Urban Planning
2025 • Volume 10 • Article 10615
https://doi.org/10.17645/up.10615

ARTICLE

Open Access Journal

Measuring Food Supply Through Closeness and Betweenness: Halls and Open-Air Markets in Metropolitan Barcelona

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Submitted: 26 April 2025 **Accepted:** 31 July 2025 **Published:** 30 September 2025

Issue: This article is part of the issue "Understanding Change in Urban Food Environments: The Contemporary Challenges of Conceptualization, Definition, and Measurement" edited by Claire Thompson (University of Hertfordshire) and Dianna Smith (University of Southampton), fully open access at https://doi.org/10.17645/up.i404

Abstract

This article presents an approach to food procurement systems employing the concepts of closeness and betweenness. The objective is to define tools for measuring proximity related to food supply within dense urban contexts, where procurement is guaranteed but is still an essentiality that affects the quality of life of residents. This is due to the structured network that supports everyday movements, where food providers function as catalysts for the establishment of proximity routes. The research focuses on Barcelona's metropolitan area, employing a quantitative methodology associated with mapping systems to study the spatial distribution of publicly managed halls and weekly open-air markets, as well as the proximity service they offer in terms of relative distances and times. The results obtained demonstrate a novel approach to analyzing a territory based on its public food supply, transferable to other geographies. In contrast, a precise diagnosis of the metropolitan fabric studied is provided, highlighting vulnerabilities in the system and establishing a foundation for proposing new urban planning and design actions to address food supply.

Keywords

Barcelona; food systems; market halls; open-air markets; proximity

1. Introduction

The average European household allocates 13.0% of its budget to food purchases, making it the second-largest expenditure category after housing (23.7%) and just ahead of transport (12.8%; Eurostat, 2024). Moreover, the hospitality sector, encompassing both restaurants and lodging, accounted for 9.1% of the aggregate figure,

thereby positioning it as the fourth-largest spending category per household. However, while the disciplines of urban design and planning address issues concerning how citizens live or move, the question of how people eat is not generally accorded a place among the priorities in the design of the metropolis. The American Planning Association prompted studies on food supply systems when Pothukuchi and Kaufman (2000) raised a similar concern, pointing out that among the basic elements of life—air, water, shelter, and food—planners had traditionally addressed them all except for food (Morgan, 2009).

Food supply, as well as consumer amenities, are both shaped by and contribute to the dynamics of economic geography (Sonnenschein et al., 2022). Furthermore, territorial interactions play a critical role in shaping food supply systems, as they influence the spatial configuration of production and distribution networks, the relational proximity between actors, and the governance mechanisms that support localized food practices (Felici & Mazzocchi, 2022; Horvath et al., 2024; Pascual & Guerra, 2024; Recine et al., 2021). Within this framework, and at the urban scale, planning and design contribute to shaping the spatial distribution of suppliers and the accessibility of these locations for consumers (Kesarovski & Hernández-Palacio, 2022). In contexts where food security is guaranteed—understood in terms of the accepted definition, when "all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organization, 1996)—the relationship between urban form and food suppliers is often two-fold. On the one hand, dense and compact environments facilitate walkable access to essential services, which has been demonstrated to lead to the creation of more inclusive spaces (Marquet & Miralles-Guasch, 2015). Moreover, the decline in automobile usage, along with reduced emissions, fosters walkability, a phenomenon shown to promote improved health and well-being across diverse social groups and over time (Carmona, 2018; Valls & Clua, 2023). In contrast, in expansive suburban areas, inadequate public transportation leads to a reliance on private vehicles, limiting access to food and daily activities for those without them—particularly the elderly and low-income groups (Bose, 2024; Dumas et al., 2021). This phenomenon unveils profound structural inequalities.

The movement restrictions imposed during the Covid-19 pandemic highlighted the importance of effectively distributing essential urban amenities (Boz et al., 2024; Faedda et al., 2022; Jabareen & Eizenberg, 2021). Accordingly, promoting healthy habits in daily activities—such as food procurement—is hypothesized to support urban sustainability (Barton & Grant, 2006; Kaaronen & Strelkovskii, 2020; Rydin et al., 2012; Siri, 2016). This involves encouraging short trips, ideally on foot, by bicycle, or via public transport.

Escalating economic, welfare, and technological advancements have triggered an increase in inequality regarding food environments (Thompson & Smith, 2025). On the one hand, there is a shift towards lifestyles that rely on food delivery through digital platforms and the revival of urban theories advocating for "kitchenless" households (Puigjaner, 2015). On the other hand, rising food insecurity has led to the expansion of food-related charities and food banks (Esmaeilidouki et al., 2023; Gracia-Arnaiz et al., 2021). Nevertheless, access to fresh food is still recognized as a key indicator of well-being and quality of life among urban residents. Numerous studies have established a direct link between the availability of healthy food options and various health outcomes (Pechey et al., 2022). Evidence associates food availability with dietary behaviors and health outcomes in urban settings of low- and middle-income environments (Turner et al., 2020). Contrarily, limited access to healthy foods in urban food deserts correlates with poorer diet quality and higher body mass index among residents (Dubowitz et al., 2015). Furthermore, urban

populations with restricted access to healthy food, particularly low-income and minority groups, experience higher rates of obesity and food insecurity (Freedman & Bell, 2009).

In this context, it is pertinent to question whether it is viable to seek and promote proximity in the food procurement system. Proximity is understood here not as the origin of the goods offered by the food system, but rather as the frequency and distance that citizens travel to obtain them. The present research puts forward a series of propositions to investigate the relationship between providers and households in terms of rhythms. In order to achieve this objective, closeness and betweenness centrality—concepts associated with urban network analysis—are used for analysis. Understanding these centrality measures enables urban planners and designers to make informed decisions aimed at improving accessibility and flow within urban environments (Fushimi et al., 2020; Shi et al., 2024). Closeness centrality assesses how near a location is to all others in a network, highlighting areas with high accessibility. This measure is instrumental in identifying zones that facilitate efficient access to services and amenities, thereby promoting urban vibrancy and sustainability (Z. Chen & Huang, 2024). Conversely, betweenness centrality identifies nodes that frequently occur on the shortest paths between other nodes, indicating their role as critical connectors or potential bottlenecks within the urban fabric. High betweenness values can reveal areas susceptible to congestion but also opportunities for strategic interventions to enhance connectivity and resilience (Curado et al., 2020).

The following pages propose an approach to measuring closeness and betweenness in the food system, focusing on two defining features of metropolitan Barcelona: the strength of its public dimension and the widespread presence of this public dimension in the territory. Section 2 of the article introduces the geography of the metropolis and the explanation of the elements that make up the food system, to expose the specificity of the main object of this research, a structural part of the constellation of providers: the market halls—publicly owned facility buildings that house privately owned stalls and, in most cases, also a supermarket—and the open-air markets—publicly managed groupings of stalls that occupy streets, squares, or parks in many municipalities on a weekly or biweekly basis. Section 3 presents the methodology of the quantitative analysis. The first subsection (3.1) measures the relationship between markets and the metropolitan population to assess their potential as proximity providers of food on foot. The second subsection (3.2) examines the distances between market halls to develop hypotheses about networking and to propose pedestrian routes that promote local centers of activity. Finally, a series of considerations are presented on the possibilities of optimizing the system of markets to achieve a healthier metropolis, guaranteeing that a slow rhythm habitat—manifested through reduced traffic congestion, greater access to green spaces, and walkable neighborhoods—can enhance residents' opportunities to obtain healthier diets by encouraging active travel to fresh food sources, and supporting community food initiatives, thereby linking territorial tempo with nutritional outcomes (Almanza et al., 2012; Anandhi et al., 2025; Quintero & Restrepo, 2023).

