Distribution of Spatial Inequalities Across Social Groups: a Case Study of Messina, Italy

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Abstract. In response to contemporary urban crises, including social inequality, environmental degradation, and climate change, the 15-min city has emerged as a promising framework for fostering equity, social cohesion, resilience, and sustainability. Rooted in chrono-urbanism, this model seeks to improve quality of life by reducing travel time to essential urban functions. However, existing studies have largely focused on spatial accessibility, often overlooking broader dimensions of social justice such as digital inclusion, recognitional justice, and procedural participation. Addressing these gaps, this study adopts Fainstein's reform-oriented perspective on social justice and examines the extent to which existing cities comply with the principles of diversity, distributional equity, digital inclusion, and participation. To this end, it develops a quantitative and replicable methodology combining spatial and configurational analysis to assess access to eight categories of fundamental services, political participation, diversity, socio-economic disadvantage, and digital inclusion across six population groups differentiated by age and nationality. The city of Messina, Italy, is used as a case study. The main contribution of the study lies in the development of a composite social justice metric and in the proposal of a transferable evaluation framework capable of supporting transparent, evidence-based governance in the implementation of the 15-min city.

Keywords: 15-min city · social justice · spatial equity · participation · diversity

1 Introduction

Emerging crises affecting contemporary cities, including social inequality, environmental degradation, and climate change, have generated the need for a spatial reorganization of urban systems. Within this context, the 15-min city (15MC) concept has emerged as a relevant model promoting equity, social cohesion, resilience, and sustainability in urban areas. Grounded in the concept of chrono-urbanism, the 15-min city model posits that quality of life is closely related to patterns of time use and can be improved by reducing the time required to travel in order to access fundamental urban functions [1–5]. Consequently, the model envisions an organization of urban areas in which essential functions are located within a radius corresponding to a travel time of approximately 15 min on foot or by bicycle from one's residence [4, 5]. In this perspective, the conceptualization of the 15-min city incorporates principles associated with social justice: equity, understood as the fair distribution of resources; diversity, referring to the co-presence and

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inclusion of different identities, cultures, and social groups; and participation, intended as the transparency and inclusiveness of governance and political processes [6].

Nevertheless, emerging critiques of the 15-min city concept observe that only a limited number of studies explicitly investigate the justice implications of the model, and that even those addressing the topic often do not ground their analyses in established conceptualizations of social justice. Moreover, additional critiques underline the insufficient consideration of the social, economic, and political factors determining injustice, as well as the predominant focus on spatial inequalities related to service distribution and accessibility. This emphasis tends to disregard complementary dimensions of justice, including exclusion resulting from the digital divide, recognitional justice, and procedural justice [6]. To address these limitations, the study builds on the liberal, reform-oriented perspective on social justice advanced by Fainstein [7] – based on a conceptualization of social justice around the dimensions of equity, democracy, and diversity - and investigates a specific question: to what extent existing cities are compliant with principles of diversity, distributional equity, digital inclusion and participation?

To answer this question, the proposed study develops a quantitative method that utilizes spatial analysis and configurational analysis to evaluate levels of access to eight categories of fundamental services, political participation levels, diversity, socio-economic disadvantage, and digital inclusion, across six distinct population groups defined by age and nationality. The city of Messina, in Italy, is selected as a case study. The relevance and novelty of the contribution lie in several distinct aspects. First, it contributes to the operationalisation of social justice, as conceptualised by Fainstein, by developing a composite spatial metric that integrates the dimensions of participation, digital divide, diversity, socio-economic disadvantage, and spatial equity.

Second, it proposes a replicable, robust, and transferable procedure for evaluating conditions of spatial justice across urban areas and urban populations. The objective is to foster transparent and evidence-based governance processes in the implementation of the 15-min city model - in order to mitigate the risk of reproducing forms of marginalisation and inequality - by enabling the understanding of conditions of intra-urban disparities. The article is structured into six sections. After the introduction, Sect. 2 elaborates on the conceptual foundations, while Sect. 3 details the proposed methodology. Section 4 provides an overview of the results, which are subsequently examined in Sect. 5. The Conclusions summarize the principal findings and offer suggestions for future research directions.

2 Literature Review

2.1 Definitions of Social Justice

Ensuring justice in decisions related to spatial transformations represents a central concern of urban policies [8]. Justice is not only a fundamental policy objective in itself, but the claim of pursuing an equitable distribution of benefits and disadvantages also confers legitimacy on policy decisions. In this context, the notion of social justice has emerged as a central analytical and normative concept for evaluating urban policies and spatial planning processes. Social justice focuses on the effect of social structures in reproducing or mitigating inequalities across the dimensions of resource distribution, inclusivity

of political processes, and recognition of diversity [6]. The definition of social justice has evolved, over time, from a predominant focus on distributional equity to broader conceptualizations integrating aspects of procedural and recognitional justice. The recent literature identifies multiple definitions of social justice, including utilitarian, liberal egalitarian, Marxist, and libertarian perspectives.

