Measuring the Potential for Meaningful Usability of Spaces: The Case Studies of Two Social Housing Districts in Cagliari, Italy

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Abstract. The ongoing debate on the adaptation of urban environments in the context of climate alterations and the COVID-19 pandemic underlines the need for an organization of urban spaces and structures that promote active mobility, socialisation, sports, and recreational activities. This emerging need intersects with the broader issue of the built environment's impact on individuals' quality of life. This study examines the centrality of positive emotions in determining quality of life and introduces the concept of meaningful usability to conceptualize the potential of built environment factors to promote positive emotional responses. The study aims to answer two questions: first, what are the components and qualities of public spaces that influence individuals' positive emotional responses? Second, how can a set of metrics be defined to measure relevant environmental conditions that are conducive to meaningful usability? The case study focuses on the districts of Is Mirrionis and Mulinu Becciu in the Metropolitan City of Cagliari (MCC). The study contributes to the field of urban studies by developing a procedure that measures access to urban services, Green amenities, Public transit, distance form the urban centre and diversity of functions to structure a cognitive foundation for the development of urban regeneration strategies. The analysis demonstrates the validity of spatial and configurational metrics in identifying vulnerable areas, criticalities in terms of access to services and urban quality and defining the objectives of urban regeneration strategies.

Keywords: Configuration · Morphology · Vitality · Urbanity

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1 Introduction

The emerging need for the adaptation of cities to the post-pandemic scenarios re-proposes the issue of the relation between the built environment (BE) and quality of life. Strategies for the post-Covid 19 scenario focus on a re-organisation of cities, including the adaptation of built form, the re-organization of services and amenities, the transformation of mobility and transport systems and the re-configuration of the public space [1–5]. Moreover, the pandemic altered the influence of distinct aspects of cities on specific life domains [6]. This study focuses on a specific aspect of quality of life, emotional response, and investigates the impact of built environment components on individuals' emotional response. Previous studies tend to focus of residents' perceptions of specific aspects of the built environment. This study considers the emotional response of residents and non-residents and investigates the potential influence of distinct aspects of the built environment on users' satisfaction. The districts of Is Mirrionis and Mulinu Becciu, in the Metropolitan City of Cagliari (MCC), in Italy, are selected as the area of study. The study introduces the concept of meaningful usability to denote the latent or potential influence of built environment macro-scale factors on residents' satisfaction and develops a set of metrics for the evaluation of determinants of built environment's meaningful usability. The proposed method can guide practitioners, planners, and policy makers in the construction of the cognitive base propaedeutic to the development of projects for the adaptation of the urban environment in the post-pandemic scenario. The article is articulated on six sections. After the introduction an extensive literature review on quality of life, emotional response and the built environment is presented in Sect. 2. Section 3 describes the method and data of the study. The Results are presented in Sect. 4 and the implications of the findings are summarised in the final section.

2 Literature Review: Factors Impacting Users' Emotional Response

The analysis of the literature focuses on two distinct issues: i) the conceptualisation of quality of life and the relevance of positive emotions resulting from momentary experience; ii) the identification of built environment objective and perceived factors that elicit specific emotions. Quality of life is a central concern of urban policies. Quality of life is formalised and measured in terms of subjective well-being (SWB). Yet, Distinct interpretations of good living can be identified. SWB is interpreted as a trait, a predisposition of individuals to focus on positive stimuli and to engage in positive and protective memory bias [8], or as a state, resulting from eudemonic aspects, including sense of purpose, satisfaction of central needs and the realization of one's potential [9], and to hedonic aspects related to positive emotions and life satisfaction. Moreover, the evolutionary perspective reflects on the relevance of positive emotions in developing one's personal resources, thus underlining the enduring influence of emotions on quality of life. A conceptualization of quality of life as a combination of eudemonic and hedonic aspects can be identified in urban studies. Mouratidis identifies eudaimonia, happiness, life satisfaction, and emotional well-being as central components of subjective well-being [7, 10, 11]. Alternative conceptualisations of quality of life focus on concepts

of hedonic happiness [12], urban happiness [13] and life satisfaction [14]. Moreover, Mouratidis develops a conceptual model, that identifies a set of interdependent factors, including travel, leisure, work, social relationships, residential well-being, emotional responses, health, as variables that mediate the influence of the built environment on distinct aspects of SWB. This model thus recognises satisfaction and emotions elicited by the built environment as relevant aspects of quality of life. A similar focus on the individuals' immediate experience of the built environment is observed in studies investigating pedestrians' satisfaction [15, 16], residential satisfaction [17–20], emotional response to environmental stimuli [21–23] and basic emotions. The latter are defined as emotions that present a biological basis, and are influenced by constraints resulting from evolution [24–27]. Lastly, studies on the emotional response to the built environment propose distinct set of emotional states. Mouratidis identifies as relevant emotional responses, contentment, pleasure, and fear. Birenboim [28] conceptualises emotional responses to the built environment in terms of momentary experiences, resulting from discrete emotions, including sense of security, comfort, happiness, and annoyance. An analogous conceptualisation of emotional response is found in Perrée, Dane and Van Den Berg [21]. Lastly, Resch et al. [29] focus on a set of discrete emotions including happiness, sadness, fear, anger/disgust. The third issue concerns the identification of built environment factors that elicit positive and negative emotions.