After these sections, the research seeks to address the following research question: Can the distances traveled and time spent on food procurement—both in terms of space and rhythm—affect overall well-being and quality of life in urban communities?

2. Context: Barcelona Metropolitan Area, a Territory Supplied by a Public Food System

Barcelona's metropolitan area comprises 36 municipalities, with the city of Barcelona accounting for 27.6% of the total area (100.3 of 363 sq km) and 49.6% of the population (1,686,208 of 3,398,219 inhabitants; Institut d'Estadística de Catalunya, 2024a). The territory is crossed from north to south by the Marina, Collserola, Ordal, and Garraf mountain ranges; by the Llobregat river in the south; and by the Besòs river in the north (Busquets, 2005) .

The municipalities that comprise the metropolis have maintained their commitment to guaranteeing citizens' access to fresh food, even before the creation of the first common administrative entity in 1974, the Metropolitan Corporation, predecessor of the current Àrea Metropolitana de Barcelona, established in 2011. The infrastructure of food providers that feeds the metropolis responds to a unique supply model and is supported by a public system of public halls and weekly open-air markets that has been continuously reinforced across decades. The food retail offer is complemented by a dispersed network of grocery shops and supermarkets, totalling 17,765 establishments (Àrea Metropolitana de Barcelona, 2014).

On the one hand, the 90 food market halls respond to a wide variety of building types that allow their integration into very different types of urban fabric: The first halls were built in more compact and dense urban fragments; while the latter respond to massive housing estates or open low-density environments, or are in the vicinity of railway and road infrastructures. The commitment to constructing market halls began in 1840. Although the most recent was built in 2016, many existing buildings have been renovated over the past 40 years, as market halls continue to be a priority within the metropolitan facility program. The process was replicated in the towns surrounding the capital city, resulting in a total of 90 markets built over 76 years across the 36 municipalities that have formed the Barcelona metropolitan area since 1976.

In parallel, up to 74 weekly open-air markets—ranging from groups of stalls in peripheral open spaces to those located in dense and compact urban areas adjacent to market halls—intermittently complement the metropolitan food procurement system. Although these temporary infrastructures occupy public spaces and are nearly as numerous as the permanent halls, they do not operate daily. Their offering is limited to fruits and vegetables, and sometimes eggs, dairy products, cold cuts, and pickles, but rarely fresh meat or fish. Weekly markets add a layer of discontinuity to the food system, enabling mobility between elements and their coexistence with other uses. Their low implementation cost allows weekly markets to serve as potential testing grounds for future market hall locations, helping to consolidate the built network of public facilities.

Previous works at the municipal scale of Barcelona that have approached the local food system have been considered in the research. On the one hand, historical research (Guàrdia & Oyón, 2010; Miller, 2015) has highlighted the uniqueness of the local food system in Barcelona, which preserved its market halls—and even built new ones—while many other European cities demolished theirs, viewing them as incompatible with the modernity their urban centers were expected to embrace. On the other hand, topological research (Fuertes & Gómez-Escoda, 2020; Gómez-Escoda, 2025) has recently highlighted the potential of the public system of market halls to trigger neighborhood centralities and lead a change in designs and policies related to food suppliers. Finally, the contribution of the privately-owned small-scale providers to accessibility to healthy food in terms of availability has also been discussed (Gómez-Varo et al., 2023; Goossensen et al., 2023).

The role of the spatial distribution of food providers in shaping the quality of life has also been tackled in relation to metropolitan Barcelona. Recent investigations show how lower-income neighborhoods and areas with a higher proportion of non-Spanish residents tend to have reduced access to organic food outlets, reflecting broader patterns of spatial inequality, as unequal access to food retailers, particularly those offering fresh and healthy options, tend to exacerbate urban health disparities and social inequalities (García et al., 2020). Similarly, research has demonstrated that Barcelona's compact urban form facilitates greater walkability and supports more equitable access to everyday services, including food provisioning, thereby enhancing residents' well-being (Marquet & Miralles-Guasch, 2015). These findings are echoed in policy-oriented initiatives such as the Barcelona City Council's Healthy and Sustainable Food Strategy 2030, which highlights the importance of an equitable food retail network for achieving food justice and improving quality of life across all city districts (Ajuntament de Barcelona, 2021). Moreover, the Barcelona Challenge for Good Food and Climate emphasizes the spatial dimension of food vulnerability, calling for structural reforms in the urban food system to ensure sustainable and nutritious diets for all (Herrero & Carrascosa, 2022).

Considering this background, and drawing on the aforementioned closeness and betweenness analyses, this article develops two main approaches for assessing the quality of the urban food system in metropolitan Barcelona: (a) the degree of potential demand to which fresh markets are subject, and (b) the distances between public food supply facilities. In this regard, the results of this research indicate that halls and open-air markets ensure access to fresh food and qualify the territory as well supplied.

3. Methods: Unfolding an Approach to Barcelona's Market System Through Closeness and Betweenness

The research begins with the potential of the food system to be accessible on foot and translates it into a topological analysis that quantifies the relation of distances that markets establish. The analysis makes use of the increasing accessibility of information—via digital archives and open cartographic resources—and the potential of geographic information systems (GIS) to both measure and visualize urban phenomena. Two approaches are taken based on the same data sources. The first examines journeys on foot around market halls and open-air temporary markets to observe the degree of territorial coverage offered intermittently by both complementary systems. The second approach drafts the distances between market halls, regarded as a metropolitan infrastructure with the capacity to activate urban centralities and pedestrian movements connecting them.

In both cases, a common methodology was used to prepare the specific calculations. The plot map for the entire metropolis was obtained from the Cartography Geoportal (Àrea Metropolitana de Barcelona, 2025). Data concerning road networks and urban plots were sourced from the Spanish Cadaster (Sede Electrónica del Catastro, 2025). Demographic data were derived from the Statistical Institute of Catalonia's population register (Institut d'Estadística de Catalunya, 2024a). Data on population were extracted from Població de Catalunya georeferenciada (Institut d'Estadística de Catalunya, 2024b), which consists of a geolocated population count on a dynamic 62.5 × 62.5m grid, with the most up-to-date information from 2016. The aggregate population has been allocated pro rata to the built-up roof of each plot.

QGIS is used as the main tool to complete the georeferencing tasks, produce maps, and estimate quantifications. The urban street network is based on Open Street Maps, and Open Route Service and the

QNEAT3 plugin have been used to establish isodistances to calculate routes and catchment areas. Graph analysis is used to determine weighted networks through betweenness centrality measurements (Sevtsuk et al., 2016), in which each market place is considered a node so that shortest paths between nodes are established, and in which the weighted proportion of capacity is related to the number of households in a shortest path of 400 meters around each market so that the degree of service to residents can be calculated. The closeness analysis counts the amount of footfall passing from given points, when households are set as origins, and destinations are either market halls or temporary open-air markets.

