non-motorised accessibility (retail activity indicators are kept as a constant), transformations from short-distance to motorised environments will facilitate the identification of DAPs for the respective population group. The same holds true for transformations from non-motorised to long-distance environments. The opposite transformations will facilitate the identification of AAPs (Fig. 5).

Special attention was paid to compare DAPs and AAPs between very and less vulnerable socio-economic groups. For the purpose of this research *the young unemployed* and *seniors* were considered as very vulnerable groups, due to their low-income levels, which make them more dependent of non-motorised transport modes. On the other hand, *the young employed* and *adults* were considered as less vulnerable groups, since they have medium to high income levels, which provide more opportunities to access other transport modes

Table 1
Non-motorised and retail activity indicators for generic and relative RMEs.
(Adapted from Arranz-López et al. (2017)*)*

Indicator	Equation	Description
Walking accessibility	$A_i = \sum_{dwi}(\Sigma_{j\neq i} E_j e^{-\beta x_{ij}})$ where A_i is the accessibility for zone i; dwi are the three retail typologies; x_{ij} is the travel time between zones i (origin) and j (destination), E_j is the number of shops in j and β is a parameter of the impedance function. Impedance function for generic RMEs is assessed for all individuals, while for relative RMEs is assessed for the groups identified.	$A_i \geq 0$ It represents the number of retail activity at each destination (cells) and the time-willingness of citizens to reach them. The origin-destination matrix was calculated using GIS, taking into account two core elements: (i) distance, expressed as street length; and (ii) travel speed, taken 4 km/h as average walking speed (Marquet & Miralles-Guasch, 2014) and 12 km/h average cycling speed, according to the bicycle's barometer for Spain).
Bicycling accessibility		
Betweenness	$B_i = \sum_{j,k\in G-\{i\};d[j,k]\leq r} \frac{n_{jk}[i]}{n_{jk}}$ where B_i is the betweenness for each retail store (i); n_{jk} is the number of shortest paths from retail j to retail k in G (study area); $n_{jk}[i]$ is the subset of these paths that pass through i, with j and k lying within the network radius r from i.	$B_i \geq 0$ It results from the topological relationship between retail activity and the street/bicycle network. Larger values mean a better location for retail.
Retail density	$Den = \frac{n}{a}$ where n is the number of retail in one cell, and a is the area of that cell.	$Den \geq 0$ It represents the intensity of retail activity in each cell, and it increases as the number of stores increase. The result for each cell was called Density Zone (DZ).
Retail diversity	$Div = \sum_{i=1}^{S} \frac{n_i}{N}$ Where S is the number of retail shops considered in the study; n_i is the number of retail stores of the type I; N is the total number of retail activities.	$Div \geq 0$ It represents the number of different types of retail in each cell. It increases as the variety of retail increase. The result for each cell was called Diversity Zone (DiZ).
Retail contiguity	$C_i = \bar{D}_{kj}$ where i is the cell, D is the distance between stores k and j.	$Cont \geq 0$ It represents the average distance from one store to all other retail in one cell on the street network. The result for each cell was called Contiguity Zone (CZ).

(e.g. private car). Finally, 26 semi-structured interviews with respondents from the four target groups were carried out in DAPs locations, to support the analysis via qualitative data on individual perceptions on reaching retail by non-motorised modes in those locations. All participants lived in the DAP locations under evaluation and were randomly selected. In total, four questions were asked. The first three questions concerned the ease to reach retail activity by both walking and cycling, as well as whether there were any types of retail (daily, weekly, and incidental) that were especially difficult to reach. These questions were scored on a five-point Likert scale. The last question inquired how participants perceive the shopping experience in DAP locations, soliciting an open-ended response. Semi-structured interviews were used to gain insight into DAPs characteristics, to confirm barriers to reaching retail by non-motorised modes, and to complement the analytical results previously obtained.

5. Results

5.1. Generic and relative RMEs

This section shows the spatial location of generic and relative RMEs (see Fig. 6 and Table 2). The results are detailed according to the different RMEs identified.