The analysis of the literature focuses on articles retrieved from the Scopus database via multiple queries containing the terms "emotion*" or "subjective well-being" or "happiness" and "walkability" or "public space*" or "urban". A comparative content analysis is conducted to identify the aspect of built environment experience considered as the dependent variable and the built environment factors identified as relevant independent variables. Among the factors influencing individuals' satisfaction, Land use diversity is co-related to positive emotional response [11, 12, 16, 23] and to pedestrian satisfaction [16]. Land use density, conceptualised as a condition for access to urban functions, is co-related to emotional response [11, 23] and to pedestrian and residential satisfaction [17–19, 33]. Interestingly, a negative co-relation to neighbourhood happiness is observed in Oslo by Mouratidis and Yiannkou [33]. Built-up areas factors have a limited relevance in eliciting satisfaction and positive emotional response. Density, in particular, is observed to be negatively related to residential and pedestrian satisfaction and to individuals' emotional response [23, 33]. However, Mouratidis observes that density, if relevant urban problems - including noise, perceived unsafety and signs of neglect - are mitigated, can be positively associated to SWB [10, 11]. Built environment (BE) factors relevant in terms of influencing the emotional state of users include access to natural and semi natural areas, trees coverage, safety, and intrinsic, compositional qualities of public spaces. Access to green infrastructure is positively related to emotional response in 11 out of 20 selected studies [11, 12, 14, 17–120]. An important factor is also trees coverage of public spaces, as observed in five studies on quality of life, emotional response to the BE and residential satisfaction [11, 13, 15, 16, 22]. Contrasting results are found by Mouratidis and Yiannakou, in their study on residents' satisfaction and contentment in Thessaloniki, Greece, and Oslo, Norway [33]. Safety emerges as a central determinant of satisfaction and positive emotional response [10, 11, 13, 16–118]. Moreover, safety is frequently formalised as a perceived condition [10, 17, 18, 33, 41]. Gim et al. [35]

conceptualise safety as a condition resulting from satisfaction related to specific built environment factors including rest and green areas, noise, pollution, crime, cleanliness and parking areas. Moreover, specific built environment components are identified as factors conducive to perceived safety: Sepe [13] identifies the presence of road lamps and the design of spaces conducive to multiple practices as determinants of perceived safety. Bivina and Gupta [16] formalise safety and security in terms of presence of police operators, presence of road lamps and presence of road signs. Lastly, several studies [37–42] build on the Broken Window Theory (BWT) to relate perceived safety to the absence of signs of neglect. The BWT, in fact, investigates the impact of urban disorder and anti-social practices on the perception of safety and the probability of future criminal activities [43]. This study introduces the concept of meaningful usability and defines it as the potential of built environment macro-scale factors to increase residents' satisfaction. Based on the scientific literature, the relevant macro-scale determinants of meaningful usability include density of services, diversity of services, access to natural and semi-natural areas, access to public transit, distance to central areas. The set of metrics developed to evaluate these built environment factors is presented in the sub-sequent section.

3 Methodology

The study is articulated on stages: i) Definition of macro-scale factors influencing built environment meaningful usability; ii) Selection of the area of study and construction of a spatial database related to the selected macro-scale factors; iii) definition of the unit of analysis; iv) Definition of a set of spatial, configurational and statistical metrics to measure built-environment factors; v) Indicators' calculation and visualization of results. In particular, the relevant macro-scale factors influencing residents' satisfaction include density of services, diversity of services, access to natural and semi-natural areas, access to public transit, and distance from central areas. Services are grouped in seven categories, including healthcare facilities, educational facilities, cultural services, subsistence services, retail activities, recreational functions, and public services. Each category of services is divided in two sub-categories, based on the frequency of fruition of individual services. Each sub-category of services is represented by a point vector layer. Points of interest, related to individual services, are retrieved from the Google Maps web service. The spatial structure of the area of study is represented by a segment map. A segment map represents a spatial system as a set of lines, delimited by consecutive intersections, that intersect all the convex spaces comprised in a spatial layout. The segment map is created using the road center line (RCL) map obtained from the Open Street Map database. Residential buildings and public transit stops are represented by point vector layers, retrieved from the Territorial Information System of the Sardinia Region. More precisely, points representing residential buildings correspond to the centroids of buildings' ground projection. The census tract is selected as the spatial unit of analysis for developing a detailed quantitative description of the spatial variation of determinants of residents' satisfaction. The census tracts' polygons are retrieved from the Open database of the Italian Institute for Statistics (ISTAT) and refer to the 2011 National census. The 2011 census tract is, in fact, the spatial unit related to the most

complete available information on population and buildings at the sub-district scale. Density of services is calculated as the weighted average of measures of proximity of the i-th census tract to services of the j-th category (Table 1). Proximity is measured as the number of points of interest of the j-th category, located within a predefined distance from each census tract, weighted by the distance via an attenuation function. Proximity is calculated via the Attraction Reach (AR) function of the Place Syntax Toolkit (PST). The radius is set at 800 m, a distance relevant for pedestrian movement, equivalent to a 10-min trip. The weights of the AR metrics are calculated using a pairwise comparison matrix that represents the importance of the i-th variable relative to the k-th indicator. The procedure is based on the Analytical Hierarchy Process introduced by Saaty [44–46].

Land use diversity is measured by the Simpson's diversity index, via the Eq. (1):

$$D = 1 - \frac{\Sigma n(n-1)}{N(N-1)} \tag{1}$$

where:

n = number of points of interest of land use category k-th;

N = total number of points of interest.

