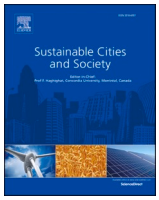
Sustainable Cities and Society 119 (2025) 106096

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs



Can proximity forge strong bonds? Exploring the relationship between urban proximity and social cohesion at the neighbourhood level

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ARTICLE INFO

Keywords:
Urban proximity
Urban design
15-minute cities
Social cohesion
Sustainable and resilient cities
People and environment
Urban structure
Structural equation modelling

ABSTRACT

Urban proximity has recently regained prominence in urban and transport planning. While the environmental and health benefits of increased proximity are well documented, its social implications, particularly in relation to social cohesion, remain under-researched. This is important because social cohesion is often associated with increased community resilience and societal stability. While previous research has examined how features of the built environment affect social cohesion, few studies have isolated the impact of proximity to daily destinations. We address this gap by integrating objective and subjective measures of proximity to daily destinations and assessing their impact on neighbourhood social cohesion. Using survey data on social cohesion and perceived proximity, together with georeferenced data on destination distances in five Spanish cities, we apply an SEM approach to analyse the relationship. The results indicate a negative relationship between distance to destinations and social cohesion, mediated by perceptions of proximity. This means that the impact of distances to destinations over social cohesion is stronger when destinations are perceived to be closer or further than they actually are. Urban planners and policymakers should consider objective and subjective measures of proximity and focus on equitable access to essential services to promote community cohesion.

1. Introduction

In recent years, the notion of urban proximity has experienced a resurgence in urban and transport planning discourses and policies. In its contemporary conceptualisation, urban proximity is understood both as geographical proximity, indicating the location of people, services, and activities close to each other, and as temporal proximity, expressing the time it takes people to reach these amenities (Moreno et al., 2021; Marquet et al., 2024). This revival of urban proximity extends beyond academic circles, as cities worldwide are increasingly adopting proximity planning approaches to address spatial and transport inequalities (Ferrer-Ortiz et al., 2022; Khavarian-Garmsir et al., 2023; Megahed et al., 2024). Proximal urban environments are associated with positive environmental, health, and social outcomes. While the link between urban proximity, environmental sustainability, and health benefits is well documented in the scientific literature (Neves & Brand, 2019; Vich et al., 2019; Allam et al., 2022a), the social impacts whether positive or negative, of proximity planning have been largely been theorised and remain to be tested.

Social cohesion is often studied in relation to urban environments. Social cohesion refers to the interdependence, shared bonds and solidarity between members of society (Durkheim, 1893) and has been associated with various benefits, including increased community resilience (Aldrich & Meyer, 2015). According to Schiefer and Van der Noll (2017), social cohesion encompasses three subdimensions: social relations, orientation towards the common good, and attachment and belonging. Of these, attachment and belonging, which refers to individuals viewing the group as an integral part of their identity, is of particular interest given its strong dependence on how individuals relate to their urban environment (i.e., the neighbourhood).

To date, a number of studies have examined how characteristics of the built environment, such as density, diversity, design, and walkability, can influence social cohesion (Mazumdar et al., 2018). However, only a handful of them have specifically isolated the impact of proximity to destinations on social cohesion. These studies have often chosen to limit their focus to analysing distance to specific destinations, such as

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https://doi.org/10.1016/j.scs.2024.106096
Received 9 July 2024; Received in revised form 28 October 2024; Accepted 19 December 2024
Available online 22 December 2024

parks, sports facilities, or retail spaces (Lund, 2003; Jennings & Bamkole, 2019; Clarke et al., 2023; Yang at al., 2023). Furthermore, urban proximity is often analysed only from a spatio-temporal perspective, without considering the subjective measures of proximity that can help to understand the evolving relationships between people, built environments and open spaces (McCormack et al., 2008; Brennan & Martin, 2012; Guzman, Oviedo, & Cantillo-Garcia, 2024). As a result, there is still a lack of systematic empirical evidence to support the idea that proximity to amenities can effectively promote more socially cohesive communities. This is particularly true with regard to (1) our understanding of the relationship between proximity to destinations that encompass all essential urban functions and social cohesion, and (2) whether this relationship is mediated by community members' perceptions of proximity.

Therefore, we aim to integrate objective and subjective measures of proximity to daily destinations and assess the influence of urban proximity on social cohesion at the neighbourhood level. To this end, we use survey data measuring social cohesion and perceptions of proximity as well as georeferenced data measuring distance to destinations in five Spanish cities (Madrid, Barcelona, Valencia, Palma de Mallorca, and Granada). We then use partial least squares structural equation modelling (PLS-SEM) to statistically analyse the relationship between proximity and social cohesion, mediated by perceptions of proximity.

We begin by reviewing the relevant literature on how urban proximity and social cohesion have been conceptualised and measured, and how the two concepts have been analysed together (Section 2: Theoretical background). We then look at the data sets and the PLS-SEM framework used to test the relationship between the variables under study. (Section 3: Data and methodology). We present the results of our statistical analysis (Section 4: Results). We then discuss these findings and their implications for urban policy and planning (Section 5: Discussion). Finally, in the concluding remarks, we discuss the limitations of the research and avenues for future research (Section 6: Conclusion).

2. Theoretical background

2.1. Theory and measurement of urban proximity

The concept of urban proximity has deep roots in urban planning movements. Its early advocates emphasised the role of urban proximity in fostering community engagement (Perry, 1929; Jacobs, 1961). Similarly, Oldenburg and Brisset's concept of "third places" (1982) advocated for inclusive spaces for social interaction beyond the home and the work, while the New Urbanism movement championed dense, walkable, and mixed-use cities (Haas, 2008). More recently, urban proximity has been framed as a fundamental pillar of Carlos Moreno's strategy for the 15-minute city - an urban planning model that proposes the (re)design of polycentric cities that allow everyday destinations to be reached within a 15-minute walk or bike ride (Moreno et al., 2021; Moreno, 2022). The 15-minute city approach represents the latest, and arguably more widespread, shift away from mobility-centred planning (i.e., centralised services, motorised transport) towards proximity-enhancing planning (i.e., decentralised services, active modes of transport) (Silva et al., 2023).

In this new understanding, proximity-centred environments are often tasked with responding to environmental, health, and societal challenges. The link between urban proximity, environmental sustainability and health is well documented in the scientific literature (Newman & Kenworthy, 1989; Ewing et al., 2011; Capasso Da Silva et al., 2020). Studies have shown how proximal environments promote the adoption of low-carbon transport modes (Marquet & Miralles-Guasch, 2015a; Neves & Brand, 2019; Allam et al., 2022a) and how proximity to amenities, such as green spaces (Sturm & Cohen, 2014; Vich et al., 2019; Orstad et al., 2020; Buffoli & Rebecchi, 2023; Cardinali et al., 2023) and sports facilities (Anzaldua, 2009; Leite et al., 2024), affect mental and physical health.