5.1.1. Short-distance environments

For generic RMEs, short-distance environments were mainly located in the oldest and traditional neighbourhoods and in the city centre, which have high or very high population densities (≥750–1000 dwellings/Ha.). They were places where daily, weekly, and incidental retail activity could be easily found, as these locations are used by everyone in Zaragoza, rather than only by the residents of these neighbourhoods. For relative RMEs, short-distance environments presented the largest geographical extension for *the young employed* and the least for *the young unemployed*, while *seniors*, and *adults* were in between. As for generic RMEs, it had a continuous spatial distribution in the city centre (e.g., *Casco Histórico* and *Centro*) for the four population clusters. However, differences were found in traditional neighbourhoods (e.g., *Las Fuentes*, *Casablanca*), where short-distance environments appeared more frequently for *the young employed* and *seniors* than for *the young unemployed* and *adults*.

5.1.2. Non-motorised environments

For generic RMEs, these places were identified with parks or public amenities, such as the university campus, the bullring, and Aljafería Palace. Retail activities are very limited in this type RME. In the case of relative RMEs, non-motorised environments presented a wider spatial spread for *the young employed* and the least for *the young unemployed.* Again, *seniors*, and *adults* were in between. Variations by neighbourhoods for non-motorised environments between groups of population were negligible. Only in the *Centro* and *Almozara* neighbourhoods, close to the riverside, this relative RME had a further extension for *the young employed.*

5.1.3. Motorised environments

For generic RMEs, this typology was seen as a transition area between short-distance and long-distance environments. In those places, the density of dwellings is between 500 and 750 dwellings/Ha., and weekly and incidental retail dominate. Residents could cover their daily needs, but in most of cases motorised modes are required. Motorised environments followed similar spatial patterns for relative RMEs, excluding *La Jota*, *Las Fuentes*, and *San José* neighbourhoods, where this RME had a strongest presence for *the young unemployed*, *adults*, and *seniors* than for *young employed.*

5.1.4. Long-distance environments

Regarding its spatial distribution in Zaragoza for generic RMEs, two significant locations are noted: (i) the edge of old neighbourhoods, such as *Las Fuentes* and *San José*; and (ii) new urban developments, such as *Rosales del Canal*, *Valdespartera*, and *Miralbueno*. Both locations are residential areas close to ring roads. In the case of relative RMEs, long-distance environments showed similar geographic spread. *Young unemployed* presented the largest geographical extension, but closely followed by adults, seniors, and young employed. However, they varied for each group between neighbourhoods. For example, in *Parque Goya* long-distance environments returned higher values for *the young employed* than for *the young unemployed*, while the opposite was the case in *Parque Venecia.*

Fig. 3. Retail Mobility Environments scheme. Adapted from Arranz-López et al. (2017).

5.2. Social and spatial effects of RMEs

This part examined the variations between generic and relative RMEs, to determine the spatial benefits of distribution of non-motorised accessibility, paying special attention to the comparison between very and less vulnerable groups. The accessibility benefits for each socio-economic group were measured through the balance between DAPs and AAPs, which determined advantages and disadvantages. For each target group, DAPs and AAPs (see Fig. 7 and Table 3) revealed access inequalities throughout Zaragoza. In general, it was observed that *the young unemployed* and *adults* shared very similar patterns for DAPs, while *the young employed* and *seniors* had similar distributions for AAPs.

The young unemployed, as a very vulnerable group, were the target group in which DAPs were more present. Neighbourhoods such as *La Jota* and *Universidad* were particularly affected. In the case of *La Jota*, DAPs were concentrated in the outskirts of the neighbourhood where retail activity is limited. During semi-structured interviews, participants confirmed that they perceived non-motorised access to traditional groceries as difficult or very difficult. As a result, *the young unemployed* with low-income levels chose supermarkets to cover their daily needs, and they shopped once per week or every fortnight, being forced to use a car[2] to reach retail destinations, bearing an extra domestic expense. In addition, *the young unemployed* from *La Jota* were closer to 40–44 years of age, with lower income and education levels than the city average. Adding up all these factors points to a risk of social exclusion, especially in terms of their ability to meet their basic needs (e.g. access to daily food stores). It is worth mentioning that some *young unemployed* also declared during the semi-structured interviews that they perceived retail as easy to reach before losing their jobs during the economic crisis. This can be explained by the fact that they stopped using their motor vehicles. As a result, they experienced non-motorised environments more frequently, resulting in a worse perception of non-motorised accessibility levels due to increased exposure. Looking at the *Universidad* neighbourhood, DAPs were identified in the north-west of that area. In this case, the population's income and educational levels are higher than the city average, and *the young unemployed* were also identified with student lifestyles. They usually did not have widespread accessibility to motorised modes, and they went shopping every two to three days due to their inability to transport heavy loads. But the most significant aspect was that *the young unemployed* from *Universidad* did not mind walking longer distances to reach