The considered categories of urban functions include the categories of services considered for the calculation of the indicator density of services and the residential buildings category. The number of points of interest of the k-th category, is calculated via the AR function of PST, by counting the number of potential destinations comprised in the k-th category and located within a 800 m radius from each census tract. Similarly, the indicators access to natural and semi-natural areas and access to public transit, are calculated via the AR function, as the number of destinations within a 800 m radius, weighted by the distance. Lastly, the distance of the i-th census tract from the centre of the urban area, is measured as the topological distance from the i-th census tract to the urban centre. The topological distance refers to the number of turns along the route from an origin point to a destination point, and it is measured via the Attraction Distance function of PST.

The urban centre is identified as the cluster of census tracts presenting optimal access to urban services. The indicators are normalised via a range standardisation function. The indicators values are thus converted into values comprised in the 0–1 interval, where 0 indicates a negative condition and 1 an optimal condition.

An aggregate indicator of Meaningful Usability is then calculated as the weighted average of the metrics related to individual built environment macro-scale factors (Table 1 and Eq. 2).

$$\begin{aligned} I_{MEUS} = {} & I_SER * (0.341) + I_DIV * (0.128) + I_TR * (0.128) + \\ & I_DCC * (0.054) + I_UGA * (0.341) \end{aligned} \tag{2}$$

These metrics are calculated for two districts of the Metropolitan City of Cagliari (MCC), the Is Mirrionis and the Mulinu Becciu districts, which are described in the sub-sequent section.

Table 1. Indicators of macro-scale determinants of meaningful usability

Indicator	Description of the Indicator	Weight
I_SER	**Access to Urban Services**	**0.341**
AR_REC	Access to recreational services	0.074
AR_CUL	Access to cultural Services	0.074
AR_RET	Access to Retail Activities	0.074
AR_BAS	Access to Subsistence Services (Grocery Stores, Pharmacies)	0.289
AR_HEA	Access to Healtcare services	0.221
AR_EDU	Access to educational services	0.221
AR_GEN	Access to General Services (Financial Services, Post Office)	0.033
I_DIV	**Diversity of Functions**	**0.128**
I_TR	**Access to Public Transit**	**0.128**
AR_BUS	Access to Bus Stops	0.552
AR_BEU	Access to Regional Bus Stops	0.095
AR_MET	Access to Tram Stations/ Stops	0.247
AR_TRN	Access to Train Stations	0.095
I_UGA	**Access to natural and semi-natural areas**	**0.341**
I_DCC	**Distance from the urban centre**	**0.054**

3.1 Selection of the Areas of Study

The selected areas of study are the Is Mirrionis and Mulinu Becciu districts in the city of Cagliari, Italy (Fig. 1). Cagliari is the capital city of the Sardinia Region and the core of the MCC, a polycentric urbanised territory that comprises 17 municipalities [30–32]. The MCC presents an isotropic structure, consisting of the compact centres of ancient formation, integrated into a system of scattered settlements that colonise and fragment the rural landscape.

The configuration, land use pattern, and density gradient of the metropolitan structure are determined by both the radial configuration of the transport infrastructure and the structure of geomorphological, pedological, hydrographical, and botanical systems. The Is Mirrionis and Mulinu Becciu districts are two social housing districts built in the 60s and 70s as part of distinct programs of public policies aimed at regulating the urbanisation processes and at addressing the housing emergency resulting from the destructions produced by the 1943 air bombing campaign and the migration of population from rural areas, determined by the economic development, based on industrial production, of urbanised areas. The areas of study are located in the northern periphery of the urban area of Cagliari, along major road infrastructures. The Is Mirrionis district was completed in 1962 and represents the last intervention promoted by the INA Casa Plan. The Mulinu Becciu district, on the other hand, was included in the Plan for Social Housing adopted by the City Council of Cagliari in 1962. The Plans for social housing