A Marxist perspective is intrinsic to definitions of social justice advanced by Marcuse and Lefebvre. Marcuse [9] identifies specific spatial aspects of injustice – namely confinement and unequal distribution of resources – and conceptualizes spatial injustice as a derivative of social injustice determined by specific social, political, and economic conditions. Lefebvre's notion of the right to the city [10] underlines individuals' entitlement to participate in decisions structuring urban space and to access and produce spaces responding to social needs. Similarly, Harvey [11] argues for the incorporation of social justice considerations into procedures addressing locational problems, proposing the operationalization of concepts such as need, contribution to the general good, and merit as criteria for favouring just distributions of spatial resources.

A critical liberal egalitarian perspective is advanced by Rawls and developed in urban studies by Soja and Fainstein. Rawls conceptualizes justice in terms of the equitable distribution of resources and goods. Building on this perspective, Soja focuses on the spatial dimension of justice/ injustice and conceptualizes spatial injustice both as an outcome - manifested in uneven distributional configurations - and as the set of processes that produce injustice via the organization and control of space [12–14].

Fainstein's concept of the Just City [7] contributes to the operationalization of spatial justice by proposing justice as the normative principle guiding urban policies. In this context, democracy, equity, and diversity constitute the fundamental principles of urban justice [7].

The present study adopts a liberal perspective, which underlies many empirical studies investigating spatial inequalities in the distribution of urban amenities and infrastructures, namely transport systems [15], Services of General Interest [16–18], and natural and semi-natural spaces[19]. Within this perspective, the question of spatial justice is intrinsic to recent urban concept, particularly the 15MC and the x-minute City, as observed by Murgante et al. [16–18].

2.2 The 15-Minute City Concept

The concept of the 15-min city (15MC) - more broadly framed as the x-minute city [20]- was introduced by Moreno in 2016 [2, 5, 21] and has been adopted by municipal governments and transnational initiatives as a model for adapting cities to emerging crises including climate alteration, environmental degradation and social injustice. Examples include initiatives promoted by the C40 Cities initiative and the implementation of related policies in several cities, including Milan, Paris, Bogotá, Portland, and Melbourne [22, 23].The 15MC concept refers to a model of socio-spatial reorganization of urban areas aimed at ensuring fair access to essential services and urban amenities by promoting active mobility and reducing travel times. The model aims to reorganize urban functions so that fundamental needs can be met within a distance from one's residence corresponding to a travel time of 15 min on foot or by bicycle.

Expected benefits include improvements in quality of life, social inclusion, economic vitality, ecological resilience, and spatial justice [2, 16–18, 24–26].

Moreno identifies four central criteria for the implementation of the 15MC: proximity, density, diversity, and digitalization. Proximity refers to the optimal spatial distribution of urban functions in order to facilitate access to services, while promoting active mobility and reducing dependence on private cars. Diversity concerns the coexistence and integration of varied activities, functions, and social identities at the local scale. Density refers to the optimal number of people per unit area that can be sustained in terms of service provision and resource consumption [5, 25]. Finally, digitalization involves the use of Information and Communication Technologies (ICT), Internet of Things (IoT) systems, distributed sensors, and digital twin platforms to optimize service provision, increase transparency and participation in governance processes, promote sustainable mobility solutions, respond to the needs of vulnerable users, and improve the safety, comfort, and usability of public spaces [16–18, 27]. Additional criteria discussed in the literature include trans-scalarity, intermodality, adaptability, and human-scale urban design [2, 21]. Trans-scalarity refers to the interdependence among different spatial levels - micro, meso, and city scale. Human-scale urban design focuses on the regeneration of public spaces centered on person–environment interactions, and proportion of urban space elements in relation to the human body and its capabilities. Intermodality refers to the integration of public transport systems and active mobility solutions. Criteria of decentralization and diversity of urban functions, proximity of Services of General Interest, optimization of density, access to natural and semi-natural spaces, compact urban structure, and the prioritization of active mobility and pedestrian-oriented development are also central to several earlier urban models. These include the Neighbourhood Unit Concept (NUC) [28], Transit-Oriented Development (TOD) [29, 30], New Urbanism [31], neo-traditionalist design concepts [32], multi-fractal urban models [33], and the conceptualizations of urbanity and urban vitality advanced by Jane Jacobs [34], Christopher Alexander [35], and Jan Gehl [36].

Considering these antecedents, the 15-min city does not represent an entirely new paradigm. Rather, it can be interpreted as a contemporary operational reframing of consolidated principles and longstanding normative aspirations concerning proximity, mixed-use development, and human-scale urbanism. Moreover, the 15-min city model has been subject to significant criticism. The most prominent critiques concern the conceptual framing of the model, inconsistencies in the quantitative methods employed to operationalize and measure its foundational dimensions, and questions regarding its practical feasibility [37–39]. Lastly, critical perspectives underline the inadequate conceptualization and operationalization of social justice aspects and the risk that the implementation of the model may reproduce or exacerbate existing socio-spatial inequalities [37, 40].