Proximity environments have also been associated with social sustainability. Some authors (Bibri, 2021; Allam et al., 2022b; Longo et al., 2022; Khavarian-Garmsir et al., 2023) focus on the potential positive outcomes, such as greater equity in access to amenities and reduced transport costs. Other authors warn of the trade-offs between social and environmental goals of proximity (Abbiasov et al., 2024). Proximity-centred environments could increase property values in densely populated areas with good transport links, thereby exacerbating social inequality (Lobner et al., 2021; Pozoukidou & Chatziyiannaki, 2021; Casarin et al., 2023). However, with the exception of a few studies linking urban proximity to housing prices (Yang et al., 2018; Tong et al., 2023; Trichês Lucchesi et al., 2023; Villar-Abeijón et al., 2024) and research by Abbiasov et al. (2024), showing that the use of local amenities correlates with increased segregation of low-income residents, the social effects of urban proximity have so far only been theorised and are yet to be fully explored.

Despite this lack of empirical knowledge, cities worldwide are increasingly supporting proximity planning strategies to address spatial and transport inequalities (Ferrer-Ortiz et al., 2022; Khavarian-Garmsir et al., 2023; Megahed et al., 2024). Municipalities such as Paris, Melbourne, Portland, and Shanghai, have given different names to these initiatives, such as *"ville de quarte d'heure"*, 20-minute city, complete neighbourhoods, or "*15-minute Community Life Circle*", among others. In Spain, notable examples include Barcelona's "*superilles"* (superblocks), Palma de Mallorca adoption of the 15-minute city principle, Valencia's announcement of its first superblock project, and the plans of Madrid and Granada. These policies are often based on assumptions rather than evidence-based research. Thus, it is crucial for the academic literature to tap into the unmeasured social dimension of urban proximity.

2.1.1. Objective and subjective measurement

When evaluating the impact of proximity planning, the question of which dimension of proximity to measure—whether spatial or temporal, perceived, or a combination—is not trivial. Focussing on x-minute cities, Megahed et al. (2024) reviewed common objective measures of proximity and found a prevalence of the point of interest (POI) catchment area approach. This spatio-temporal method uses geographic information systems (GIS) to analyse the coverage areas of services. It calculates the walking distances from service locations, marked as origin points, to all buildings in the study area, marked as destinations. A pedestrian street network is established and buffers walking distances (e.g., 10, 15 or 20 min) are defined. Proximity to amenities is then assessed based on these buffers (Monteiro et al., 2023). Other methodologies include the origin-destination approach, building catchment area, network-based methods, index-based methods, and mixed approaches (Megahed et al., 2024).

However, there are limitations to relying solely on objective proximity (Van Der Vlugt et al., 2022; Pot et al., 2021; Orrego-Oñate & Marquet, 2024). These limitations are rooted in the divergence between calculated proximity and individual perception. Therefore, several studies have opted to use perceptions of proximity as a substitute or a complement to objective measures of proximity. Proponents of this additional level of understanding argue that proximity to amenities should not be evaluated solely on the basis of concrete factors such as time, distance, and other spatial data, but rather within its contextual framework (McCormack et al., 2008; Brennan & Martin, 2012; Guzman et al., 2024). People might perceive everyday destinations as being closer or farther away than they actually are, depending, for example, on the relative importance assigned to those destinations or on the frequency of visits. In simple terms, individuals may perceive a 15-minute walk to a hospital as close, but a 15-minute walk to the grocery store as farther away. In addition, socio-demographic intersectional characteristics must be considered, as they influence the way in which distances are perceived by individuals. To date, studies have focused on perceived proximity in older and disabled adults (Levasseur et al., 2011), older adults with low socio-economic status (Chen et al., 2016), children

(Giuffrida et al., 2024) and different genders (Gil Solá & Vilhelmson, 2022).

With the exception of Guzman et al. (2024), who analysed both perceived and objective proximity to several destinations, most of the literature incorporating measures of perceived proximity has focused on access to parks (Lackey & Kaczynski, 2009; Moore & Kestens, 2011; Moran et al., 2020; Phillips et al., 2023). In terms of methodology, all the studies use survey data to assess perceived proximity.

2.2. Theory and measurement of social cohesion

The intellectual origin of the concept of social cohesion can be traced back to the work of Émile Durkheim (1893). Durkheim conceptualises social cohesion as the interdependence, shared loyalties, and solidarity between members of society (Durkheim, 1893). Over the years, the notion of social cohesion has been appropriated by a variety of disciplines (psychology, sociology, urban studies, public health, among others), applied to different societal scales, and studied using different methodological approaches (theoretical insights, experimental studies, and, more recently, social network analysis) (Fonseca et al., 2019). In the urban sphere, social cohesion is often seen as a key element in addressing contemporary challenges (Stigendal, 2010; Moustakas, 2023). Social cohesion has been studied in relation to environmental sustainability (Uzzell et al., 2002), health outcomes (Mulvaney-Day at al., 2007; Cradock et al., 2009; Kawachi & Bergman, 2015; Mepparambath et al., 2024), and community resilience and well-being (Aldrich & Meyer, 2015; Delhey & Dragolov, 2015). However, scholars also warn that social cohesion is a quasi-concept to which researchers or policymakers can attach their own interpretations or values (Bernard, 1999).

To limit the scope of this study, we adopt the definition and framework of social cohesion proposed by Schiefer and Van der Noll (2017). Social cohesion is thus defined as "a descriptive attribute of a collective, indicating the quality of collective togetherness" (Schiefer & Van der Noll, 2017, p. 17). The authors align to an essentialist framework (Chan et al., 2006; Green & Janmaat, 2011) that views social cohesion as a multidimensional construct consisting of three subdimensions: (1) social relations, consisting of social networks, participation, trust, and mutual tolerance; (2) attachment and belonging; and (3) orientation to the common good, which includes feelings of responsibility, solidarity, and acceptance of and compliance with social order and rules. Since attachment and belonging, defined as the self-perception of the group as an integral part of one's self-identity (Schiefer & Van der Noll, 2017), is the dimension most closely related to the relationship between people and place (i.e., the neighbourhood), this study focuses on this subdimension.

Given the conceptual overlap, the McMillan and Chavis's (1986) theory of sense of community can serve as a proxy for measuring attachment and belonging. Sense of community is defined as a combination of four elements: (1) group membership (sense of belonging), (2) influence (sense of mattering), (3) needs fulfilment (sense that needs are being met), and (4) emotional connection (belief in shared history, places, and time) (McMillan & Chavis, 1986). The concept captures the collective value of the attachments that individuals have to their social milieu, experienced in geographical entities (French et al., 2013). This theory provides an empirically measurable framework through Peterson et al.'s (2008) Brief Sense of Community Scale (BSCS).