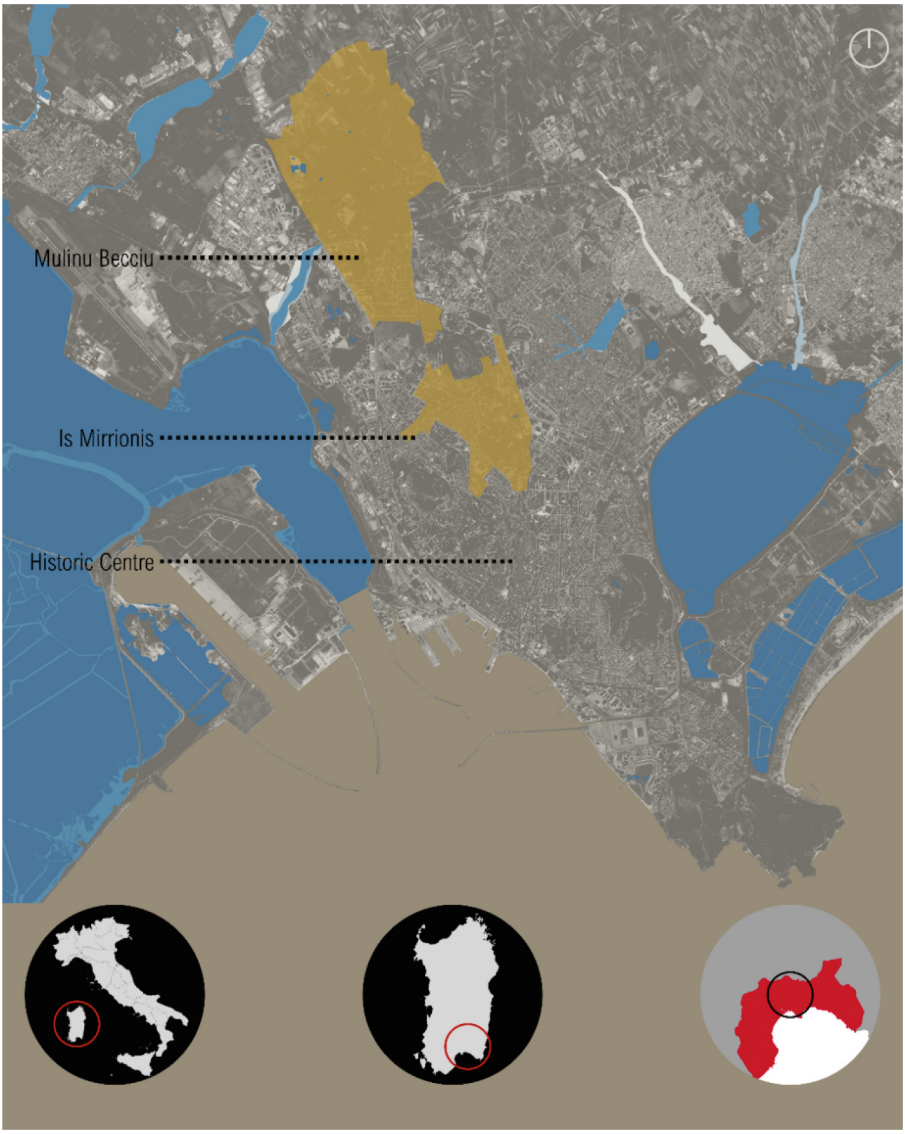

Fig. 1. The City of Cagliari and the districts of Is Mirrionis and Mulinu Becciu (authors' elaboration).

represent the last significant direct intervention of public institutions in the organisation and development of urbanised areas. These social housing districts present a distinctive urban form, resulting from a unitary design and from the experimentation of functional and spatial configurations that reflect the investigation on the organisation of the contemporary city and of its parts. In particular, in the MCC, these districts emerge as peripheral

centralities, characterised by the plurality and variety of functions, by articulated spatial, functional and perceptual relations with the environmental dominants, and represent significant nodes of the polycentric system that structures the metropolitan area. Therefore, these districts constitute a fundamental component of the urban landscape and, consequently, a central dimension for defining strategies of urban transformation aimed at building resilient, inclusive, sustainable urban systems.

4 Results

The analysis underlines the significant diversity of the areas of study in terms of macroscale factors conducive to meaningful usability. In particular, the indicator density of services underlines an adequate condition of access to urban functions in the census tracts of the Is Mirrionis district, contiguous to spaces integrated at both the local (radius equal to 800 m) and at the global scale.

A similar condition is observed in the Mulinu Becciu District. Tracts contiguous to a set of segments integrated at the global scale present a more relevant presence of services. In general terms the values of the indicator density of services are comprised in the range 0.365–0.596 in the Is Mirrionis district and range from 0.071 to 0.403 in the Mulinu Becciu district (Fig. 2). The mean and the median are equal to 0.493 and 0.506 in the Is Mirrionis District and to 0.258 and 0.257 in the Mulinu Becciu area. In particular, the mean and median values observed in the Is Mirrionis district is superior than the values measured for the entire Urban core of Cagliari, which are equal, respectively, to 0.461 and 0.472. The indicator diversity of functions, present a significant internal variation in the investigated areas. Areas presenting functional diversity are located along roads integrated at the global scale in both districts. In the Is Mirrionis district the diversity of function ranges from modest, equal to 0.168, to adequate, equal to 0.399 (Fig. 3). A more relevant variation is observed in the Mulinu Becciu district. The values of the indicator diversity of functions are comprised in the 0.000–0.643 interval. The mean and the median values are, respectively, 0.306 and 0.312 in the Mulinu Becciu district, and 0.277 and 0.271 in the Is Mirrionis area. The level of integration of distinct functions of the areas of study is thus comparable to the average condition observed in the urban core of Cagliari. The measure of central tendency measured for the entire urban area, in fact, are equal to 0.321 (mean value) and to 0.258 (median value). A distinctive aspect of the areas of study is the proximity to natural and semi-natural areas, constituting significant nodes of the metropolitan ecological infrastructures (Fig. 4).

In particular, the Is Mirrionis district presents values of the indicator access to urban green areas comprised in the 0.313–0.644 interval, thus denoting adequate to good conditions of access to natural and semi-natural areas (Fig. 4). A greater variation and limited conditions of access to urban green areas is observed in the Mulinu Becciu area. The values range from 0.029 to 0.377, and the inter-quartile range, equal to 0.164, underlines the disparities, in terms of access to urban green amenities, between the denser part of the district, and the sparser census tracts, contiguous to the remains of the agricultural areas.