3 Methodology

The study advances a quantitative method that combines spatial and configurational analysis to compute a composite metric capturing factors of social injustice and to assess levels of distributional equity, digital inclusion, participation, socio-economic status,

and diversity across six distinct population groups. The procedure is organised into four stages: (i) data collection; (ii) selection and computation of indicators; (iii) computation of a composite spatial justice metric; and (iv) estimation of the distribution of adequate spatial justice conditions across urban population groups. The procedure is applied to the urban area of Messina (Fig. 1), which provides an appropriate empirical setting for examining socio-spatial inequality through the interpretive lens of the 15-min city. Messina is a medium-sized city located at the north-eastern tip of Sicily. Covering approximately 213.75 km^2 and with a population of 216,566 inhabitants, the city combines a relatively dispersed municipal territory with a dense urban core structured around the port, the waterfront, and the main axes of connection across the Strait.

Its contemporary spatial configuration is strongly influenced by the post-1908 reconstruction, which introduced a rationalized street layout and new building typologies, partly replacing the pre-existing historical fabric. Subsequent planning phases, including the 1976 Tekne plan, the 2002 master plan, and the current updating of the Urban Plan (PRG), have further contributed to uneven patterns of urban growth, land consumption, and access to services. These characteristics make Messina a highly relevant case study for investigating conditions of social injustice through the interpretive lens of the 15-min city. Specifically, the city's complex relationship between topography, coastal infrastructure, neighbourhood distribution, public space, and service provision offers a useful setting for assessing whether everyday urban opportunities - such as accessibility to essential services, mobility options, and collective facilities - are equitably distributed across different populations and areas. In this perspective, Messina can be understood as a critical urban laboratory in which historical legacies, spatial fragmentation, and contemporary planning challenges intersect, making visible the territorial dimensions of socio-spatial inequality.

3.1 Data Collection

Data are retrieved from open data platforms to ensure the replicability and reproducibility of the analysis. Population data at the census tract level - including the total number of residents and the number of residents by age, gender, education level, employment status, and nationality - are obtained from the 2021 Census provided by the Italian National Institute for Statistics [41]. Concerning Services of General Interest, the categories considered include: grocery stores; pharmacies; secondary schools; public transport stops; green areas; retail activities (including bookshops, clothing stores, and personal care retail); general services (including post offices and banks); and food and beverage service activities. Points of Interest (POI) data are collected from Google Maps using the G Maps Extractor browser extension (version 2.4.7).

Google Maps is adopted as the primary data source for Services of General Interest (SGIs) due to its extensive spatial coverage, enhancing the transferability and replicability of the proposed procedure. Nevertheless, data derived from Google Maps may present limitations related to accuracy, completeness, and classification consistency [42]. Data on educational services are obtained from the Italian Ministry of Education platform. Data are georeferenced and verified for positional accuracy. Spatial data on green areas are retrieved from the OpenStreetMap platform and from the land use–land cover layer of the Urban Atlas service of the Copernicus platform. Points representing access to urban