[2] During the semi-structured interviews, which were made in DAPs of traditional neighbourhoods, people referred to the lack of access to daily retail (e.g. groceries, supermarkets). Since they declared that they did not use public transport to reach daily retail locations, it has not been included in the qualitative analysis.

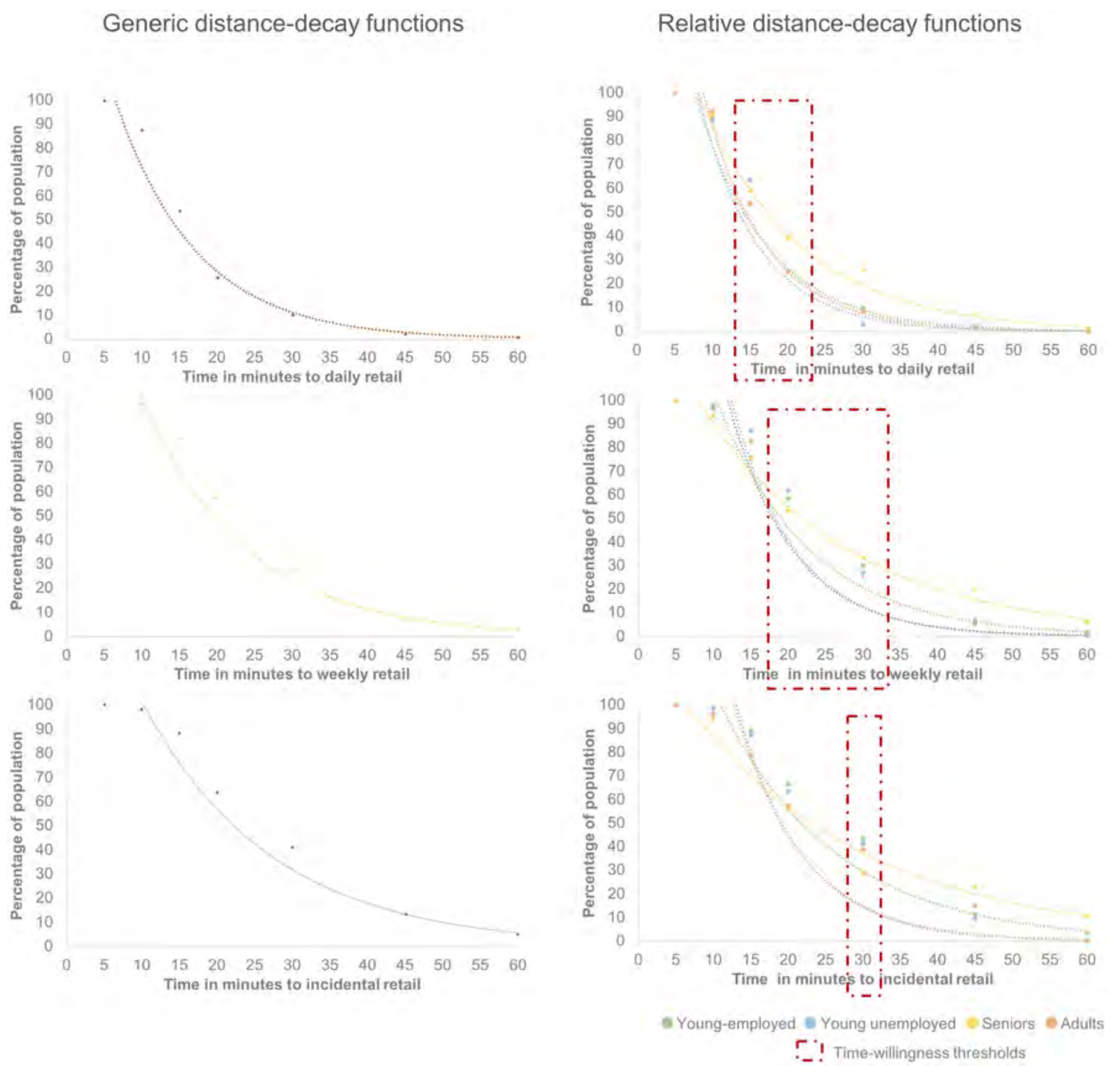

Fig. 4. Walking distance-decay functions for generic RMEs (on the left) and relative RMEs (on the right).

other types of retail (e.g. clothes, technology), since they perceived it as a leisure time.

Seniors were the other very vulnerable population group, but they were three times less affected by DAPs than *the young unemployed*. DAPs were identified to a larger extent in *Las Fuentes*, *San José*, *Centro*, and *Torrero-La Paz*, all of them with densities of the population over 65 years of age higher than the city average. The most unfavourable conditions were found in *San José* and *Torrero-La Paz*, where traditional daily retail has disappeared in favour of supermarkets in the last few years. Semi-structured interviews revealed that *seniors*, who generally did not have access to motorised modes, had to walk longer distances to cover their basic needs, supposing an extra physical effort for people with potential physical deficiencies. Consequently, in some cases *seniors* needed to employ someone to help them with their daily tasks related to retail accessibility. Furthermore, they supported the revitalisation of traditional food stores (e.g. butchers, greengrocers), since they perceived them as a socialisation space as well as a source of higher quality products. Nevertheless, some of the interviewed *seniors* perceived walking as a healthier option and did not mind walking longer distances to reach retail stores. Regarding AAPs for this population group, they