The mean values, equal to 0.228 for the Mulinu Becciu district and to 0.477, compared to the values measured for the urban core of Cagliari, equal to 0.499, underline conditions

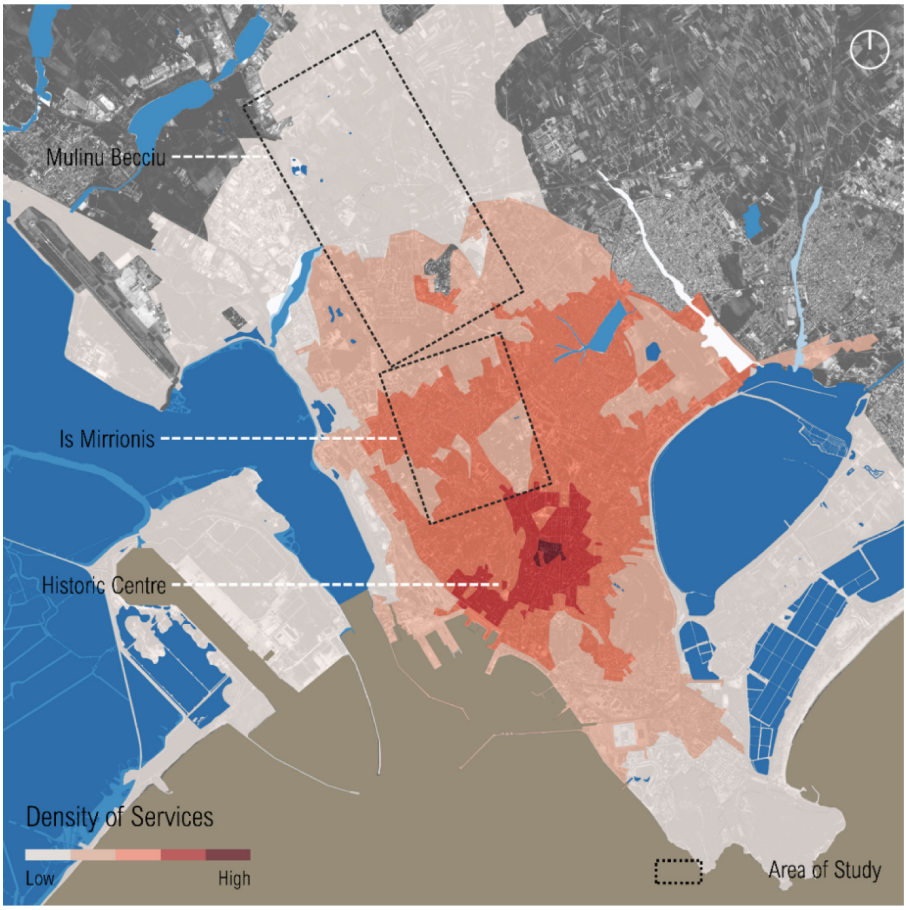

Fig. 2. Variation of the Density of services in the area of study (authors' elaboration).

of proximity to natural and semi-natural areas in line with the city average in the Is Mirrionis area, and inferior in the Mulinu Becciu district. Conditions of access to public transport are inadequate and reflect a distribution similar to that of density of services. In the Is Mirrionis district values range from 0.007 to 0.376 in areas contiguous to segments of secondary and tertiary roads integrated at the global scale. The mean value is 0.246 and the median is equal to 0.257.

In Mulinu Becciu district the level of access to public transport range from 0.000 to 0.433, indicating an adequate condition of proximity to public transit stops limited to census tracts contiguous to the G. Brotzu Hospital (Fig. 4). The mean and the median values are respectively 0.184 and 0.195. Conditions observed in the areas of study are lower than the average level of access observed in the urban core of Cagliari. The mean and the median for the entire urban core are, in fact, equal to 0.282 and to 0.264. Moreover, the mean topological distance from the urban centre is equal to 32 for the Is Mirrioinis district, and to 48 for the Mulinu Becciu district.