2.3. The link between urban proximity and social cohesion

A growing body of literature argues that the study of urban proximity can no longer be concerned only with the spatiotemporal dynamics of people's access to spatially distributed services, but must also consider the relationships that develop between people, built spaces, and open spaces (Fior et al., 2022; Longo et al., 2022). Therefore, a key question is how to plan, build and manage more cohesive socio-environmental urban spaces (Swyngedouw & Cook, 2012).

Among these spaces, the neighbourhood is the spatial context in which people meet their basic needs and interact with each other. This dual function strengthens an individual's attachment to a place and sense of community (Mahmoudi Farahani & Lozanovska, 2014). If residents feel connected to their neighbourhood, they are more likely to use local facilities in their daily lives rather than travelling further afield. Similarly, when the place where people spend most of their time is perceived as positive, they tend to form deeper emotional bonds with the community (Gil Solá & Vilhelmson, 2019).

A recent literature review by Mazumdar et al. (2018) highlights the growing interest in the interaction between social and physical infrastructure at the neighbourhood level. Research has focused on assessing the relationship between measures of social cohesion and built environment characteristics such as density (Skjaeveland & Garling, 1997; Brueckner & Largey, 2008; Hanibuchi et al., 2012; French et al., 2013), diversity (Lund, 2003; Wood et al., 2010), design (Kim & Kaplan, 2004; Nguyen, 2010; Podobnik, 2011), and destinations (Du Toit et al., 2007; Rogers et al., 2011, 2013; Leyden & Goldberg, 2015). The results reveal a correlation between social cohesion and the built environment, generally positive with accessibility to destinations/walkability, design, and diversity, and negative or inconclusive with density. Later studies have also explored these relationships, focussing on walkability, measured objectively (Sonta & Jiang, 2023) or by a combination of objective and perceptual measures (Hua et al., 2022), low (Abass et al., 2019) and high density (Koohsari et al., 2021), and urban vitality (Mouratidis & Poortinga, 2020).

However, previous studies on proximity to destinations have often conflated the concept of proximity with neighbourhood walkability or limited the scope of destinations analysed, particularly to green spaces (Jennings & Bamkole, 2019; Clarke et al., 2023; Yang at al., 2023), libraries (Johnson, 2010), and retail spaces (Lund, 2003). Thus, there is still a lack of systematic empirical evidence to support the notion that proximity environments can effectively foster more socially cohesive communities. This research aims to address this gap by integrating objective and subjective measures of proximity to essential daily destinations to measure social cohesion at the neighbourhood level.

3. Data and methodology

This section presents the datasets and modelling approach used to explore the relationship between urban proximity, perceived proximity, and social cohesion, while controlling for socio-demographic variables. We hypothesise that (1) there is a significant relationship between the walking distance to everyday destinations and social cohesion, and that (2) this relationship is mediated by the perceptions of proximity of community members.

3.1. Study area and data sources

The study focuses on five Spanish cities: Madrid, Barcelona, Valencia, Palma de Mallorca and Granada. The cities were selected based on the availability of data and the similarity of their urban morphology (Mombelli et al., 2024). The compact and walkable urban layouts of these cities provide an appropriate context for examining the relationship between proximity and social cohesion.

The study uses three sources of data (Fig. 1). We gather data charting the proximity to daily destinations in the selected cities. These data are then combined with survey data measuring social cohesion and perceived proximity. Both data sources are geographically specified at the level of the individual's place of residence. This geographical scale provides precise information on how close individuals are to basic services and amenities. We obtain socio-demographic data from the aforementioned survey and from census track data from the Spanish National Statistics Institute (INE).

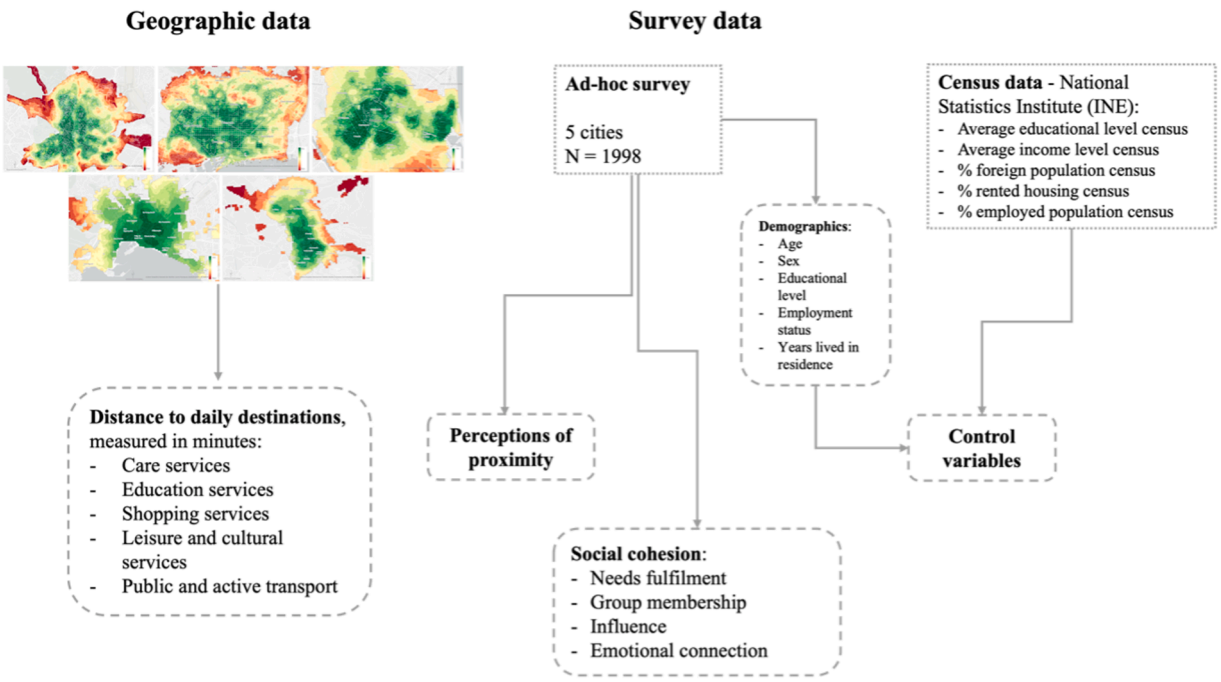

Fig. 1. Overview of data sources.

3.1.1. Distance to daily destinations

We calculate the spatial distribution of 25 destinations and group them into urban functions. These functions are care, education, shopping, leisure and culture, and public and active transport (Table 1).

For each city, we obtain the location of facilities from municipal databases, transport entities, and chambers of commerce. For the categorisation of shopping services, we rely on the Census of Economic Activities, which identifies both food and non-food businesses. We exclude activities serving mainly non-residents and occasional users, such as souvenir shops, business services, and wholesalers. Only urban areas are considered, using cadastral urban boundaries to exclude rural areas.