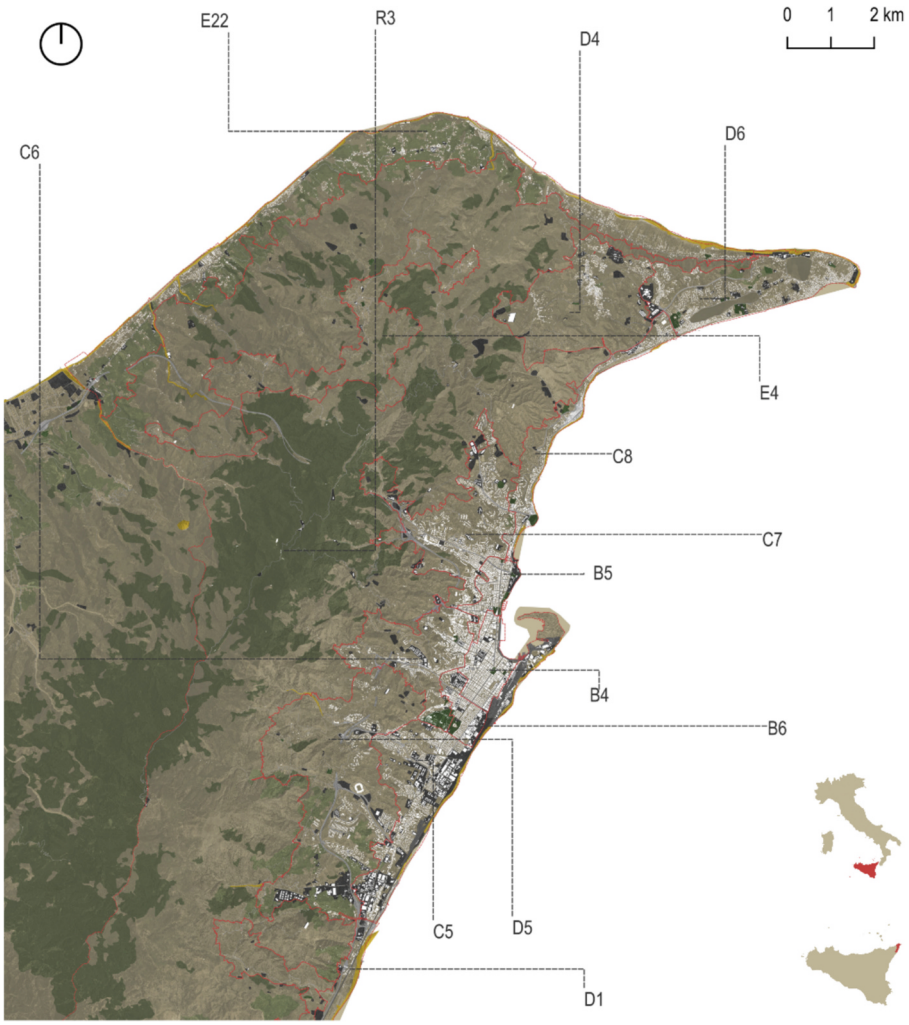

Fig. 1. Description of the study area: the urban area of Messina.

green areas are generated by intersecting the perimeters of green spaces with segments representing pedestrian and cycling routes; resulting points are retained as destination locations. The urban area is partitioned into 16 zones according to the classification of the Real Estate Market Observatory (OMI) of the Italian Revenue Agency. These zones are categorised as: B - central areas; C - semi-central areas; D - suburban areas; E - peri-urban areas; and R - rural areas. This classification is adopted here as a spatial proxy to capture intra-urban variation in spatial and socio-economic conditions.

The system of urban roads, and streets is represented as a segment map derived from a road centreline dataset retrieved from the OpenStreetMap platform. The road centreline layer is verified for topological errors and edited by removing geometries

representing spaces unsuitable for pedestrian or cycling mobility. In particular, segments labeled as motorway, trunk, service roads, and tracks are excluded. The remaining lines are converted into segments using the Place Syntax Tool by partitioning geometries at intersections. The resulting segment map is then verified to identify and remove isolated segments. Regarding broadband service availability, data on expected download speed at the 20 m grid cell level are retrieved from the dataset provided by the Italian Communications Regulatory Authority (AGCOM) [43]. For civic participation, voter turnout data are obtained from the open data platform of the Municipality of Messina. The number of registered voters and the number of actual voters in the most recent election are aggregated at the electoral section level. Voter turnout is used as an indicator of local levels of civic participation.

Lastly, data on socio-economic disadvantage are retrieved from the dataset provided by the Italian National Institute of Statistics (ISTAT), which identifies census tracts categorized as areas of socio-economic vulnerability. These areas are defined by aggregating contiguous census tracts with similar socio-economic conditions, measured via the IDISE metric - a composite indicator based on nine variables representing fundamental dimensions of socio-economic disadvantage. Socio-economic disadvantage is defined as a condition of inadequate access to social, economic, employment, and educational resources that prevents individuals from meeting their basic needs.

3.2 Selection and Computation of Indicators

Five dimensions of spatial justice - namely distributional equity, diversity, socio-economic status, civic participation, and digital inclusion - are operationalised in terms of five binary variables computed at the census tract level. Each variable assumes a value of 1 when a predefined condition of justice is satisfied and 0 when a condition of injustice is observed.

For the dimension of distributional equity, the minimum requirement is that at least two destinations for each category of Services of General Interest are located within a distance of 800 m from each census tract. The minimum value of two accessible destinations is adopted to account for a basic level of choice and redundancy in service availability. The number of accessible destinations within the predefined radius of 800 m is computed using the Attraction Reach function of the Place Syntax Tool, which measures the number of points of interest located within a specified network distance along the segment map. The 800m threshold is adopted to measure access to Services of General Interest (SGIs) within the 15-min city perspective, as 800 m approximately correspond to a travel time of 15 min at a speed of 3 km/h. This value is used as a conservative estimate of pedestrian movement across different population groups. For each service category, a destination attractiveness index is computed for every point of interest by combining three variables: (i) service quality, measured as the product of the number of user reviews and the average user rating; (ii) angular integration at a radius of 1000 m of the closest street segment; (iii) distance from infrastructural barriers.

These variables are selected to represent the intrinsic quality of destinations and the ease of pedestrian access to each point of interest. In particular, local angular integration is used as a metric of pedestrian accessibility, as it measures the relative centrality of street segments within a spatial system and has been positively associated with levels of

pedestrian movement and spatial accessibility in space syntax studies [44, 45]. Angular Integration is computed at a 1000 m radius to represent configurational properties at the neighbourhood scale, whereas the 800 m threshold adopted in the Place Syntax analysis captures local conditions of access to services corresponding to a 15-min travel time. The use of different radii reflects the distinct analytical purposes of the two measures.