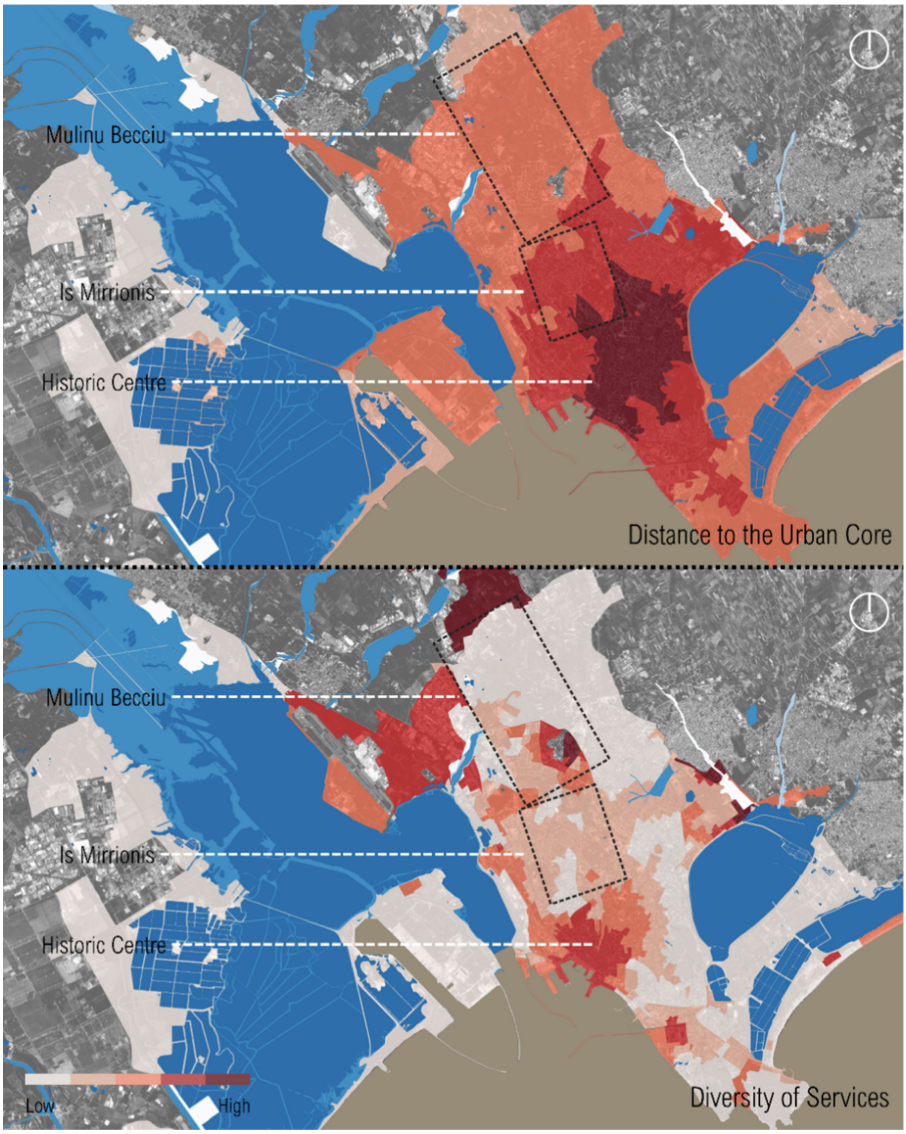

Fig. 3. Distribution of the conditions of diversity of services and distance to the urban core (authors' elaboration).

The indicator of meaningful usability (I_{MEUS}) underlines the limited potential of macro-scale factors to elicit residents' satisfaction in the Mulinu Becciu district (Fig. 5). The values of the aggregated indicator are comprised in the 0.071–0.394 interval, with a mean equal to 0.255 and a median equal to 0.253. In the Is Mirrioinis area, vice versa, present a more favourable condition, in terms of macro-scale qualities conducive to

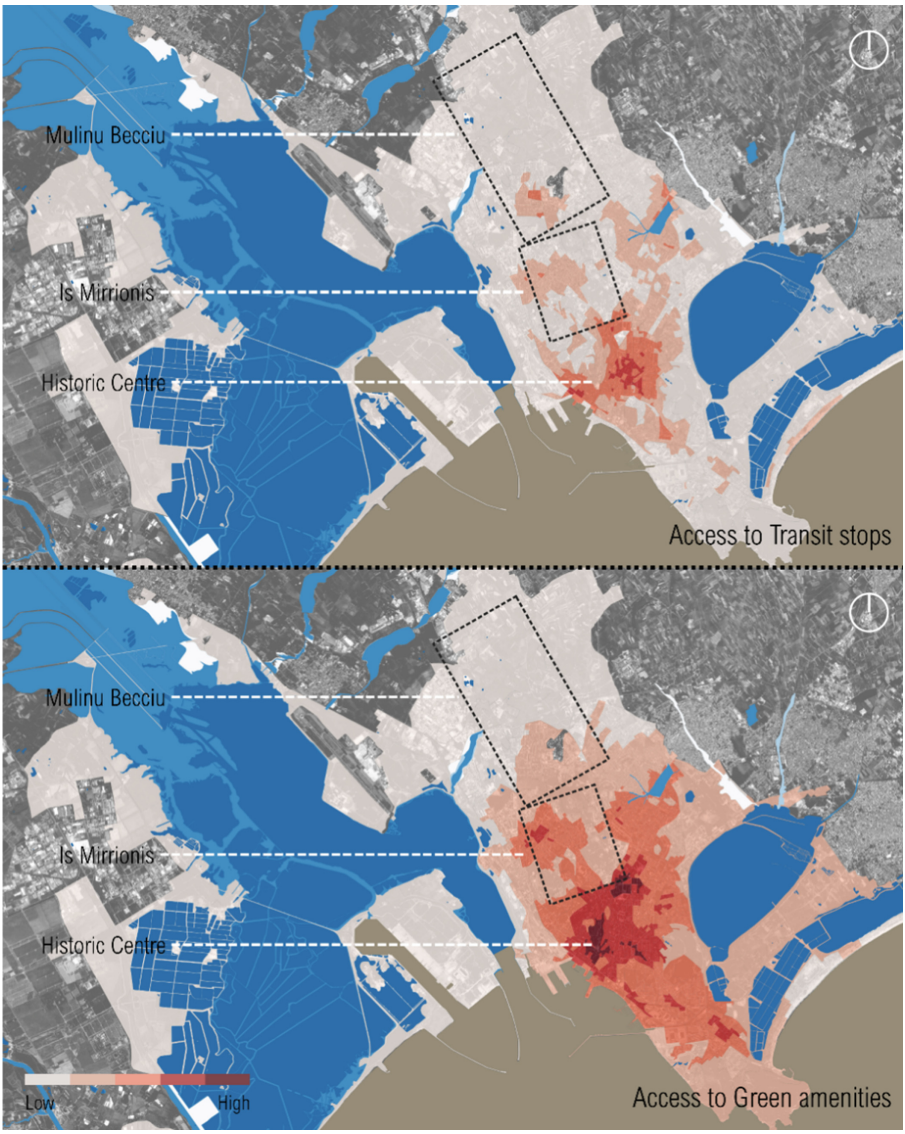

Fig. 4. Conditions of access to public transit and to green amenities in the area of study (authors' elaboration).