3.1. Halls and Open-Air Markets as Nodes of Closeness Centrality

This section quantifies the relation between markets and the resident population around them in affordable distances, set at 400 meters – 5 minutes on foot for middle-aged people without functional diversity, taking an average speed of 1.31 meters per second (Murtagh et al., 2020). To evaluate these daily journeys, accessibility is not measured by identifying locations that are closest to as many customers as possible (Sevtsuk, 2020), but in a basic calculation that relates travel time between market halls and households, as the research only considers one of the multiple layers of activity at the sidewalk level.

To determine the population within 400 meters walking distance from each market, Open Route Service is used to generate isochrones, delineating catchment areas based on pedestrian accessibility. For the sake of a clear territorial understanding at both large and medium scales, the base road network was simplified to a single-axis model, disregarding variations such as pavements or dedicated lanes for public transport and cycling. Each market's routing itineraries are unique, illustrating: (a) the relative share of population within the catchment area of each market in relation to the entire system, and (b) the relative significance of each route within the full set of itineraries constituting the market network. To ensure accurate route calculation, manual verification is conducted to confirm the continuity of network axes and the topological consistency of intersections, particularly regarding pedestrian accessibility and topographic alignment at critical nodes.

Each market's destination point is defined at its geometric centroid. For permanent market halls, a more granular approach may be warranted in future research to account for multiple access points, adjusting centroid placement accordingly. In the case of temporary markets—often located adjacent to market halls or in expansive public spaces such as streets, squares, or parks—multiple destination points are assigned to reflect their spatial extension more accurately. Origins of routes are placed at the central point of each residential building façade facing the street. In wide thoroughfares where building fronts are set back from the road, manual adjustments are made to correct mismatched origin points. Similar corrections are applied to large plots fronting multiple streets to eliminate duplicate origins. A data cleansing process ensures that each residential plot is represented by a single origin point, thus preventing the overrepresentation of any given location in the resulting network. Routing pathways are generated using an algorithm applied to the simplified road network, with origin points taken from residential plots and destination points from the markets. While the algorithm efficiently generates routes for most urban configurations, certain wide avenues require manual correction of origin points to align them more closely with the street axis. In some instances, destination points are also relocated manually to better reflect primary access locations or alignment with major routes (Gómez-Escoda & Fuertes, 2022).

Although the generated routes in this process represent connections from residential plots to their nearest markets, they do not inherently capture differences in population density or usage patterns. Two weighting processes are therefore applied. First, each route is weighted relative to the market serving the largest population within the system. Accordingly, line thickness varies proportionally, with thicker lines indicating routes used by a greater number of residents. Second, assuming a homogeneous population distribution within each market's service area, it is considered that longer routes are more frequently used than shorter ones. Therefore, within each market's catchment area, routes are additionally weighted in relation to the length of the longest route in that system. Concerning the graphic expression of the calculations, and in order to make the area of proximity to the markets more visible, isochrones are added at 5, 10, and 15 minutes from the points of origin of the weighted routes. The resulting map is presented in Figure 1, and the associated data are disclosed in Supplementary File 1. To ensure the most accurate interpretation of the system's behavior, the halls (blue) are distinguished from the open air (magenta).

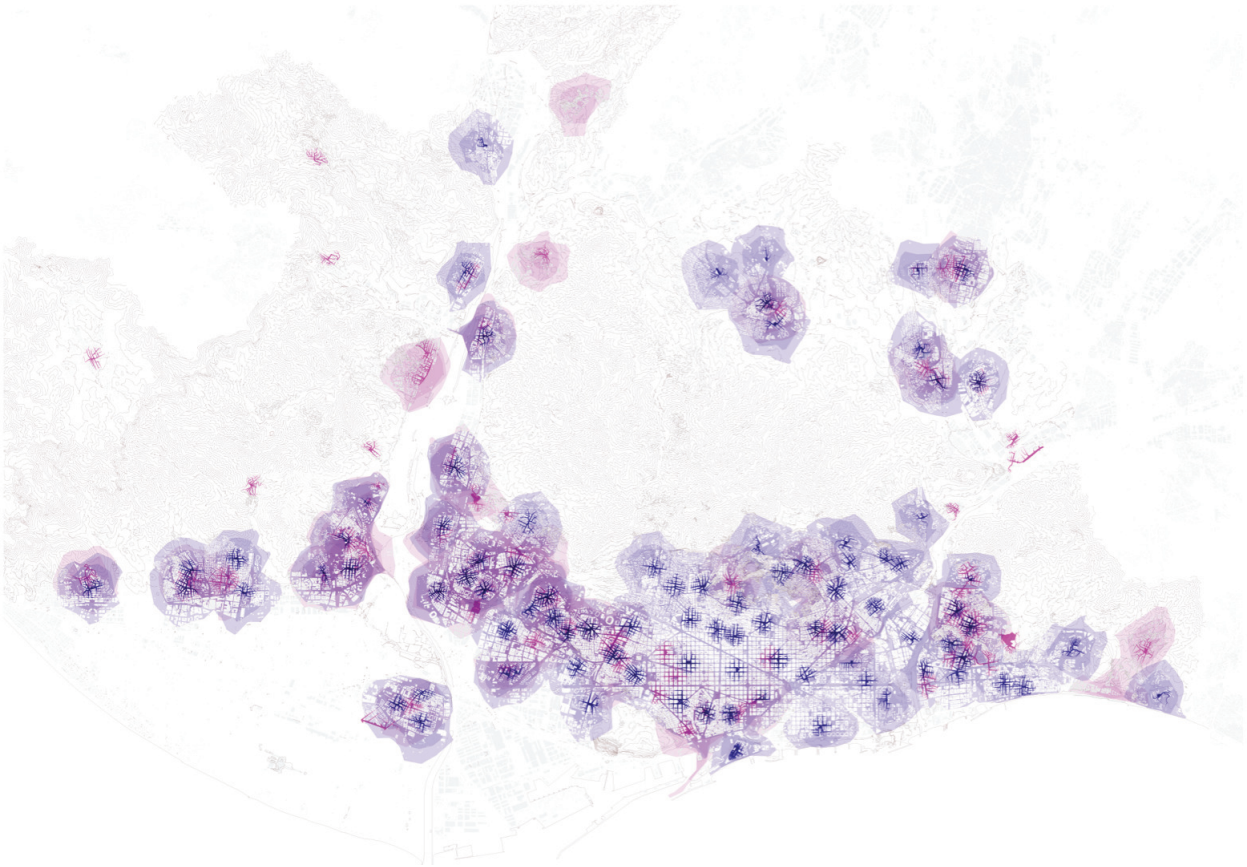

Figure 1. Closeness map around halls and open-air markets in metropolitan Barcelona, 2025.

3.2. Pathways Connecting Markets as Potential Betweenness Catalyzers of Activity

In a parallel analysis, the shortest pedestrian routes between market halls are outlined. The hypothesis here is that the search for these minimal routes between markets that reflect human movement patterns may uncover intermediate locations that could supplement the provision of food with other essential commodities. As walkable access to urban services—food supply in this case—depends on the actual travel distance through the street network, rather than just straight-line distance, knowing the shortest paths between them can

become essential for evaluating how easily people can reach key destinations (Boncinelli et al., 2025). At the same time, although pedestrians often navigate based on the general direction of their goal, shortest paths offer a valuable baseline for assessing the efficiency of real-world navigation and for informing better city planning (Bongiorno et al., 2021).