To obtain the spatial distribution, the following geoprocessing method is used. For each city, we create an orthogonal grid with a spatial resolution of 100 x 100 metres. We map the road network, using Open Street Map (OSM), version 2022 data, and compute travel times using a pedestrian-friendly city grid, that includes pavements, pedestrian crossings, and paths in parks. Motorways, cycle paths, and other non-pedestrian infrastructure are excluded. We use an impedance of 5 km/h, which reflects the average walking speed of a typical adult in an urban environment. The shortest routes are chosen, with calibration assistance from Google Maps.

A "service area" is defined for each of the 25 destinations. We set the maximum travel time to 120 min, as the maximum time to reach the destinations on foot. The resulting areas represent the shortest walking distance calculated by the street configuration. These times are then used to calculate the average times to access the urban functions. Table 2 provides a summary of the variables.

Table 1
Urban functions and destinations used to calculate walking access time.

Urban Functions	Destinations
Care services	Health centres, social services, day care centres
Education services	Nurseries, schools, colleges
Shopping services	Supermarkets, markets, fresh food, daily non-food shopping, Catering, various services
Leisure and cultural services	Civic centres, libraries, theatres and cinemas, playgrounds, Sports facilities, gyms, parks under 1,000m2, parks over 1,000m2
Public and active transport	Day bus stops, night bus stops, railway stations, bike-sharing stations, cycling infrastructure

3.1.2. Survey and census data

An ad hoc telephone survey was conducted among 1998 participants living in the selected cities. The survey questionnaire consists of two blocks of questions, one designed to measure social cohesion at the neighbourhood level, and the other focusing on perceptions of proximity. The questions used to assess social cohesion were adapted from the eight-item Brief Sense of Community Scale (BSCS) developed by Peterson et al. (2008), which serves as a proxy to measure the attachment and belonging aspects of social cohesion (Schiefer & Van der Noll, 2017). All questions on social cohesion are measured on a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The exceptions are the question on neighbourhood satisfaction, which ranges from very dissatisfied (1) to very satisfied (5), and the question on outsiders' assessment of the neighbourhood, which is coded from very negative (1) to very positive (5). We use another block of survey questions to assess perceptions of proximity. Participants were asked to rate their proximity to various destinations, including work or school, regular place for everyday shopping, regular place for occasional shopping, restaurants, friends and family, primary care services, hospitals, schools, cultural facilities, green spaces, and gyms and sports facilities. The questions use a five-point Likert scale from very distant (1)

Table 2
Summary of urban proximity variables.

Variable name	Minimum	Maximum	Mean	Standard deviation
Time to access care services*	0	105	12.8	11.2
Time to access education services*	0	103	7.2	6.9
Time to access shopping services*	0	100	8	9
Time to access leisure and cultural services*	0	69	10.4	8.3
Time to access public and active transport *	0	70	6	7.2

* Time in minutes.

to very near (5).

Finally, the survey includes socio-demographic information on sex, age, education level, employment status, and years lived in the current residence, which are used as control variables. We assign additional socio-demographic information to each respondent, based on their home address. These census data come from the Spanish National Statistics Institute (INE) and include average education, average income, percentage of rented dwellings, percentage of employment, and percentage of foreign population in the census area. Table 3 shows a summary of the variables.

3.2. Modelling approach

Exploratory factor analysis (EFA) is used to identify the factors that explain the relationships between the observed variables. Partial least squares structural equation modelling (PLS-SEM) is then utilised to examine the statistical relationship between the variables. PLS-SEM is a statistical approach that uses ordinary least squares regression to maximise the explained variance of the dependent latent variable, combining factor and path analysis. Factor analysis helps to establish links between observed variables (e.g., responses to survey questions) and the latent variables they represent (e.g., social cohesion), forming the measurement model. Path analysis uses multiple regression to examine the statistical relationships between latent variables (e.g., how social cohesion is affected by distance to destinations), comprising the structural model.

The PLS-SEM framework is consistent with our early stage research objectives, as it emphasises theory exploration rather than confirmation. Opting for PLS-SEM offers advantages over the conventional covariance-based structural equation modelling (CB-SEM), which relies on stringent data assumptions. PLS-SEM is preferable when dealing with non-normally distributed data and when working with secondary data rather than in controlled experiments (Hair et al., 2019). However, a drawback of PLS-SEM is its non-parametric nature, which requires bootstrapping for significance testing, which involves generating confidence intervals for specific model parameters, such as weights in the measurement model and coefficients in the structural model.

Table 3
Summary of social cohesion and perceptions of proximity variables.

Variable name	Minimum	Maximum	Mean	Standard deviation
This is my ideal neighbourhood	1	5	4.1	0.9
Rate your satisfaction level with your neighbourhood	1	5	4.2	0.9
The characteristics of my neighbourhood make it easier for me to meet my daily needs	1	5	3.9	1.1
I feel integrated in this neighbourhood	1	5	4.2	0.8
I identify with the people in this neighbourhood	1	5	3.9	1
This neighbourhood is part of my identity	1	5	3.8	1.1
People in this neighbourhood can be trusted	1	5	3.6	0.9
It's easy to make friends in this neighbourhood	1	5	3.6	1.1
People in this neighbourhood are sociable	1	5	3.9	0.8
People in this neighbourhood are friendly	1	5	3.9	0.8
People in this neighbourhood are cooperative	1	5	3.7	0.9
How do you think people who live outside your neighbourhood feel about your neighbourhood?	1	5	3.9	1.1
General opinion of proximity to: Work or study destination	1	5	3.6	1.1
General opinion of proximity to: Regular place for daily shopping	1	5	4.6	0.7
General opinion of proximity to: Regular place for occasional shopping	1	5	4	0.9
General opinion of proximity to: Restaurants	1	5	4.2	0.9
General opinion of proximity to: Social relationships, friends, and family	1	5	3.8	1.1
General opinion of proximity to: Doctor (primary care)	1	5	4.4	0.8
General opinion of proximity to: Doctor (hospital)	1	5	3.6	1
General opinion of proximity to: Schools	1	5	4.6	0.7
General opinion of proximity to: Culture	1	5	3.7	1
General opinion of proximity to: Green areas	1	5	4.6	0.7
General opinion of proximity to: Gyms/sports facilities	1	5	4.4	0.9

3.3. Model definition

To examine the relationship between distance to destinations and social cohesion, and the role of perceptions of proximity in mediating this relationship, we define a higher-order model. Higher-order models allow a construct to be modelled on a more abstract dimension (e.g., social cohesion) and its more concrete subdimensions (e.g., needs fulfilment) (Becker et al., 2019).