were heavily concentrated in the *Actur* and *Delicias* neighbourhoods. In the case of *Actur*, the concentration of the over-65 population was generally lower than the city average. As a result, despite the positive impact of AAPs on *seniors*, given their status of vulnerable group, AAPs will become especially relevant when adults from *Actur* become seniors. Therefore, it is important to maintain high levels of non-motorised accessibility. However, AAPs in *Delicias* were identified in the west of the neighbourhood, where there is a high density of populations over 65 years of age. Considering that these areas display income and educational levels lower than the city average, the presence of AAPs resulted in improved mobility of this vulnerable group and a reduction in inequalities of access to opportunities.

The young employed, as a low vulnerability group, were the target group with least number of DAPs. They were mainly found in *Torrero-La Paz* and *Oliver-Valdefierro*. In the case of *Oliver-Valdefierro*, with income levels over the city average but educational levels lower than the city average, large supermarkets could mainly be reached on motorised transport modes. *The young employed* declared during the semi-structured interviews that they had to spend more time to meet their basic needs, especially if they had small children. They also declared that, given their limited time due to their jobs, some of them tend to do their daily shopping on the Internet, which resulted in user comfort but also in an additional expense. Regarding AAPs, they were mainly found in traditional neighbourhoods such as *Actur*, *La Jota*, *Las Fuentes*, *Delicias* and *Casco Histórico*. In the specific case of *Las Fuentes*, *the young employed* perceived reaching retail as easy or very easy. They found that the retail supply was good, but they