To calculate the shortest walkable paths between the access points of each market and the nearest market, this study utilizes the QNEAT3 plugin within QGIS. The QNEAT3 plugin enables network analysis over vector-based road data, used to calculate least-cost routes between a given set of spatial points—in this case, 90 market halls—employing a walkable road network as the underlying graph structure. The functionality of these tools is predicated on the implementation of Dijkstra's algorithm, which facilitates the identification of minimum-distance paths based on a designated cost attribute—in this case, estimated time. The road network dataset is preprocessed to ensure topological connectivity, thereby facilitating accurate routing across the urban fabric. This method provides both vector outputs of route geometries and tabular data expressing pairwise distances, which are essential for subsequent spatial accessibility analysis. Concerning the graphic expression of the calculations, and to make the area of proximity to the vertices more visible, 400-metre circles highlighting the urban fabric were added to highlight the markets' locations. The resulting map is presented in Figure 2, and the associated data are disclosed in Supplementary File 2.

Figure 2. Betweenness map relating market halls with their closest pair in metropolitan Barcelona, 2025.

4. Results: An Approach to Measuring Food Supply Proximity

This section presents the results obtained in the measurements, which show a twofold reality in relation to food supply proximity. In terms of environmental characteristics, compact and dense environments are defined by the physical contiguity of public suppliers and the proximity between market halls. This results in the formation of urban nodes characterized by high levels of activity intensity. Conversely, in suburban areas, distinguished by a more rugged topography and a greater reliance on infrastructure, each of the suppliers assumes a pivotal role in municipal activity.

4.1. Closeness to Households

Calculations and mapping of the potential demand to each of the 90 metropolitan market halls and 74 open-air markets shed light on the nuances of the system in relation to urban fabric type and diversity of use. From Supplementary File 1, which lists the population within a 400-metre distance from every marketplace in the metropolis, some considerations can be taken. Market halls potentially serve 1,025,198 people living within a 400-meter distance, which is equivalent to an average of 11,309 inhabitants per building. This represents a service slightly lower than that of the temporary markets, which at the same distance procure food to 888,055 people, that is, 12,000 on average. Adding one system to the other, the average figure of service for each of the public markets is 11,666 people. These figures suggest that, if temporary markets are already assuming a role of higher service than that of the market halls, they could be used as a natural lever to strengthen the metropolitan food system, filling some existing service gaps in the territory.

In topological terms, it is possible to find some fragments of the metropolis in which weekly markets and market halls are tangent or overlap. Some temporary markets reinforce market halls, overlapping the service, overflowing the activity, and attracting customers from the surrounding areas; others fill food gaps and take responsibility for feeding an entire neighborhood with fresh food; and others are embedded between the areas served by market halls and generate territorial continuities that constitute food routes that could be considered structuring for the metropolitan form. Ultimately, when open-air markets are integrated into suburban areas, they can strengthen local food supply resilience by connecting nearby food production with consumers, reducing reliance on distant sources, and enhancing community food security.

Figure 3 highlights six fragments—5,000 by 5,000 meters—of Figure 1 in more detail, so that situations related to the diversity of metropolitan urban fabrics and the distribution of food suppliers can be observed: (a) temporary markets connect two market halls and leave another two isolated—which in turn serve a considerably smaller number of citizens; (b) the temporary markets are attached to the halls, and the contiguities are clearly interrupted by a motorway in the north–south direction, and in a less obvious way, by the railway in the east–west direction; (c) the temporary markets are staggered with the halls inserted in the grid; (d) two temporary markets bond the urban fabric and barely leave the residential fabric without service when they are in operation; (e) while the left fabric depends exclusively on market halls, the right area ensures the food supply of the urban fabric with overlaps between open-air markets and halls; and (f) despite the density of halls and temporary markets that are attached to them, the few free spaces left by the system are also temporarily occupied with open-air markets.

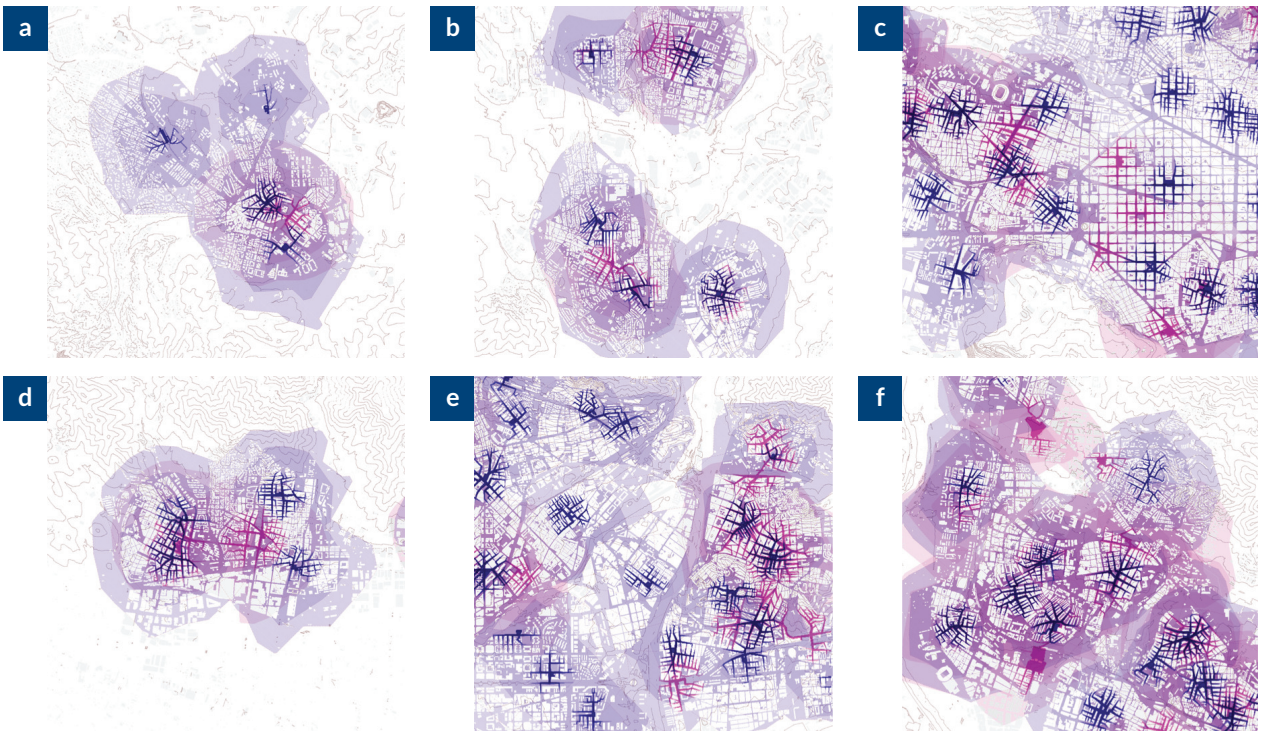

Figure 3. Six fragments of the closeness map around halls and open-air markets in metropolitan Barcelona, 2025.