Following EFA, we define our measurement model (Fig. 2). The independent variable, *distance to destinations* (DD), is assessed through a reflective measurement approach, using five indicators related to distance to urban functions (care, education, shopping, leisure and culture, and public and active transport). The dependent variable, *social cohesion* (SC), is modelled as a higher-order construct composed of the lower-order constructs of *needs fulfilment* (NF), *group membership* (GM), *influence* (IN), and *emotional connection* (EC). These constructs are based on the twelve indicators derived from survey questions focusing on social cohesion and are measured reflectively. Finally, the mediating variable, *perceptions of proximity* (PP), is also assessed reflectively, using eleven indicators derived from the questionnaire.

We model all constructs as reflective measures because each indicator is influenced by the underlying latent variable and is expected to be correlated with other indicators. Correlated indicators can represent the construct interchangeably, and removing one indicator should not change the conceptual meaning of the latent variable (Jarvis et al., 2003). For instance, the latent construct *distance to destinations* (DD) remains consistent regardless of the different destination categories used. These measures can be used interchangeably, as our focus is on distinguishing between proximal and non-proximal urban environments and their influence on social cohesion, rather than differentiating between proximity to different types of amenities. Previous studies have also reported reflective measures of social cohesion when subcomponents of the concept are analysed separately, as in our case (Schiefer & Van der Noll, 2017; Sonta & Jiang, 2023).

The structural model (Fig. 2) thus posits that *distance to destinations* (DD) affects *social cohesion* (SC), with this relationship being mediated by *perceptions of proximity* (PP). We model *perceptions of proximity* as a mediating variable because it is caused by the independent variable and influences the dependent variable, helping to explain the relationship between the two constructs. In addition, several socio-demographic variables are included in the model as control factors. As demographic covariates are not latent variables in themselves, we generate dummy latent variables for each covariate (e.g., "latent age" derived only from "age"), establishing a direct path from each socio-demographic variable to social cohesion (Hair et al., 2016; Sonta & Jiang, 2023). These socio-demographic variables are presented as an aggregated block in

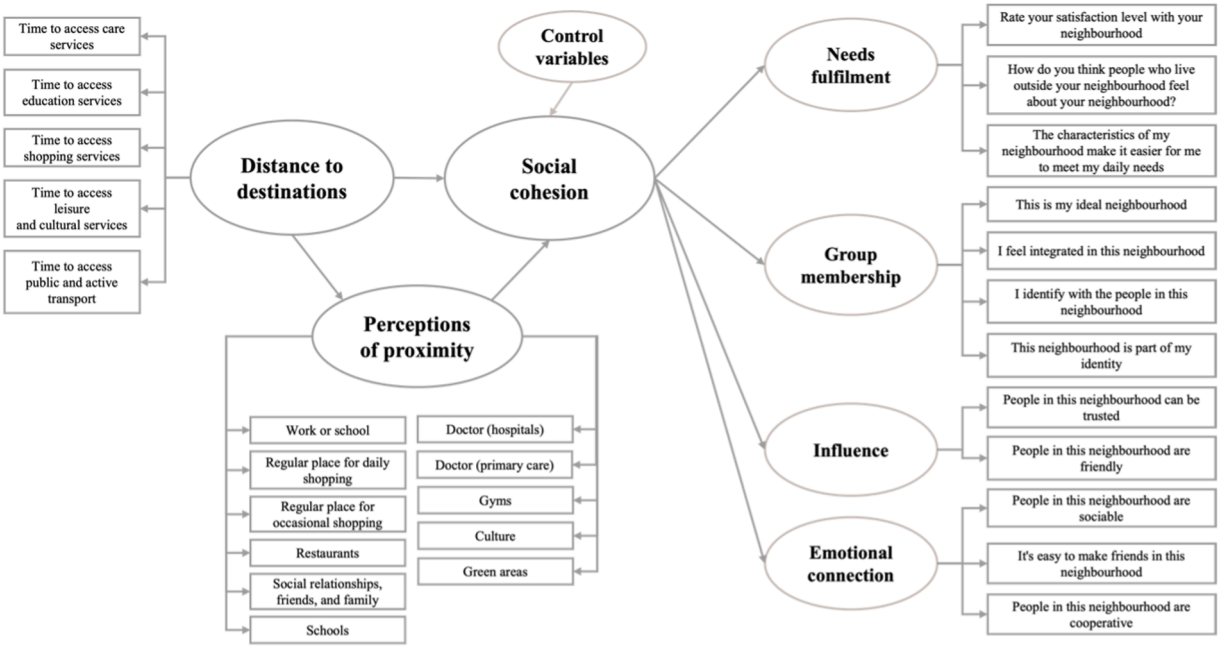

Fig. 2. PLS-SEM model.

Fig. 2. For model estimation, we used the "SEMinR" package in the statistical programming language "R" (Ray et al., 2021).

4. Results

Following data collection, we perform EFA to identify the factors that explain the relationships between the variables. We then evaluate the PLS-SEM model in two stages. First, the measurement model validity is assessed to ensure that the indicators represent the latent variables. Then, the structural model is analysed to test for statistical associations. This process is carried out for both the lower- and higher-order models.

4.1. Exploratory factor analysis

We conduct EFA on *distance to destinations* (DD), *perceptions of proximity* (PP), and *social cohesion* (SC) using the Minimum Residuals (Minres) extraction method, with the Oblimin oblique rotation method. This approach is chosen because it allows for potential correlations between the factors, in line with the conceptual relationships between the items.

Table 4 shows the metrics used in the evaluation. All analyses show Kaiser-Meyer-Olkin (KMO) values above the 0.6 threshold and significant Bartlett's sphericity tests, indicating suitability for factor analysis (Tabachnick & Fidell, 2013). Following Kaiser's criterion for eigenvalues greater than 1, a one-factor model is extracted for *distance to destinations* (DD), with an SS loading of 3.76, which accounts for 75 % of the variance. Standardised loadings for individual items range from 0.78 to 0.96. Following the same analytical approach, a one-factor solution is obtained for *perceptions of proximity* (PP), resulting in an SS loading of 2.89, explaining 26 % of the variance. The item loadings range from 0.31 to 0.66. Finally, for *social cohesion* (SC), a four-factor solution is identified, explaining a cumulative variance of 59 %. We identify these four factors as *needs fulfilment* (NF), *group membership* (GM), *influence* (IN), and *emotional connection* (EC). The fit indices are also presented in table 4. The Tucker-Lewis indices (TLIs) range from 0.996 to 0.877, which is above the accepted threshold of 0.85 set for exploratory research. The root mean square error of approximation (RMSEA) indices are below the threshold of 0.1 (Hu & Bentler, 1999; Kline, 2015).

4.2. Measurement model validity

To establish the quality of the constructs in the study, the reliability and validity of the lower- and higher-order measurement model are assessed. As the independent variable - *distance to destinations* (DD) -, the dependent variable – *social cohesion* (SC) -, its lower-order constructs, *needs fulfilment* (NF), *group membership* (GM), *influence* (IN), and *emotional connection* (EC), and the mediating variable – *perceptions of proximity* (PP) -, are all measured reflectively, the metrics examined are indicator loadings (IL), internal consistency reliability using Cronbach's alpha, and convergent validity using the average variance extracted (AVE) metric (Hair et al., 2019). Table 5 presents the metrics used for the evaluation.