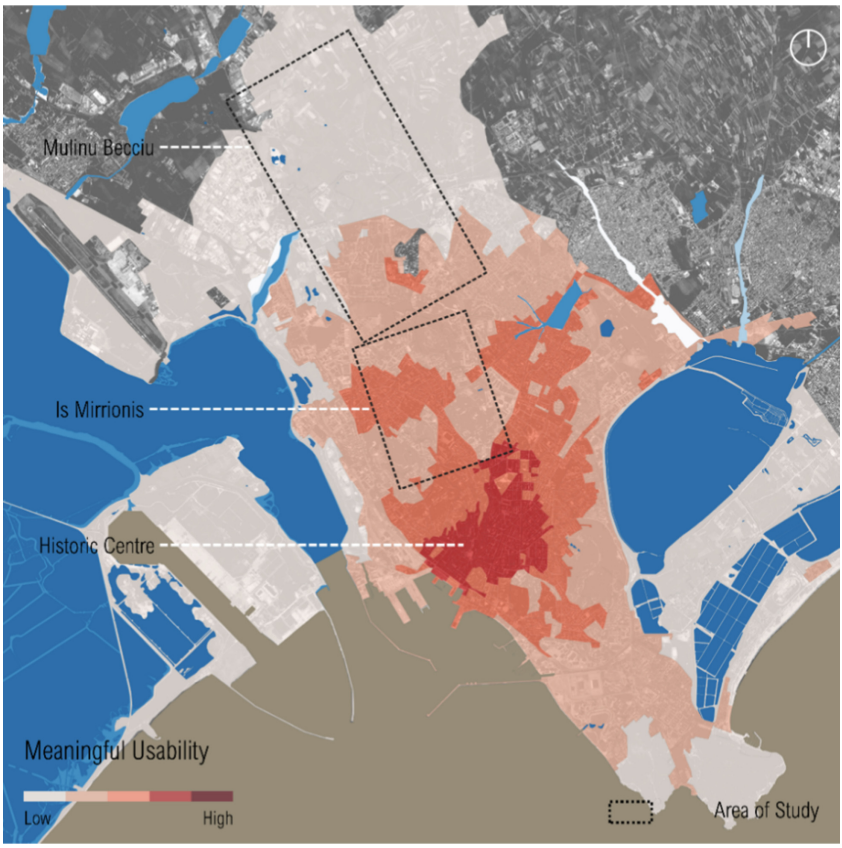

Fig. 5. Distribution of the values of the synthetic Index of Meaningful Usability (authors' elaboration).

residents' satisfaction. The values of the I_{MEUS} indicator, in fact, range from to 0.324 to 0.533, with a mean value of 0.436 and a median of 0.441.

Compared to the average condition of the Urban area of Cagliari (mean equal to 0.444, median equal to 0.432), the values observed in the Is Mirrionis area underlines the integration of the district into the urban structure and its emergence as an eccentric centrality, defined by good conditions of density of services, access to public transit, and proximity to natural and semi-natural areas.