4.2. Betweenness in the Food Permanent Infrastructure

The research shows that most market halls have another market at an average minimum distance of 1,280 meters, following pedestrian paths. The closest couple of buildings according to this criterion are 400 meters apart from each other; the pair of markets that are the most distant from each other are 5 kilometers apart. Disregarding the metropolis and considering only the city of Barcelona, the closest at are 600 meters from each other; on the other hand, the furthest pair are 2,200 meters apart.

Figure 4 highlights six fragments—5,000 by 5,000 meters—of Figure 2 in more detail, so that different hypotheses of civic networks between metropolitan markets are presented: (a) market halls are separated not only by the longest distance of 5 kilometers but also by the topography, which places the shortest pedestrian path to the valley of the river, next to a road and a motorway; (b) distances depicted would enable synergies between the markets of the first two municipalities (separated by 1.6 km) and between those of the second pair (separated by 1.3 and 1.5 km); (c) cluster of market halls belonging to four different municipalities, at distances between 600 and 1,600 meters; (d) networks formed by distances between 400 and 1,600 meters; (e) concentration of clusters formed by groupings of two or three markets in the northeast of the metropolis, which present relative distances between 600 and 1,800 meters; and finally (f) a central fragment of Barcelona is shown in which 18 market halls appear at distances between 700 and 1,800 meters.

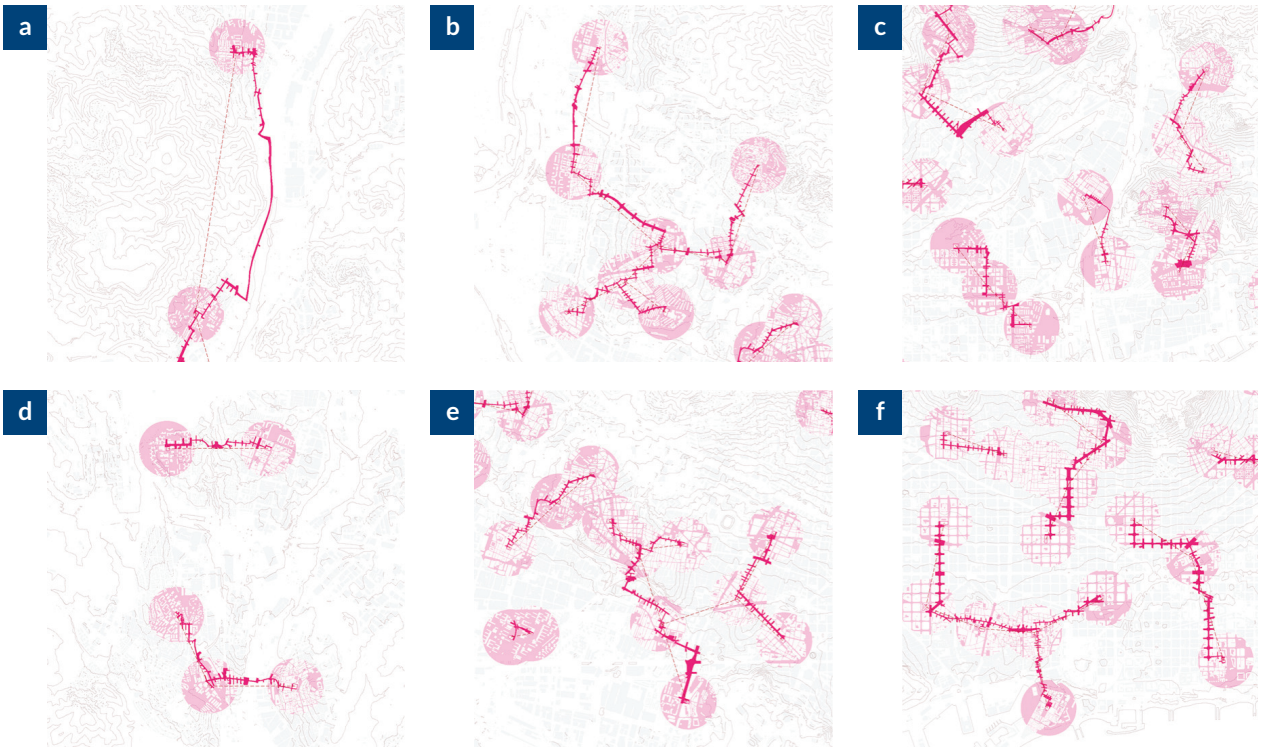

Figure 4. Six fragments of the betweenness map relating market halls and their closest pair in metropolitan Barcelona, 2025.

5. Discussion

The coupling between space and time is present in all steps of the food chain: production, transport, supply, preparation, consumption, and organic waste management. This fact triggered the comparison between meals in an agricultural society and a contemporary society by Ellegård (2018), which in turn exemplified the differences between short- and long-distance societies (Hägerstrand, 1988). The passage of groceries from food providers to households—from collective to domestic pantries—is, in the case of compact urban realities, related to movements on foot and, therefore, to proximity considerations. The understanding of these network dynamics can inform planning strategies that aim to enhance the role of markets as central nodes in both urban and suburban contexts (Fuchs-Chesney et al., 2023). Thus, recognizing and enhancing the intermediary role of markets, particularly in low-connectivity settings, is essential for improving territorial equity in food provision.

The concept of proximity has gained prominence in urban agendas, especially in the wake of the Covid-19 pandemic, which underscored the importance of accessible essential services within neighborhoods (Crosas & Gómez-Escoda, 2020). The "15-minute city" model exemplifies this shift, advocating for urban designs where residents can access most necessities within a short walk or cycle, thereby enhancing livability and sustainability (Klebl et al., 2022). In this context, closeness centrality is a pivotal metric in urban network analysis, quantifying how accessible a particular node is to all others within a network. This measure is instrumental in assessing the spatial integration of locations, thereby informing decisions related to service provision and infrastructure development. Normalized closeness centrality can be used to evaluate the

impact of catchment area locations within idealized urban networks, offering insights into optimal service placement (H.-H. Chen & Dietrich, 2023).

Betweenness centrality, on the other hand, is a key indicator of a node's potential to act as an intermediary in the flow of movement across urban networks, which offers valuable insights into the spatial function of market halls and open-air markets within metropolitan food systems. In dense and compact urban areas, where street networks are more continuous and interlinked, markets positioned at nodes of high betweenness centrality can act as spatial and social connectors, supporting frequent and diversified flows of pedestrians and facilitating efficient access to food (Mehmood et al., 2021). Marketplaces serve not only local neighborhoods but also function as bridging points within larger urban structures, integrating food access into daily mobility patterns, so that retailers situated at nodes with elevated betweenness centrality tend to attract higher footfall due to their strategic placement within the urban grid (Buzzacchi et al., 2021). This positioning not only enhances the accessibility of food resources but also integrates these markets into the daily routines of urban dwellers. Localized betweenness analysis reveals how even within broadly centralized cities, particular sub-centers or market nodes can emerge as key intermediaries depending on street hierarchy and spatial structure (Yamaoka et al., 2021). Conversely, in suburban contexts characterized by fragmented or hierarchical street networks, markets often exhibit lower betweenness centrality, reducing their potential as connectors and limiting multimodal access. Spatial normalization of betweenness metrics is crucial in such areas, where structural decentralization may distort raw centrality values, masking spatial inequities in access (Werner & Loidl, 2023).