The variables are normalised using range standardisation (min–max normalisation) and aggregated via arithmetic averaging to obtain the composite attractiveness index. Only destinations with index values above the mean are retained to ensure that access is evaluated with respect to destinations of adequate and comparable attractiveness. Civic participation is operationalised in terms of voter turnout in the most recent election. The condition of civic participation is considered satisfied when voter turnout in the closest electoral section is equal to or greater than 50% of registered voters. This value identifies areas where a minimum level of electoral engagement is observed. The digital divide dimension is operationalised using broadband infrastructure availability. The condition is considered satisfied when an expected broadband download speed of at least 1000 Mbps is available across at least 80% of the surface area of each census tract. This criterion ensures that advanced digital infrastructure is accessible to the majority of the tract area. Socio-economic disadvantage is evaluated using the IDISE index provided by the Italian National Institute of Statistics (ISTAT). The condition is considered satisfied when a census tract is not included within areas classified by ISTAT as zones of socio-economic disadvantage. Lastly, social diversity is measured through a multidimensional index computed at the census tract level. For each tract, Simpson's diversity index is calculated separately for age structure, educational level, employment status, and nationality across the focal tract and contiguous census tracts. The four dimension-specific scores are then normalised and aggregated through arithmetic averaging to obtain a composite indicator of multidimensional social diversity. The multidimensional social diversity index is subsequently converted into a binary variable, assuming that a condition of adequate social diversity is satisfied when the index value exceeds the median. Lastly, a composite metric is computed as the sum of the five variables, capturing the simultaneous satisfaction of the conditions of justice. A value of 5 indicates that all conditions are satisfied, whereas a value of 0 denotes the co-presence of five dimensions of social injustice.

3.3 Spatial Justice Across Populations

The final stage of the analysis evaluates the distribution of spatial justice conditions across different population groups. The resident population is classified into six groups defined by nationality and age: Italian residents aged 0–14 years, Italian residents aged 15–64 years, Italian residents aged 65 years and over, foreign residents aged 0–14 years, foreign residents aged 15–64 years, and foreign residents aged 65 years and over.

For each group, the analysis calculates the percentage of individuals residing in census tracts that exhibit adequate conditions of spatial justice across five dimensions: distributional equity, socio-economic status, digital inclusion, civic participation, and diversity. The results of this assessment are presented in the sub-sequent section.

4 Results

The spatial distribution of justice conditions indicates that census tracts presenting adequate conditions across the five selected dimensions are primarily located in the central compact core of the Messina urban area (Fig. 2), comprising zones B4, B5, B6 and the semi-central area C6. However, some census tracts located in central areas - particularly in zone B4 - also present conditions of marginalisation and segregation, in particular resulting from inadequate levels of diversity and civic participation. Census tracts presenting adequate conditions of socio-spatial justice across four out of the five dimensions are mainly situated at the interface between central and semi-central areas, particularly in central zone B4, and along the coastline in the semi-central area C8 and in the suburban zone D6.

Moreover, isolated clusters of census tracts characterized by mild conditions of injustice are located in suburban and peri-urban areas, including zones D1, E1 and E2.

Areas presenting conditions of social injustice ranging from severe to intense (indicator values equal to 1 and 2) are distributed across semi-central, peri-urban and suburban areas. Notably, multiple dimensions of deprivation – related to inadequate service provision, socio-economic status, and limited civic participation - are observed along the interface between central and semi-central areas, particularly between zones B6 and C5.

The distribution of justice conditions across population groups reveals substantial levels of deprivation, as well as distinct configurations of disadvantage affecting specific groups (Fig. 3). In particular, only 16.9% of the resident population can access at least two alternative destinations for each category of service. Similarly, on average only 38% of residents live in diverse census tracts, indicating relatively limited socio-spatial diversity across the study area.

More favorable conditions emerge in other dimensions. With respect to socio-economic status, 92% of individuals reside in areas classified as not vulnerable to socio-economic disadvantage. Positive outcomes are also observed for digital inclusion, with 85.5% of individuals living in areas where at least 80% of the surface is covered by broadband services with a download speed of 1,000 Mbps. Civic participation also presents relatively positive conditions, as 87.6% of individuals reside in census tracts where voter turnout exceeds 50%.

However, the analysis underscores relevant differences across population groups (Table 1). In relation to service provision, the most deprived group is represented by Italian residents aged 0–14 years, whereas foreign residents in the same age group appear to be the least disadvantaged. More precisely, 14.1% of Italian residents aged 0–14 and 35.8% of foreign residents in the same age group reside in areas with adequate levels of access to Services of General Interest.

Regarding socio-economic status, the proportion of individuals living in areas categorized as not disadvantaged varies across groups, ranging from 85.1% among foreign residents aged 65 years and over to 93% among Italian residents in the same age group. Substantial inter-group disparities are also observed in relation to civic participation: 88.4% of Italian residents aged 0–14 years reside in census tracts with voter turnout above 50%, compared to 78.9% of foreign residents aged 65 years and over.