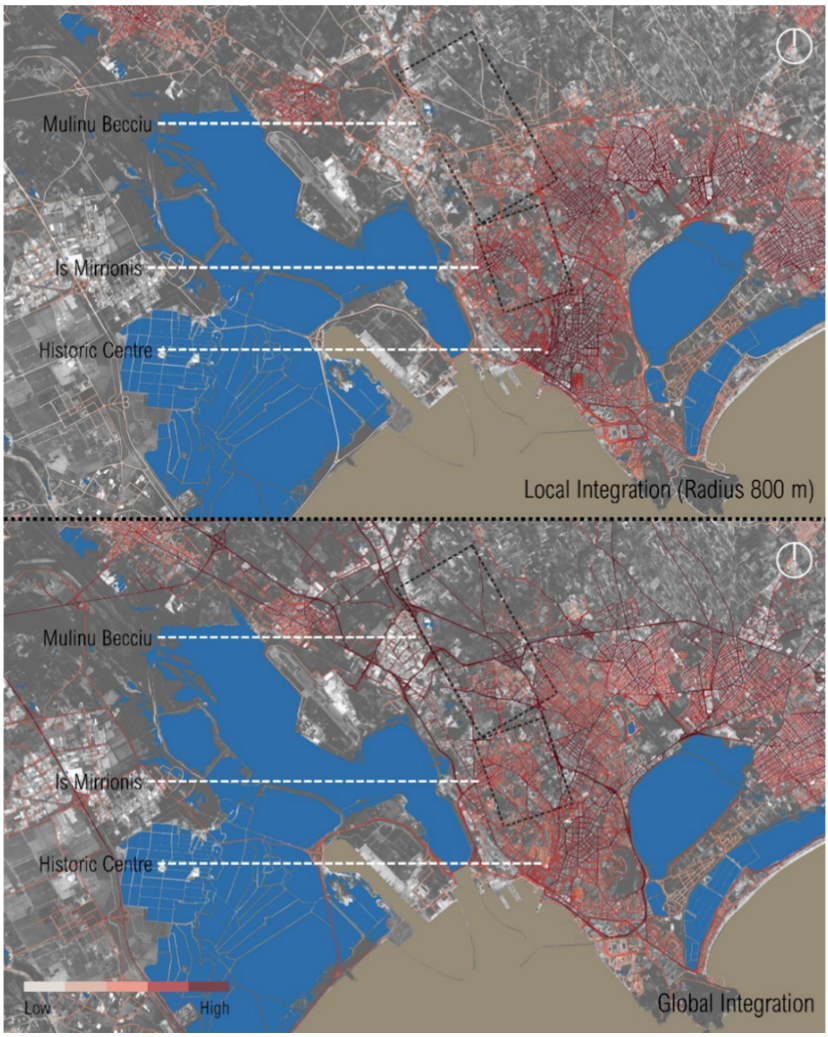

Fig. 6. Distribution of conditions of integration at the local and at the global (metropolitan) scale (authors' elaboration).

5 Discussion and Conclusions

The results presented in the previous section underline a configuration of access to services, contiguity to the ecological infrastructure, and of functional diversity, specific to each district. In particular, the study demonstrates the emergence of the Is Mirrionis district as an eccentric centrality, a pole of local and urban scale services, and, consequently, as a node of metropolitan structural relations aimed at integrating the ecological infrastructure, the production landscape, services and residential areas. Vice versa, the Mulinu Becciu district presents a stronger internal variation of conditions of density and diversity of services and of proximity to the ecological infrastructure. In particular, the

denser census tracts delimited by Via Peretti, an important distributor road, contiguous to the G. Brotzu hospital, and by the 554 National Road, present a more significant potential to elicit residents' satisfaction as a consequence of macro-scale built environment factors. The values of the indicator of meaningful usability, in fact, ranges from 0.141 to 0.394 (mean equal to 0.270 and median equal to 0.281). Nevertheless, in general terms, the Mulinu Becciu area presents levels of density and diversity of services and of access to public transit and urban green areas inferior than the Is Mirrionis district. The analysis of the configuration of the spatial structure and of the urban form underlines several structural aspects that can be related to the partial deprivation of the Mulinu Becciu district. Both areas are intersected or are contiguous to road segments integrated and central at the metropolitan scale yet, on average, the Mulinu Becciu district presents minor level of local (radius 800 m) angular integration. The mean value of angular integration of segments in the Is Mirrionis area is equal to 155.54 and to 74.31 in the Mulinu Becciu district (Fig. 6). Moreover, the spatial structure of the Is Mirrionis district is more permeable. Permeability, measured in terms of road intersection density, normalised via a range standardisation function, is equal to 0.113 in the Mulinu Becciu district and to 0.389 in the Is Mirrionis district. The density of road intersections is an indicator of the availability of multiple alternative routes, a condition that favours the distribution of pedestrian movement among spaces, increasing opportunities for social interaction and the availability of suitable locations for economic activities [41, 47]. As a result, the minor integration at the local scale, and the minor permeability of the spatial structure, can be related to the minor density and diversity of urban functions in the Mulinu Becciu area. A relevant aspect concerns the urban form. The is Mirrionis district presents a more compact and dense structure than the Mulinu Becciu area, as indicated by values of the Ground Surface Index (GSI) (the mean value is equal to 0.264, compared to the value of 0.123 measured in the Mulinu Becciu area) and of the Floor Area Ratio (FAR) metric (mean equal to 0.189 in the Is Mirrionis district and to 0.087 in Mulinu Becciu area). The values of the GSI and the FAR metrics are normalised in the 0–1 interval and measure, respectively, the ratio of the ground projection surface of buildings to the total area of the census tract, and the ratio of the total floor area of buildings to the surface area of the census tract. Lastly, a relevant consideration concerns the building typology. A qualitative evaluation of the street space underlines that the most frequent building typology in the Mulinu Becciu area is represented by the isolated building, separated from the public space. As a consequence, the public space is not delimited by a continuous and active street frontage, a fundamental condition for the location of economic activities, for their profitability and, consequently, for urban vitality. As a result, the study underlines two aspects: first, the transformation of the compact, integrated, social housing district of Is Mirrionis into an eccentric centrality of the metropolitan area, thus overturning the stereotype of the degraded suburb, often associated with social housing districts [48, 49]. Second, urban regeneration policies, aimed at improving macro-scale factors conducive to residents' satisfaction, require interventions focused on increasing permeability and integration of the spatial structure, the density of the built-up area and the formation of continuous active street frontages. The future development of this research will be focused on two aspects: i) the investigation of the impact of space configuration on macro-scale factors relevant to residents' satisfaction [50]; and ii) the definition of a set

of metrics for evaluating micro-scale factors of public spaces, related to users' emotional response, so as to broaden the notion of meaningful usability [51–53]. The aim is the development of a set of tools that can support informed decisions in the formulation of urban regeneration strategies by public agencies, in particular in relation to four aspects: i) The identification of vulnerable areas; ii) Identification of criticalities in terms of configuration of the spatial structure and access to specific services; iii) Definition of targeted strategies of urban regeneration, based on the identified criticalities of deprived areas; iv) Evaluation of alternative scenarios and v) Evaluation of the impacts of policies of urban regeneration. Thus, the expected result is the definition of information-based processes that can increase the transparency of policies of urban regeneration and their impact in terms of improvement of quality of life and of sustainability, resilience and inclusivity of cities.

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