From the reading of the resulting maps and tables presented in this article, a characterization of the urban fabric can be depicted that allows an analysis both at the metropolitan and neighborhood scales. First, there are iteration places where proximity routes around the markets branch out through the municipalities, crossing without overlapping with any main road itinerary. Second, the distribution of food suppliers reflects a morphological reading in which various urban patterns are visible: the regular grids of the 19th-century and modern city extensions; the irregular radial plots typical of the old population centers; the sinuous plots that follow contour lines in areas where the topography is more accentuated; or the unique plots of residential estates, made up of isolated blocks. Third, some asymmetrical and distorted routings reflect the lack of permeability and the discontinuities of the urban fabric as a result of its proximity to large territorial roads, railways, and water infrastructures. Fourth, some food oases are identified, where a clear concentration of permanent and temporary markets in certain areas can serve as a valuable tool for prioritizing streets that could be pacified or redeveloped due to their role as a concentration of essential services. This observation may help guide the consolidation of new shortest pedestrian paths with a certain potential for urban structuring. Ultimately, the existence of food deserts, understood as areas in which procurement cannot be resolved on foot, has been identified. This phenomenon contributes to the exacerbation of inequalities among residents by impeding the guarantee of a sufficient food supply within walking distance.

The research presents some limitations, both from a methodological and a conceptual perspective, to be implemented in future studies. Among them, it is worth mentioning some data that would be decisive to qualify the above observations. For instance, convenience stores have not been considered in this regard. However, in the smallest municipalities, it is more probable that the supply will be provided by a corner store than by a public market. This omission is partly due to the lack of an updated database (the research is based on the latest open census, dated 2014), which would allow for a more accurate automation of calculations

and proximity distances. Furthermore, the escalating costs of goods in the most central and tourist-pressured areas of the metropolis have not been considered. These areas have experienced a notable increase in prices, which has led to the transformation of marketplaces into catalysts for gentrification. This has resulted in a distortion of their original function of supplying essential goods. Additionally, the temporal parameters of market opening hours, which are considerably more constrained than those observed in convenience stores, have not been duly considered. Moreover, the data have not been filtered according to the days of the week, considering all markets—both halls and open-air—in absolute terms. This is in contrast to the more comprehensive service provided by market halls as opposed to temporary markets. Finally, recognising the pivotal role of markets in connecting food production and consumption, a more thorough examination of spatial and socio-economic dynamics would enhance the study's contribution to urban food planning.

Despite the mentioned shortcomings, the preliminary findings of this research can be used to develop targeted interventions in different urban contexts. First, in areas that do not seem to meet the theoretical conditions for a balanced food supply, policies should focus on improving the conditions by proposing new nodes for the provision of food. Second, in areas that already present a considerable potential for well-balanced food procurement, efforts should be directed at reinforcing new synergies between existing elements, or solutions could be implemented in the set to increase its efficiency, and guarantee that vital spaces are not triggering dynamics of social exclusion.

6. Conclusion

Food supply is an essential daily activity, historically linked to the origins of urban development and serving as a thermometer of cultural differences and social inequalities in contemporary metropolises. In the contemporary context, there is an economic and technological evolution towards life models based on living models that are not dependent on food purchases. Concurrently, there has been an increase in inequalities, especially since the onset of the pandemic, which has resulted in heightened food insecurity.

This has led to an urgent need for planners and designers to directly engage in the establishment of tools that promote equal and fair access to food. Reading and measuring the food supply system in relation to urban fabrics and households is considered essential to detect weaknesses and opportunities in the food supply system. Despite the fact that this study is grounded in a concrete reality, the methodology for measuring supplier proximity can be replicated in other realities. Moreover, the comprehensive analysis is expected to enhance the supply infrastructure in Barcelona by proposing new nodes for food distribution, establishing novel synergies between existing system components, and implementing corrective measures to enhance overall efficiency.

Acknowledgments

The authors would like to express gratitude to Professor Pere Fuertes, co-author of several research papers related to this work, for facilitating a fruitful discussion that significantly contributed to the development of the research on food supply systems developed since 2018. Elisabet Martí, an architecture student, contributed to the research by collecting data and drawing the first drafts of the graphics presented in the article. Lluís Frago and Alex Morcuende provided insightful contributions during the URBANSOSTEN research project, which have significantly enhanced this article.

Funding

This investigation is part of URBANSOSTEN-LOCALRETAILBCN – Sostenibilitat urbana i comerç de proximitat a Barcelona i la seva àrea metropolitana (Urban sustainability and local commerce in Barcelona and its metropolitan area), an 18-month research project funded by Ajuntament de Barcelona and La Caixa Foundation.

Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

References

Ajuntament de Barcelona. (2021). *Sustainable food*. https://www.alimentaciosostenible.barcelona/en

Almanza, E., Jerrett, M., Dunton, G., Seto, E., & Pentz, M. A. (2012). A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data. *Health & Place*, *18*(1), 46–54. https://doi.org/10.1016/j.healthplace.2011.09.003

Anandhi, A., Usher, K. M., Gragg, R. S., & Jiru, M. (2025). Urbanizing food systems: Exploring the interactions of food access dimensions for sustainability. *Frontiers in Sustainable Food Systems*, *9*, Article 1410324. https://doi.org/10.3389/fsufs.2025.1410324

Àrea Metropolitana de Barcelona. (2014). *Atles de l'estructura urbana comercial metropolitana*. https://estructuraurbanacomercial.amb.cat

Àrea Metropolitana de Barcelona. (2025). *Geoportal de cartografia*. https://geoportalcartografia.amb.cat/AppGeoportalCartografia2/index.html

Barton, H., & Grant, M. (2006). A health map for the local human habitat. *The Journal of the Royal Society for the Promotion of Health*, *126*(6), 252–253. https://doi.org/10.1177/1466424006070466

Boncinelli, L., Miricola, S., & Vicario, E. (2025). *Quantifying walkable accessibility to urban services: An application to Florence, Italy*. arXiv. https://doi.org/10.48550/arXiv.2504.12934

Bongiorno, C., Zhou, Y., Kryven, M., Theurel, D., Rizzo, A., Santi, P., Tenenbaum, J. B., & Ratti, C. (2021). Vector-based pedestrian navigation in cities. *Nature Computational Science*, *1*(10), 678–685. https://doi.org/10.1038/s43588-021-00130-y

Bose, P. S. (2024). Getting people to food and food to people: Considering transportation barriers and food access in the future of food. *Geographical Review*, *115*(1/2), 117–137. https://doi.org/10.1080/00167428.2024.2383459

Boz, H. A., Bahrami, M., Balcisoy, S.,Bozkaya, B., Mazar, N., Nichols, A., & Pentland, A. (2024). Investigating neighborhood adaptability using mobility networks: A case study of the Covid-19 pandemic. *Humanities and Social Sciences Communications*, *11*, Article 397. https://doi.org/10.1057/s41599-024-02881-1

Busquets, J. (2005). *Barcelona: The urban evolution of a compact city*. Nicolodi.