Conditions of digital inclusion also vary across groups. Italian residents aged 15–64 years represent the most disadvantaged group in this dimension, whereas foreign

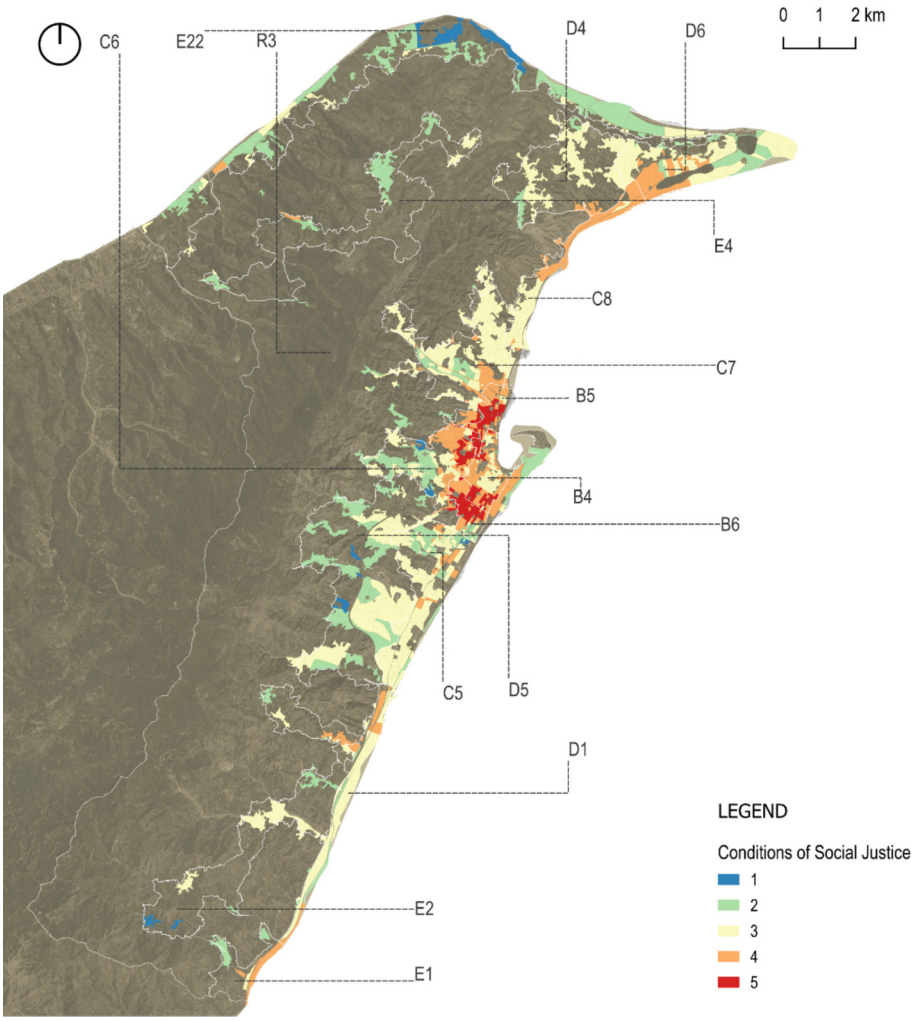

Fig. 2. Co-presence of conditions of social justice across census tracts in the city of Messina

residents aged 0–14 years appear to be the least disadvantaged, with respectively 85.1% and 92.4% of individuals residing in areas with adequate access to broadband infrastructure. Lastly, notable disparities emerge with regard to socio-spatial diversity. Adequate conditions of diversity are experienced by 35% of Italian residents aged 0–14 years, compared to 77.6% of foreign residents in the same age group. These results provide evidence on the mechanisms informing the uneven distribution of social justice conditions across population groups, as discussed in the subsequent section.