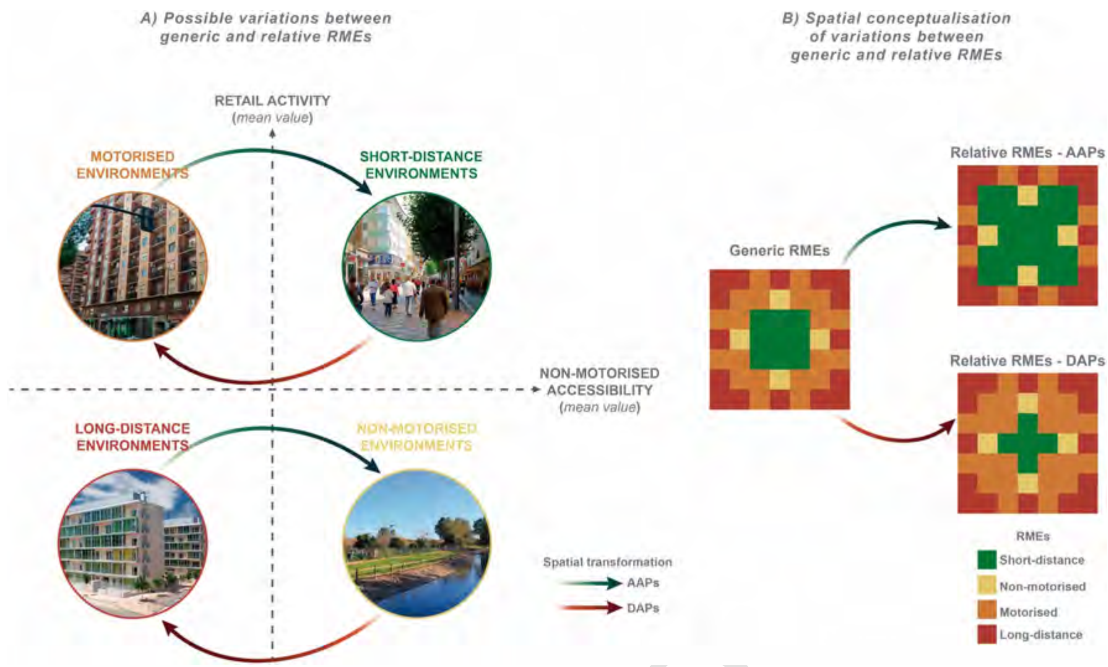

Fig. 5. Identification of DPAs and AAPs through variations in generic and relative RMEs.

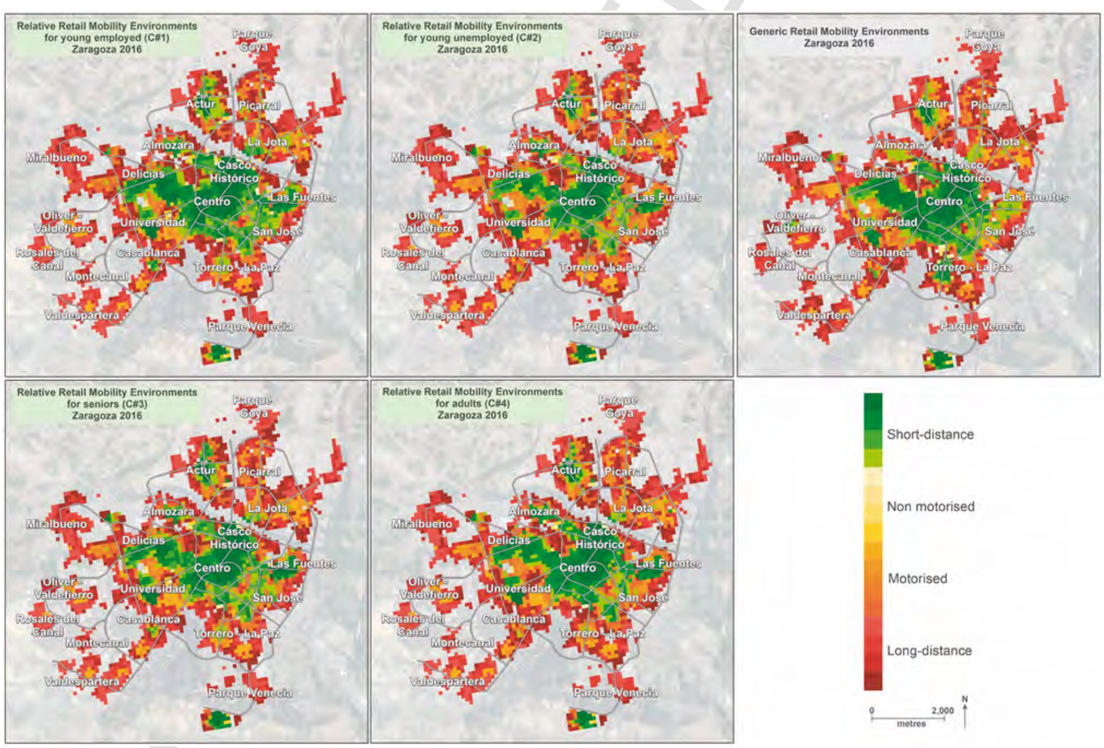

Fig. 6. Relative and generic RME.