According to guidelines (Hair et al., 2019), indicator loadings of 0.7 or higher are recommended, as they imply that more than 50 % of the variance of the indicator is explained by the latent construct. Several indicators met this threshold. Indicator loadings in the range of 0.5 to

Table 4
Exploratory factor analysis.

Variable	Factors	KMO	Bartlett's Test (p-value)	Variance Explained (%)	Fit Indices
Distance to destinations	Initially 5, reduced to 1	0.89	$\chi^2 = 9174.49$*	75 % (One-factor solution)	TLI = 0.996 RMSEA = 0.059
Perceptions of proximity	Initially 11, reduced to 1	0.87	$\chi^2 = 915.146$*	26 % (One-factor solution)	TLI = 0.877 RMSEA = 0.067
Social cohesion	Initially 12, reduced to 4	0.88	$\chi^2 = 12{,}004.811$*	59 % (Four-factor solution)	TLI = 0.915 RMSEA = 0.087

* Relationships are significant at $p < 0.001$.

Table 5
Measurement model validity.

	Loadings	Cronbach's alpha	Average Variance Extracted (AVE)
Latent variable (Construct)			
Indicator variable (Measured variable)			
Independent variable			
Distance to destinations, in minutes		0.936	0.798
DD_1: Time to access care services	0.924		
DD_2: Time to access education services	0.837		
DD_3: Time to access supply services	0.955		
DD_4: Time to access leisure and culture services	0.834		
DD_5: Time to access public and active transportation	0.910		
Dependent variables (lower-order constructs)			
Needs fulfilment		0.604	0.713
SC_2: Rate your satisfaction level with your neighbourhood	0.789		
SC_3: The characteristics of my neighbourhood make it easier for me to meet my daily needs	0.814		
SC_12: How do you think people who live outside your neighbourhood feel about your neighbourhood?	0.561		
Group membership		0.871	0.720
SC_1: This is my ideal neighbourhood	0.830		
SC_4: I feel integrated in this neighbourhood	0.854		
SC_5: I identify with the people in this neighbourhood	0.866		
SC_6: This neighbourhood is part of my identity	0.844		
Influence		0.765	0.809
SC_7: People in this neighbourhood can be trusted	0.898		
SC_10: People in this neighbourhood are friendly	0.900		
Emotional connection		0.849	0.767
SC_8: It's easy to make friends in this neighbourhood	0.839		
SC_9: People in this neighbourhood are sociable	0.911		
SC_11: People in this neighbourhood are cooperative	0.875		
Dependent variable (higher-order construct))			
Social cohesion		0.778	0.578
Needs fulfilment	0.795		
Group membership	0.812		
Influence	0.678		
Emotional connection	0.748		
Mediating variable			
Perception of proximity		0.721	0.420*
PP_1: General opinion of proximity to: Work or study destination**	< 0.500		
PP_2: General opinion of proximity to: Regular place for daily shopping	0.656		
PP_3: General opinion of proximity to: Regular place for occasional shopping	0.729		
PP_4: General opinion of proximity to: Restaurants	0.630		
PP_5: General opinion of proximity to: Social relationships, friends, and family	0.543		
PP_6: General opinion of proximity to: Doctor (primary care)	0.570		
PP_7: General opinion of proximity to: Doctor (hospital)**	< 0.500		
PP_8: General opinion of proximity to: Schools**	< 0.500		
PP_9: General opinion of proximity to: Culture	0.593		
PP_10: General opinion of proximity to: Green areas**	< 0.500		
PP_11: General opinion of proximity to: Gyms/Sport facilities**	0.515		

* Convergent validity results based on the AVE statistics show that the construct *perceptions of proximity* have slightly lower AVE than the recommended value of 0.5. However, the Cronbach's alpha value for the construct was greater than 0.7. Hence, the convergent validity is not an issue (Fornell & Larcker, 1981).

** Indicators removed from the final model.

0.7 are also considered acceptable in exploratory research (Falk & Miller, 1992; Hair et al., 2016) and are therefore retained in the model. The items PP_1 (IL = 0.307), PP_7 (IL = 0.449), PP_8 (IL = 0.424), and PP_10 (IL = 0.312) were removed from the construct *perceptions of proximity*

For consistency reliability, the Cronbach's alpha should be greater than 0.7 (Hair et al., 2011). According to Nunnally and Bernstein (1994), values of 0.6 to 0.7 are also acceptable in exploratory research, such as this study. The Cronbach's alpha ranged from 0.604 to 0.936, therefore, internal consistency reliability is established. Finally, if the AVE is greater than or equal to the threshold of 0.5, it indicates that the items effectively measure the latent construct (Fornell & Larcker, 1981). Lower thresholds of 0.4—as in the case of our model— are also accepted if the reliability values for all the constructs are above the threshold (Fornell & Larcker, 1981; Lam, 2012). Because the construct *perceptions of proximity* had a slightly lower AVE, the item PP_11 (IL = 0.507) was removed. This improved the AVE for the construct PP above the accepted threshold of 0.4. This was possible because the reliability values were all above 0.7. Thus, convergent validity was established.

4.3. Structural model path analysis

Structural model path analysis tests direct paths between the variables for statistical relationships. We first test the lower-order model relationships between *distance to destinations* and *needs fulfilment, group membership, influence,* and *emotional connection, distance to destinations* and *perceptions of proximity, perceptions of proximity* and *needs fulfilment, group membership, influence,* and *emotional connection*, and the control variables and the subdimensions. These subdimension reflect the higher-level construct of *social cohesion*, so we then test the direct paths of the higher-order model for statistical relationships. Table 6 presents the results for the higher-order model, while the results for the lower-order model are included in the supplementary material.

The presence of multicollinearity was assessed using the variance inflation factor (VIF). VIF values were found to be below the recommended threshold of 5 for all the constructs, indicating no significant multicollinearity problems. Following standard practice in the field, bootstrapping (5000 iterations) was used to assess the structural paths in order to establish a 95 % confidence level for the path coefficients.

Several independent latent variables had path coefficients significantly different from zero at the 95 % confidence level. In particular, the demographic covariates of age and educational level, and area-level variables of average educational level and proportion of rented

Table 6
Higher-order structural model results.