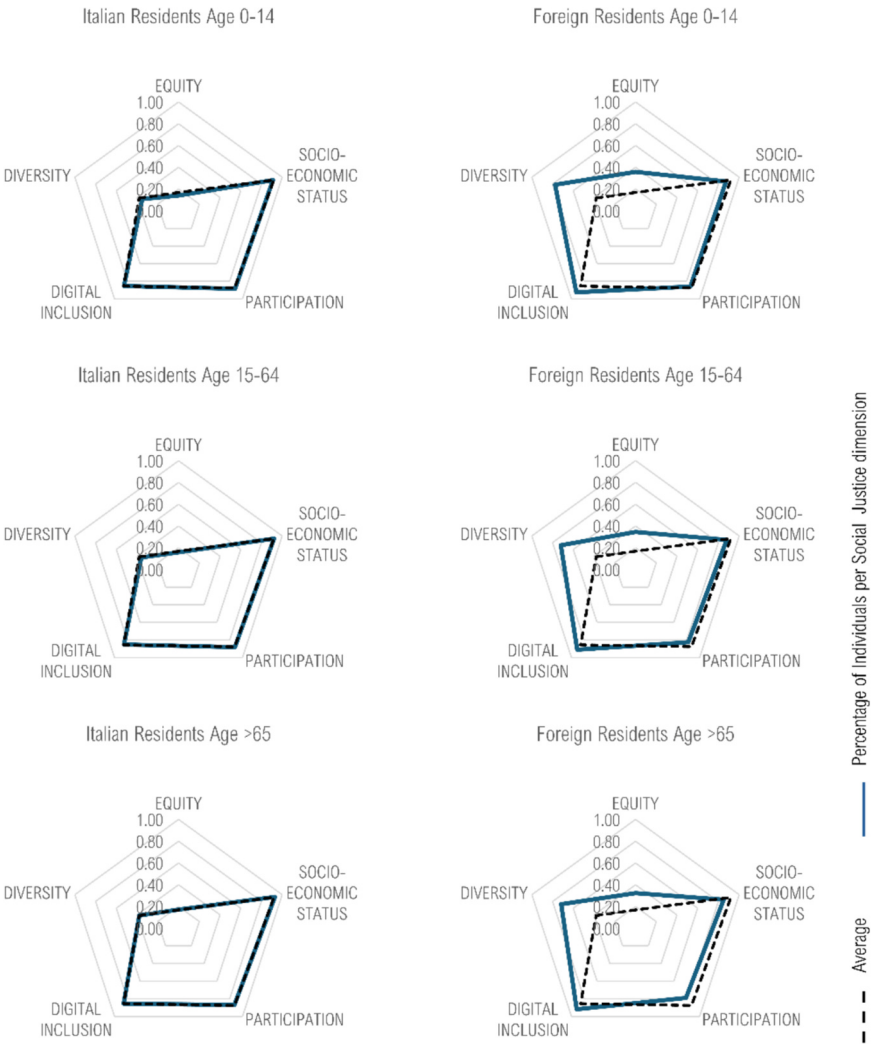

Fig. 3. Distribution of conditions of social justice across Population groups

Table 1. Distribution of conditions of social justice across six groups: Italian residents of age 0–14 years (IT_0_14), Italian residents of age 15–64 years (IT_15_64), Italian residents of age of 65 years and above (IT_OV_65), Foreign residents of age 0–14 years (FR_0_14), Foreign residents of age 15–64 years (FR_15_64), and Foreign residents of age of 65 years and above (FR_OV_65).

	Distributional Equity	Socio-Economic Status	Civic Participation	Digital Inclusion	Diversity
IT_0_14	0.141	0.912	0.884	0.852	0.350
IT_15_64	0.159	0.921	0.881	0.851	0.358
IT_OV_65	0.172	0.930	0.871	0.856	0.377
FR_0_14	0.358	0.874	0.859	0.924	0.776
FR_15_64	0.345	0.880	0.825	0.910	0.720
FR_OV_65	0.323	0.851	0.789	0.919	0.717
AVERAGE	0.169	0.920	0.876	0.855	0.380

5 Discussion

The results underscore several relevant patterns in the spatial and social distribution of urban justice across the study area. First, concerning the spatial distribution of justice conditions, the analysis reveals contrasting trends. On the one hand, a clear intra-urban divide emerges between central areas and suburban and peri-urban areas. On the other hand, central areas display internal heterogeneity, resulting in the co-presence of clusters of census tracts presenting multiple forms of deprivation and segregation alongside areas with favorable conditions. At the same time, clusters of census tracts presenting mild conditions of injustice are observed in suburban and peri-urban areas.

As a consequence, the analysis reveals a general trend resulting in a monocentric configuration. This configuration appears to be largely driven by the concentration of Services of General Interest in central areas and by elevated levels of access to advanced broadband infrastructure in denser urban zones. This trend reflects configurations observed in previous studies on the 15-min city [17, 18, 46]. However, the results also reveal substantial disparities within individual zones. In particular, intra-zone inequalities are mainly related to uneven conditions of social diversity and civic participation.

Regarding the distribution of social justice conditions across the urban population, the analysis identifies distributional equity and diversity as particularly critical dimensions. Access to urban resources and the presence of socially diverse environments remain limited and inadequate for a large segment of the urban population. Substantial disparities emerge across population groups, indicating uneven exposure to marginalisation and segregation. Italian residents are more prone to inequalities in the distribution of Services of General Interest and by spatial segregation. The percentage of Italian individuals residing in areas with adequate access to services remains limited across all age groups, ranging from 14.1% among residents aged 0–14 years to 17.2% among residents aged 65 years and above. By contrast, the corresponding values for foreign residents amount

to 35.8% among individuals aged 0–14 years and remain above 30% for the other age groups.

Foreign residents, however, face greater exposure to socio-economic disadvantage and lower levels of civic participation. More than 91% of Italian residents live in areas not exposed to conditions of socio-economic disadvantage, compared to percentages of foreign residents that range from 85.1% to 88.0%. A similar pattern is observed in relation to civic participation: the proportion of individuals residing in census tracts with voter turnout above 50% remains consistently larger among Italian residents than among foreign residents. Foreign residents also experience more favourable conditions in relation to digital inclusion and socio-spatial diversity. These patterns indicate that population groups are exposed to distinct dimensions of social justice. The observed disparities are closely related to the spatial distribution of urban populations. Foreign residents are more concentrated in central areas, where access to services, digital infrastructure, and diverse social environments is greater. Proximity to services and public transport facilitates access to fundamental urban resources, mitigating reliance on car-dependent mobility.