would like to have some more specialised shops (e.g. food, bookshops). Special attention should be paid to *Casco Histórico*, where AAPs ensured access in a neighbourhood with a significant immigrant population, which has lower income and lower educational levels than the city average.

Adults were a less vulnerable group with a greater number of DAPs. When looking into neighbourhoods, *San José* and *Torrero-La Paz* were the most affected, and to a lesser extent *Almozara*. The semi-structured interviews revealed that *adults* did not perceive their own neighbourhoods as meaningful and dynamic places for their shopping needs. Therefore, they preferred to go shopping in different neighbourhoods, even in other municipalities close to Zaragoza, generally after their job. For example, in the case of *Torrero-La Paz* they found it difficult to access all kinds of retail activities, especially daily shopping for food. As a result, they showed preference for medium-size and large-size commercial surfaces (e.g. supermarkets, mall centres) where they can find all kinds of goods (e.g. food, clothes, leisure). This meant a heavy reliance on motorised transport

Table 2
Extension in Ha. for generic and relative Retail Mobility Environments.

Mobility environment	Generic RMEs (Ha.)	Relative RMEs (Ha.)				Description
		Young employed	Young unemployed	Seniors	Adults	
Short-distance	819	907	703	799	738	• Mainly located in the city centre • High supply of daily, weekly, and incidental retail • Public places and parks
Non-motorised	47	52	21	30	25	• Some retail can be found
Motorised	503	616	584	520	415	• Motorised modes dominate
Long-distance	1439	1435	1469	1460	1462	• Lack of retail activity • City outskirts