	VIF	Path coefficients	P-values	95 % Confidence intervals
DD -> PP	1.000	−0.185	0.000*	(−0.248, −0.129)
DD -> SC	1.206	−0.090	0.000*	(−0.141, −0.040)
PP -> SC	1.066	0.304	0.000*	(0.260, 0.346)
sex -> SC	1.017	0.009	0.674	(−0.032, 0.050)
age -> SC	1.210	0.063	0.005*	(0.019, 0.110)
educational level -> SC	1.247	−0.050	0.027*	(−0.097, −0.007)
employment status -> SC	1.232	0.027	0.278	(−0.022, 0.077)
years lived in residence -> SC	1.023	−0.040	0.055	(−0.081, 0.002)
average educational level census -> SC	3.645	0.171	0.000*	(0.109, 0.255)
average income level census -> SC	3.105	−0.072	0.060	(−0.155, −0.003)
% employed population census -> SC	1.579	−0.022	0.426	(−0.073, 0.036)
% rented housing census -> SC	2.558	−0.097	0.004*	(−0.163, −0.034)
% foreign population census -> SC	2.662	−0.062	0.078	(−0.130, 0.008)

Note: VIF = Variance Inflation Factor. DD = distance to destinations, PP = perception of proximity, SC = social cohesion.
* Relationships are significant at $p < 0.05$.

housing were statistically significant. We found that, on average, older respondents and those living in areas with a lower proportion of rented dwellings reported higher levels of social cohesion. The relationship between education and social cohesion showed contrasting trends: people with lower levels of education reported higher social cohesion, while living in areas with lower levels of education was associated with lower social cohesion. This suggests that both individual and community socio-economic factors play a role in fostering social ties.

Distance to destinations and *perceptions of proximity*, included in the model as independent and mediating variables, were each found to be statistically significant, but varied in their influence on social cohesion and on its subdimensions. These relationships are developed in the following sections.

4.3.1. Direct relationships analysis

The main aim of this study is to understand the relationship between the objectively measured proximity to daily destinations and social cohesion. The results (Table 7) show that the *distance to destinations* is negatively associated with *social cohesion*, i.e., that those participants living in areas where everyday destinations are further apart are more likely to report lower levels of social cohesion. The R-Squared value for the dependent variable is 0.155, which is moderate (Cohen, 1988).

The results for the lower-order model can be found in the supplementary material. Two of the four subdimensions of social cohesion were found to have significant direct paths. *Distance to destinations* has a significant and negative effect on *needs fulfilment* (−0.131) and on *group membership* (−0.057). This means that people living in areas where daily destinations are located far apart, tend to report lower levels of *needs fulfilment* and *group membership*. The R-squared values for the variables were 0.188 (NF) and 0.084 (GM), described as moderate to weak (Cohen, 1988).

Table 7
Higher-order direct relationship between distance to destinations and social cohesion.

Relationship	Path coefficient	SE	T-value	P-value	R-sq.
DD -> SC	−0.090	0.026	3.419	0.000*	0.155

Note. SE = standard error. R-sq. = *R*-Squared. DD = distance to destinations, SC = social cohesion.
* Relationships are significant at $p < 0.05$.

4.3.2. Mediation analysis

The secondary aim of the study is to explore whether individuals' perceptions of proximity to daily destinations influence the effect of the actual distances to these destinations on social cohesion. The results (Table 8) show a significant indirect effect, demonstrating that *distance to destinations* affects *social cohesion* through the lens of individuals' *perceptions of proximity*.

The total effect of *distance to destinations* on *social cohesion*, mediated by *perceptions of proximity*, is also significant. This shows a complementary partial mediating role of *perceptions of proximity* in the relationship between the variables. The mediation analysis suggests that not only physical distances, but also how these distances are perceived, contribute significantly to the observed levels of social cohesion.

The total effect suggests that including *perceptions of proximity* as a mediator helps to explain the negative relationship between *distance to destinations* and *social cohesion*. The magnitude of the effect is stronger in the mediated relationship (−0.147) than in the direct relationship (−0.090). This means that, when individuals perceive destinations as close by, social cohesion tends to increase even more than what would be expected based on physical distance alone. Conversely, when people perceive destinations as far away, social cohesion tends to decrease even more than what would be expected based solely on physical distance alone.

In the lower-order mediation analysis *perceptions of proximity* significantly mediate the relationship for *needs fulfilment* and *group membership*, with both indirect and total effects being significant, suggesting a complementary partial mediation. For *influence*, the significant total and indirect effects suggest that *perceptions of proximity* may fully mediate the relationship, meaning that participants' reported levels of influence are entirely dependent on their perceived proximity to daily destinations. However, recent literature on PLS-SEM cautions against claiming full mediation, as this may limit theory development (Carrión et al., 2017; Memon et al., 2018). Emotional connection showed no significant effects. The results are detailed in the supplementary material.

Both the lower- and the higher-order models have a goodness of fit (GoF) metric of 0.24, which indicates a moderate fit (Hair et al., 2022).

5. Discussion

This research presents new evidence on the relationship between urban proximity, perceived proximity, and social cohesion. It examines the impact of walking distance to daily destinations on social cohesion at the neighbourhood level and explores how these relationships are influenced by perceived proximity. A higher-order PLS-SEM model with *perceptions of proximity* as a mediator between *distance to destinations* and *social cohesion* was developed, applied and evaluated.

Our results show that the availability of daily destinations within a short walking distance is conducive to socially cohesive communities. Recognising that neighbourhood social cohesion is a multifactorial phenomenon, this study finds statistically significant relationships with one of these factors: urban proximity. Classical neighbourhood planning theories have traditionally used the idea of an increased sense of community to support their push for increased proximity (Perry, 1929; Jacobs, 1961; Oldenburg & Brisset, 1982; Moreno, 2022). This theoretical framework postulates that reducing the physical distance between people's homes, workplaces, and daily destinations could increase social cohesion in two main ways. First, by promoting active travel modes such as walking and cycling that facilitate social interaction, and second, by improving access to intermediate spaces where people from different backgrounds can form social bonds. Our finding is therefore particularly significant as it quantifies a theorised social outcome of urban proximity.

Previous research has shown how public and open green spaces provide a physical place for social connection (Jennings & Bamkole, 2019; Mullenbach et al., 2022; Clarke et al., 2023; Yang at al., 2023;

Table 8
Higher-order model mediation analysis results.

Total effects (DD -> SC)			Direct effect (DD -> SC)				Indirect effects of DD on SC			
Path Coefficient	T-value	P-value	Path Coefficient	T-value	P-value	Relationships	Path Coefficient	SE	T-value	P-value
−0.147	5.444	0.000*	−0.090	3.419	0.000*	DD > PP > SC	−0.056	0.010	5.478	0.000*

Note: SE = standard error. DD = distance to destinations, PP = perception of proximity, SC = social cohesion.
* Relationships are significant at $p < 0.05$.

Mepparambath et al. 2024). These spaces are vital for shared everyday experiences, bringing residents together and encouraging social activities. However, to our knowledge, no previous study has examined the combined effect of having a wide range of destinations within a short walking distance, covering the five essential urban functions of care, education, shopping, leisure and culture, and public and active transport. Rather than focussing on access to specific services, we wanted to offer a broader perspective on the influence of urban proximity on community ties. This approach helps to highlight how neighbourhood (in)equalities affect social cohesion within a given area, providing valuable insights for policy planning.