Buzzacchi, L., Leveque, P., Taramino, R., & Zotteri, G. (2021). Using betweenness metrics to investigate the geographical distribution of retailers. *Environment and Planning B: Urban Analytics and City Science*, *48*(8), 2221–2238. https://doi.org/10.1177/2399808320971303

Carmona, M. (2018). Place value: Place quality and its impact on health, social, economic, and environmental outcomes. *Journal of Urban Design*, *24*(1), 1–48. https://doi.org/10.1080/13574809.2018.1472523

Chen, H.-H., & Dietrich, U. (2023). Normalized closeness centrality of urban networks: Impact of the location

of the catchment area and evaluation based on an idealized network. *Applied Network Science*, *8*, Article 60. https://doi.org/10.1007/s41109-023-00585-0

Chen, Z., & Huang, B. (2024). Achieving urban vibrancy through effective city planning: A spatial and temporal perspective. *Cities*, *152*, Article 105230. https://doi.org/10.1016/j.cities.2024.105230

Crosas, C., & Gómez-Escoda, E. (2020). Mapping food and health premises in Barcelona: An approach to logics of distribution and proximity of essential urban services. *International Journal of Geo-Information*, *9*(12), Article 746. https://doi.org/10.3390/ijgi9120746

Curado, M., Tortosa, L., Vicent, J. F., & Yeghikyan, G. (2020). Analysis and comparison of centrality measures applied to urban networks with data. *Journal of Computational Science*, *43*, Article 101127. https://doi.org/10.1016/j.jocs.2020.101127

Dubowitz, T., Ghosh-Dastidar, M., Eibner, C., Slaughter, M. E., Fernandes, M., Whitsel, E. A., Bird, B., Jewell, A., Margolis, K. L., Li, W., Michael, Y. L., Shih, R. A., Manson, J. E., & Escarce, J. J. (2012). The Women's Health Initiative: The food environment, neighborhood socioeconomic status, BMI, and blood pressure. *Obesity*, *20*(4), 862–871. https://doi.org/10.1038/oby.2011.141

Dumas, B. L., Harris, D. M., McMahon, J. M., Daymude, T. J., Warnock, A. L., Moore, L. V., & Onufrak, S. J. (2021). Prevalence of municipal-level policies dedicated to transportation that consider food access. *Preventing Chronic Disease*, *18*, Article 210193. https://doi.org/10.5888/pcd18.210193

Ellegård, K. (2018). *Thinking time geography: Concepts, methods and applications*. Routledge.

Esmaeilidouki, A., Rambe, M., Ardestani-Jaafari, A., Li, E., & Marcolin, B. (2023). Food bank operations: Review of operation research methods and challenges during Covid-19. *BMC Public Health*, *23*, Article 1783. https://doi.org/10.1186/s12889-023-16269-4

Eurostat. (2024). *Household consumption by purpose*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Household_consumption_by_purpose

Faedda, S., Plaisant, A., Talu, V., & Tola, G. (2022). The role of urban environment design on health during the Covid-19 pandemic: A scoping review. *Frontiers in Public Health*, *10*, Article 791656. https://doi.org/10.3389/fpubh.2022.791656

Felici, F. B., & Mazzocchi, G. (2022). Territory matters: A methodology for understanding the role of territorial factors in transforming local food systems. *Land*, *11*(7), Article 1046. https://doi.org/10.3390/land11071046

Food and Agriculture Organization. (1996). *Report of the World Food Summit*. https://www.fao.org/4/x0736m/x0736m00.htm

Freedman, D. A., & Bell, B. A. (2009). Access to healthful foods among an urban food insecure population: Perceptions versus reality. *Journal of Urban Health*, *86*(6), 825–838. https://doi.org/10.1007/s11524-009-9408-x

Fuchs-Chesney, J., Raj, S., Daruwalla, T., & Brinkley, C. (2023). All roads lead to the farmers market?: Using network analysis to measure the orientation and central actors in a community food system through a case comparison of Yolo and Sacramento County, California. *Agriculture and Human Values*, *40*, 157–173. https://doi.org/10.1007/s10460-022-10345-y

Fuertes, P., & Gómez-Escoda, E. (2020). Supplying Barcelona: The role of market halls in the construction of the urban food system. *Journal of Urban History*, *48*(5), 1121–1139. https://doi.org/10.1177/0096144220971821

Fushimi, T., Okubo, S., & Saito, K. (2020). Multiple perspective centrality measures based on facility location problem under inter-group competitive environment. *Applied Network Science*, *5*, Article 80. https://doi.org/10.1007/s41109-020-00326-7

García, X., García-Sierra, M., & Domène, E. (2020). Spatial inequality and its relationship with local food environments: The case of Barcelona. *Applied Geography*, *115*, Article 102140. https://doi.org/10.1016/j.apgeog.2019.102140

Gómez-Escoda, E. (2025). Shaping equitable access to food: Barcelona's supply planning and policies in perspective. *Urban Planning*, *10*, Article 9489. https://doi.org/10.17645/up.9489

Gómez-Escoda, E., & Fuertes, P. (2022). Proximity and temporality: the role of weekly markets in the metropolitan food system of Barcelona. In *XXIX International Seminar on Urban Form: Urban redevelopment and revitalisation: A multidisciplinary perspective. Proceedings* (pp. 379–391). Lodz University of Technology. https://doi.org/10.34658/9788367934039.30

Gómez-Varo, I., Delclòs-Alió, X., Miralles-Guasch, C., & Marquet, O. (2023). Unravelling retail diversity through its spatial relationship with social vulnerability and tourism pressures in Barcelona. *Journal of Urban Design*, *29*(3), 280–300. https://doi.org/10.1080/13574809.2023.2245761

Goossensen, M., García, X., García-Sierra, M., Calvet-Mir, L., & Domène, E. (2023). The role of convenience stores in healthy food environments: The case of Barcelona (Spain). *Cities*, *133*, Article 104118. https://doi.org/10.1016/j.cities.2022.104118

Gracia-Arnaiz, M., García-Oliva, M., & Campanera, M. (2021). Food itineraries in the context of crisis in Catalonia (Spain): Intersections between precarization, food insecurity, and gender. *Social Sciences*, *10*(10), Article 352. https://doi.org/10.3390/socsci10100352

Guàrdia, M., & Oyón, J. L. (Eds.). (2010). *Fer ciutat a través dels mercats*. MUHBA, Ajuntament de Barcelona; Institut de Cultura.

Hägerstrand, T. (1988). *Krafter som format det svenska kulturlandskapet. Mark och vatten år 2010*. Bostadsdepartementet.