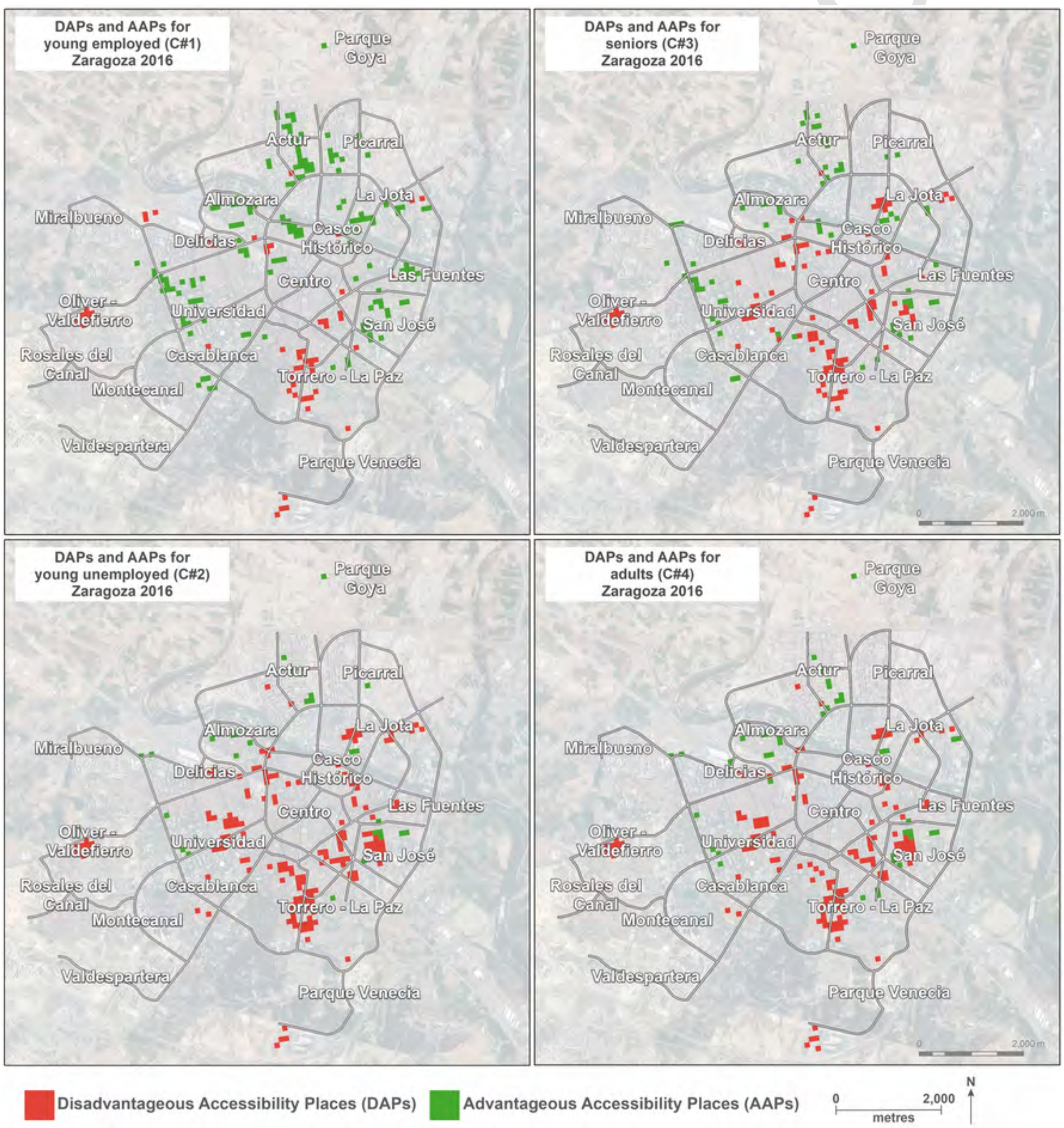

Fig. 7. DAPs and AAPs for the four socio-economic groups.

modes for meeting their retail needs. For these reasons, inequities in non-motorised accessibility for *adults* could remain in the mid- and long-term. Regarding AAPs, they appeared to be both scarce and scattered throughout the city, and adults did not perceive them as advantageous places for shopping (maybe due to their easy access to motorised modes).

6. Discussion and conclusions

This paper has presented a methodological framework for evaluating the social and spatial equity effects of how non-motorised accessibility is distributed between different population groups, with

Table 3
Extension in Ha. for DAPs and AAPs.

	DAPs (Ha.)	AAPs (Ha.)	Description
Young employed (C#1)	56	149	• Group with more AAPs and less DAPs • DAPs concentrated in *Torrero-La Paz* and *Oliver-Valdefierro* • AAPs scattered throughout the city. High concentration in *Actur* and *Casco Histórico*
Young unemployed (C#2)	158	29	• Group with less AAPs and more DAPs • DAPs concentrated in *Torrero-La Paz San José* and *Las Fuentes*, and *Oliver-Valdefierro* • AAPs scarce, without significant concentrations
Seniors (C#3)	114	72	• DAPs concentrated in *Torrero-La Paz* and *Oliver-Valdefierro* • AAPs concentrated in *Actur*, *Las Fuentes*, and *San José*
Adults (C#4)	136	43	• DAPs concentrated in *Torrero-La Paz*, *Oliver-Valdefierro*, and *La Jota* • AAPs concentrated in *Almozara*

the city of Zaragoza, Spain as a case study. To address this issue, generic and relative Retail Mobility Environments were identified and compared, resulting in the identification and mapping of disadvantageous (DAPs) and advantageous non-motorised accessibility places (AAPs). Based on the analysis of the obtained results, the following findings can be highlighted:

- *Analysis of spatial inequalities*: The use of RMEs, as the methodological basis for assessing social effects, incorporates spatial issues in the core of the debate on transportation and social equity from the very beginning (Van Wee and Geurs, 2011), in contrast to other studies where the social aspects are dominant (Farber et al., 2014; Ricciardi et al., 2015; Xia et al., 2016). That is a crucial issue, location of geographical areas where inclusive policies (e.g. subsidies for establishing retail) can be physically implemented. Our research identified and geographically defined and mapped these locations (DAPs and AAPs) (Fig. 7). Moreover, each identified DAP and AAP was related to one particular population group (*the young unemployed*; *the young employed*, *adults* and *seniors*), which can facilitate a customised policy-making process for population groups under risk of social exclusion. Furthermore, semi-structured interviews completed in DAP locations confirmed the social exclusion risk of some of that places.
- *Identification of accessibility thresholds*: This research provides a specific method to incorporate accessibility thresholds into studies on equity and transportation, thereby addressing one relevant research challenge (Guzman et al., 2017; Lucas et al., 2016c; Pereira et al., 2016). The thresholds were based on analysing significant differences in time-willingness to reach retail by non-motorised modes for different population targets groups (see Section 4.2). The noted differences in time-willingness were operationalised through the use of generic and relative RMEs, which in turn identified specific DAPs and AAPs. This provides a very useful tool for transport policymaking, since it enables the detection of the key value of time-willingness as a reference for both identifying population groups at risk of social exclusion and for testing the effectiveness of implemented policies.
- *Establishing minimum accessibility requirements*: Generic RMEs were adopted as the minimum accessibility requirement. Despite previous studies have also established minimum requirements (see Lucas, 2012; Lucas et al., 2016b; Martens et al., 2012; Páez et al., 2010a,b), generic RMEs supposed a step forward for three main reasons. First, generic RMEs represented the willingness of the population to reach retail activities across the entire city. This was accomplished by considering the average time-willingness to reach retail by non-motorised modes at city level. Second, generic RMEs are the result of the current policy implementation related to non-motorised accessibility and retail activity, and it is assumed that policymakers are interested in distributing accessibility equally between individuals. Nevertheless, generic RMEs did not represent the optimal accessibility landscape for the full spectrum of the population. Third, generic RMEs do not provide normative criteria for the city of Zaragoza, but they are a baseline showing the impact of local policies aimed at improving non-motorised accessibility to retail.
- *Linking non-motorised accessibility to social issues in transportation*: While non-motorised modes are crucially important due their universal accessibility to all population groups, most studies on transportation and social equity tend to focus on motorised modes (Delbosc & Currie, 2011; Dodson et al., 2010; Paez et al., 2012). This research highlights the importance of examining non-motorised accessibility when studying equity and social issues in transportation. Furthermore, the paper is specially focused on relating non-motorised accessibility to retail because they are two fundamental aspects for daily life of citizens.
- *Policy implications*: One of the major responsibilities of transport policy-making should be to guarantee a fair distribution of accessibility to key destinations. Since the identified DAPs and AAPs are accessibility units spatially differentiated, they can provide transport policy-makers with additional knowledge to assess the social equity impacts of past/future policy interventions located in specific places (Banister, 2018; Geurs & van Wee, 2004). In particular, the methodology presented in this research provides additional insights into how to identify specific places where the transport systems need to be reviewed. Some examples of practical questions triggered from DAPs and AAPs with high impact on policy-making can be: *to what extent is a place identified as DAP too car-oriented, and why? are the existing pedestrian infrastructure in DAPs enough, and why? are DAPs the direct result of applying policies that do not assume the relative nature of transport accessibility, and to what extent that can be avoided?* To address those questions could guide policy-makers to implement fairest economical investments in order to implement policies that work for everyone or at least for the majority of social groups.

Regarding *limitations and further paths*. First, the calculation of the minimum accessibility requirements, here based on the existing accessibility levels, can be beneficiary to include several levels of participation between the public and stakeholders about the shopping process and its travel characteristics. Second, the effects of e-shopping are not considered in this work, including whether individuals do e-shopping (or not), the frequency they do it, and the capacity of e-shopping to substitute partially or totally physical trips affecting to RME configuration. For example, an increase of e-shopping, could suppose a challenge for transport and urban planners, since travel behavior to retail could be altered modifying the city landscape. It is worthy to mentioning the need for translating the more abstract ethical arguments of fairness into the empirical methodologies. That would allow to bring accessibility measures closer to other dimensions of social exclusion (e.g. economic, societal, social networks), resulting in a more complex but also understandable results for different professional domains that take part during the planning process.

Uncited reference

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