Our study examines the effects that both objective and perceived proximity can have on social cohesion. Our model shows that social cohesion is influenced by the physical distance to destinations and is mediated by people's perceptions of how close or far these destinations are. This means that when people perceive destinations as close, social cohesion tends to be higher than what would be predicted on the basis of actual distance alone, and vice versa. Previous literature has also explored the interplay between personal perceptions of distance and GIS-based analyses (Van Der Vlugt et al., 2019; Pot et al., 2021; Orrego-Oñate & Marquet, 2024). Jun and Hur (2015) find a contrasting effect between perceived walkability, which improves the social atmosphere of the neighbourhood, and physical walkability, which does not. Similarly, French et al. (2013) highlight that residents' perceptions of their neighbourhoods are stronger predictors of sense of community than objective measures of the built environment. However, our study advances understanding by considering all three variables together, showing that *perceptions of proximity* act as an intermediate factor in the relationship between *distance to destinations* and *social cohesion*.

The model also includes several socio-demographic data as control variables, which are consistently associated with sense of community (Pendola & Gen, 2008). Individual age, education level, average education at area level and percentage of rented dwellings were statistically significant. Our results show that, typically, older participants and those living in neighbourhoods with fewer rented housing tended to report greater social cohesion. In addition, people with lower levels of personal education reported higher levels of social cohesion, but people living in areas with lower average levels of education showed reported lower levels of social cohesion. This suggests that socio-economic factors, both at individual and community level, contribute to fostering social ties.

Previous literature has focussed on older adults' demographics in relation to social cohesion and perceived and objective neighbourhood characteristics Using latent profile analysis, Hua et al. (2022) find that older people who perceive their neighbourhoods to be highly walkable and recreationally dense report greater social cohesion. Conversely, Lee and Tan (2019) highlight that third places (such as food and leisure venues) are an influential predictor of older people's social support networks. However, this effect is not found for walkability. Although our study does not focus exclusively on the older population, our findings in relation to age are consistent with the existing literature, which shows that the accessibility of daily destinations is important for older adults' social cohesion.

Finally, by modelling social cohesion as a higher-order construct reflected in the subdimensions of needs fulfilment, group membership, influence, and emotional connection, our research explores how proximity and perceived proximity affect each subdimension. Our results indicate a significant effect of distance to destinations on needs fulfilment and group membership, with needs fulfilment showing a stronger effect. This finding is explained by the fact that the ability to meet daily needs is closely linked to the physical characteristics of the built environment and, in line with theoretical expectations of neighbourhoods as spaces for meeting basic needs and facilitating social interactions (Gil Solá & Vilhelmson, 2019).

This nuanced understanding of social cohesion can be used by policymakers to tailor interventions to improve community cohesion. For example, demonstrating that needs fulfilment is significantly influenced by proximity to destinations is important not only because addressing residents' satisfaction of daily needs, with its emphasis on practical rather than emotional concerns, may be more accessible from a policy perspective, but also because it is the dimension most associated with social justice (Dempsey et al., 2011). Ensuring equitable access to essential services, facilities, and transport infrastructure within the neighbourhood is fundamental to achieving social justice (Dempsey et al., 2011). This, in turn, promotes the sustainability and resilience of a community, by fostering collective aspects of social life such as local interactions, participation in activities, community stability, pride of place, and a sense of security.

6. Conclusions

Our study provides new insights into the relationship between urban proximity and social cohesion by exploring the mediating role of perceptions of proximity. Previous research has focused on analysing how different aspects of the built environment, such as density, diversity, design and destination access/walkability, affect social cohesion. However, studies that have looked at proximity to destinations have often conflated proximity with neighbourhood walkability, limited their analysis to specific types of amenities, or relied solely on objective measures. Instead, this is one of the first empirical studies to isolate a positive social outcome of urban proximity, increased social cohesion, using both subjective and objective measures. This finding is important because social cohesion is often associated with community resilience and societal stability.

In this study, we used survey data on social cohesion and perceived proximity, together with georeferenced data on distance to destinations in five Spanish cities, to examine the relationship between urban proximity, perceptions of proximity and social cohesion. Using an SEM approach, our statistical analysis revealed that distance to destinations is negatively associated with social cohesion and that this relationship is mediated by perceptions of proximity. This suggests that the effect of destination distance on social cohesion is amplified when people perceive destinations to be closer or further than they actually are. These findings are consistent with theoretical frameworks suggesting that proximal spaces improve social outcomes, particularly social cohesion. By empirically quantifying the positive effects of proximity, this research supports the hypotheses of the classical neighbourhood planning movements. These movements have historically argued that reducing the physical distance between daily destinations promotes social cohesion by encouraging active modes of travel, such as walking or cycling, which facilitate social interaction in shared spaces.

Our results also highlight the importance of considering both actual walking distances to destinations and individuals' perceptions of these

distances, demonstrating the interaction between personal perceptions and GIS-based analysis. We also explored the confounding effects of several socio-demographic variables, and focussing on age, discussed how the accessibility of destinations is important for social cohesion among older adults. Finally, we found that needs fulfilment is the sub-dimension of social cohesion that is most affected by proximity to destinations. This finding has important implications for social equity policies, as ensuring equitable access to essential services and facilities promotes community sustainability and resilience.

This study is not without limitations that should be considered in future research. Our study analysed the relationship between urban proximity, perceived proximity, and social cohesion. However, we did not investigate whether perceptions of distance are influenced by factors such as social integration or feelings of exclusion, nor did we examine the role of modal choice in shaping these perceptions. For example, people who are more socially integrated may perceive walking distances as shorter, whereas those who feel marginalised may not feel as comfortable walking in the neighbourhood. Moreover, car users may distort distances to justify their mode of transport. Finally, our model included socio-demographic and explanatory variables available in our dataset, but additional variables could increase the depth of analysis. Future research should take these factors into account to refine our understanding of the complexities surrounding urban proximity, perceptions, and social cohesion.

CRediT authorship contribution statement

Serena Mombelli: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Carme Miralles-Guasch:** Project administration, Funding acquisition. **Oriol Marquet:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition.

Declaration of competing interest

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

Acknowledgements

This study has been funded by the MOVACTES (PDC2021–120820-I00) and MOBITOOLS (PDC2022–133212-I00) projects, funded by MCIN/AEI /10.13039/501100011033 and by the European Union Next GenerationEU/PRTR, as well as by the STEPP project: Social Equity in Transportation through Proximity Planning (SR22–00147) funded by the Social Observatory of the La Caixa Foundation. Serena Mombelli has a doctoral scholarship awarded by the Spanish State Research Agency (AEI, PREP2022–000946) and Oriol Marquet receives funding from the Spanish Ministry of Science and Innovation through a 'Ramón y Cajal' contract (RYC2020–029441-I).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.scs.2024.106096.

Data availability

Data will be made available on request.

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