The Italian population, by contrast, is more spatially dispersed across the urban area. This pattern may reflect the combined influence of structural constraints and residential preferences. The presence of Italian residents in inland areas distant from the coastline, where service provision is more limited, may partly result from economic constraints that restrict residential options. In such contexts, lower housing costs may contribute to the concentration of lower-income residents. At the same time, suburban coastal areas may attract residents due to proximity to the seaside, lower-density environments, and alternative housing typologies. In these contexts, access to urban resources depends more strongly on private car use because of the limited availability of nearby services and public transport. This spatial configuration raises significant social justice concerns, including forms of segregation related to filtering-up processes in coastal areas, marginalisation of vulnerable groups in deprived suburban areas, unequal access to fundamental urban resources, and the persistence of dependence on private motorized transport. These findings call for an integrated, place-based policy package aimed at reducing the spatial concentration of advantages and disadvantages across the urban area by coupling land-use planning, service provision, housing instruments, and governance measures. In suburban and peri-urban areas, targeted densification - particularly in zones contiguous to existing service concentrations - can reinforce the demand base and urban intensity needed to support the decentralisation of Services of General Interest. This action should be complemented by the creation and consolidation of local centralities through the conversion of existing public amenities into multifunctional hubs that combine social, administrative, cultural, and civic functions, thus increasing proximity to urban resources [16, 27].

At the same time, segregation and limited socio-spatial diversity require housing policies that integrate social housing provision into development and regeneration processes. This objective can be advanced via public provision in targeted areas, mandatory or negotiated on-site social housing requirements in private redevelopment, and in-lieu contributions - including financial payments or land transfers - alongside density-based incentives that preserve project feasibility [47]. In combination, these instruments can

promote social mix in regeneration areas and expand access to affordable housing. Lastly, uneven civic participation indicates that spatial and distributive interventions should be supported by more inclusive governance structures [48, 49]. Participation in local governance and the co-design of regeneration interventions can foster civic engagement and the capacity of urban policies to recognise and respond to the needs of diverse social groups.

6 Conclusions

The study proposes a quantitative procedure based on spatial and configurational analysis to assess justice across five dimensions: distributional equity, digital inclusion, civic participation, diversity, and socio-economic status. The procedure is intended to support evidence-based and transparent governance in the design of policies oriented to the 15-min city model, with the specific aim of mitigating the reproduction of intra-urban disparities.

The contribution of the study is twofold. First, it advances the operationalization of social justice by translating Fainstein's definition [7] into a spatially explicit set of measurable dimensions. Second, it specifies a procedure that is replicable, robust, and transferable for assessing spatial justice conditions across urban areas and populations. The results provide empirical evidence that the procedure supports the systematic identification of spatial inequalities and the incorporation of justice considerations into policy design and evaluation. The findings indicate dimension-specific configurations of disparity across spatial units and population groups. More precisely, the dimensions of social justice diverge in terms of spatial gradients and inequality intensity, producing heterogeneous combinations of segregation and deprivation across the urban area and uneven exposure across population groups. In line with previous studies on the 15-min city [17, 18, 46, 49], distributional equity exhibits a monocentric configuration: Services of General Interest are concentrated in compact central areas, producing a centre-edge divide. Beyond this general pattern, the analysis also identifies intra-zone disparities across central, semi-central, suburban, and peri-urban areas. These intra-zone contrasts are most evident for civic participation and social diversity, where census tracts with favourable conditions coexist with tracts experiencing deprivation, marginalisation, or segregation.

Across population groups, the results indicate distinct profiles of exposure across the assessed dimensions. On this basis, the study advances the hypothesis that residential location - and the resulting exposure to specific dimensions of spatial injustice - derives from the interaction between the spatial distribution of the residential built environment and housing-price gradients and individual preferences and socio-economic constraints that delimit feasible residential options. This interpretation corroborates the intrinsic spatial nature of social justice, as articulated by Soja [12–14], insofar as residential location mediates exposure to uneven distributions of urban resources.

From a planning perspective, the results support an integrated, place-based policy orientation coordinating land-use regulation, service provision, housing instruments, and inclusive governance. The findings justify measures aimed at consolidating local centralities beyond the compact core, integrating social housing into development and

regeneration processes, and combining spatial interventions with participatory structures and co-design processes capable of addressing uneven civic participation.

Several limitations define priorities for future research. Further refinement is required to develop more pertinent indicators of the quality of Services of General Interest, more robust operationalizations of civic participation, and more fine-grained representations of socio-economic disadvantage. A second priority concerns empirical investigation of the mechanisms underlying the observed patterns, with specific attention to the relationships among socio-economic status, residential preferences, the spatial distribution of residential buildings and housing prices, and exposure to the assessed dimensions of social justice.

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