Herrero, A., Carrascosa, M., & López, D. (2022). El reto de Barcelona para la buena alimentación y el clima: Un compromiso para abordar la salud global y el clima desde los sistemas alimentarios locales. *Revista Ae*, *49*. https://revista-ae.es/reto-barcelona-alimentacion-clima-sistemas-alimentarios-locales

Horvath, C., Koning, M., Raton, G., & Combes, F. (2024). Short food supply chains: The influence of outlet and accessibility on farmer and consumer preferences. Two discrete choice experiments. *Food Policy*, *129*, Article 102763. https://doi.org/10.1016/j.foodpol.2024.102763

Institut d'Estadística de Catalunya. (2024a). *Cens de població i habitatges*. https://www.idescat.cat/pub/?id=censph

Institut d'Estadística de Catalunya. (2024b). *Població de Catalunya georeferenciada*. https://betaserver.icgc.cat/poblacio-catalunya

Jabareen, Y., & Eizenberg, E. (2021). The failure of urban forms under the Covid-19 epidemic: Towards a more just urbanism. *Town Planning Review*, *92*(1), 57–63. https://doi.org/10.3828/tpr.2020.42

Kaaronen, R. O., & Strelkovskii, N. (2020). Cultural evolution of sustainable behaviors: Pro-environmental tipping points in an agent-based model. *One Earth*, *2*(1), 85–97. https://doi.org/10.1016/j.oneear.2020.01.003

Kesarovski, T., & Hernández-Palacio, F. (2022). Time, the other dimension of urban form: Measuring the relationship between urban density and accessibility to grocery shops in the 10-minute city. *Environment and Planning B: Urban Analytics and City Science*, *50*(1), 44–59. https://doi.org/10.1177/23998083221103259

Klebl, F., Walthall, B., & Vicente-Vicente, J. L. (2022). Planning for sustainable food communities: An optimal spatial allocation study of food hubs considering the 15-min city concept—The case of *LebensMittelPunkte* in Berlin. *Frontiers in Sustainable Food Systems*, *6*, Article 913412. https://doi.org/10.3389/fsufs.2022.913412

Marquet, O., & Miralles-Guasch, C. (2015). The walkable city and the importance of the proximity environments for Barcelona's everyday mobility. *Cities*, *42*, 258–266. https://doi.org/10.1016/j.cities.2014.10.012

Mehmood, M. S., Li, G., Jin, A., Rehman, A., Wijeratne, V. P. I. S., Zafar, Z., Khan, A.R., & Khan, F.A. (2021). The spatial coupling effect between urban street network's centrality and collection & delivery points: A spatial design network analysis-based study. *PLoS ONE*, *16*(5), Article e0251093. https://doi.org/10.1371/journal.pone.0251093

Miller, M. (2015). *Feeding Barcelona, 1714-1975: Public market halls, social networks, and consumer culture*. Louisiana State University Press.

Morgan, K. (2009). Feeding the city: The challenge of urban food planning. *International Planning Studies*, *14*(4), 341–348. https://doi.org/10.1080/13563471003642852

Murtagh, E. M., Mair, J. L., Aguiar, E., Tudor-Locke, C., & Murphy, M. H. (2020). Outdoor walking speeds of apparently healthy adults: A systematic review and meta-analysis. *Sports Medicine*, *51*(1), 125–141. https://doi.org/10.1007/s40279-020-01351-3

Pascual, H., & Guerra, J. C. (2024). Territory in urban food policies: The case of Spain. *Frontiers in Sustainable Food Systems*, *8*, Article 1359515. https://doi.org/10.3389/fsufs.2024.1359515

Pechey, R., Hollands, G. J., Reynolds, J. P., Jebb, S. A., & Marteau, T. M. (2022). Is altering the availability of healthier vs. less-healthy options effective across socioeconomic groups? A mega-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *19*, 88. https://doi.org/10.1186/s12966-022-01315-y

Pothukuchi, K., & Kaufman, J. L. (2000). The food system. A stranger to the planning field. *Journal of the American Planning Association*, *66*(2), 113–124. https://doi.org/10.1080/01944360008976093

Puigjaner, A. (2015). *Kitchenless city: Architectural systems for social welfare* [Unpublished doctoral dissertation]. Universitat Politècnica de Catalunya. https://www.tdx.cat/handle/10803/279387

Quintero, M. C., & Restrepo, M. (2023, June 13). Urban food security: The role of cities in food supply. *Inter-American Development Bank*. https://blogs.iadb.org/ciudades-sostenibles/en/urban-food-security-the-role-of-cities-in-food-supply

Recine, E., Preiss, P. V., Valencia, M., & Zanella, M. A. (2021). The indispensable territorial dimension of food supply: A view from Brazil during the Covid-19 pandemic. *Development*, *64*(3/4), 282–287. https://doi.org/10.1057/s41301-021-00308-x

Rydin, Y., Bleahu, A., Davies, M., Dávila, J. D., Friel, S.,De Grandis, G. & Groce, N., Hallal, P. C., Hamilton, I., Howden-Chapman, P., Lai, K. Lim, C. J., Martins, J., Osrin, D., Ridley, I., Scott, I., Taylor, M., Wilkinson, P., & Wilson, J. (2012). Shaping cities for health: Complexity and the planning of urban environments in the 21st century. *The Lancet*, *379*(9831), 2079–2108. https://doi.org/10.1016/S0140-6736(12)60435-8

Sede Electrónica del Catastro. (2025). *Buscador de inmuebles y visor cartográfico*. https://www.sedecatastro.gob.es

Sevtsuk, A. (2020). *Street commerce: Creating vibrant urban sidewalks*. University of Pennsylvania Press.

Sevtsuk, A., Kalvo, R., & Ekmekci, O. (2016). Pedestrian accessibility in grid layouts: The role of block, plot, and street dimensions. *Urban Morphology*, *20*(2), 89–106. https://doi.org/10.51347/jum.v20i2.4056

Shi, X., Liu, D., & Gan, J. (2024). A study on the relationship between road network centrality and the spatial distribution of commercial facilities—A case of Changchun, China. *Sustainability*, *16*(10), Article 3920. https://doi.org/10.3390/su16103920

Siri, J. G. (2016). Sustainable, healthy cities: Making the most of the urban transition. *Public Health Reviews*, *37*(1), Article 22. https://doi.org/10.1186/s40985-016-0037-0

Sonnenschein, T. S., Scheider, S., & Zheng, S. (2022). The rebirth of urban subcenters: How subway expansion

impacts the spatial structure and mix of amenities in European cities. *Environment and Planning B: Urban Analytics and City Science*, *49*(4), 1266–1282. https://doi.org/10.1177/23998083211056955

Thompson, C., & Smith, D. (Eds.). (2025). Understanding change in urban food environments: The contemporary challenges of conceptualization, definition, and measurement [Thematic issue]. *Urban Planning*, *10*.

Turner, C., Kalamatianou, S., Drewnowski, A., Kulkarni, B., Kinra, S., & Kadiyala, S. (2020). Food environment research in low- and middle-income countries: A systematic scoping review. *Advances in Nutrition*, *11*(2), 387–397. https://doi.org/10.1093/advances/nmz031

Valls, F., & Clua, Á. (2023). Modeling Barcelona sidewalks: A high-resolution urban scale assessment of the geometric attributes of the walkable network. *PLoS ONE*, *18*(7), Article e0284630. https://doi.org/10.1371/journal.pone.0284630

Werner, C., & Loidl, M. (2023). Betweenness centrality in spatial networks: A spatially normalized approach. In R. Beecham, J. A. Long, D. Smith, Q. Zhao, & S. Wise (Eds.), *Proceedings of the 12th International Conference on Geographic Information Science (GIScience 2023)* (Article 83). Schloss Dagstuhl – Leibniz-Zentrum für Informatik. https://doi.org/10.4230/LIPIcs.GIScience.2023.83

Yamaoka, K., Kumakoshi, Y., & Yoshimura, Y. (2021). *Local betweenness centrality analysis of 30 European cities*. arXiv. https://doi.org/10.48550/arXiv.2103.11437

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