This is an Accepted Manuscript of an article published by Taylor & Francis in European Planning Studies on 12 May 2020, available at: https://www.tandfonline.com/doi/full/10.1080/09654313.2020.1761947

A walkability assessment tool coupling multi-criteria analysis and space syntax: The case study of Iglesias, Italy

Chiara Garau, Alfonso Annunziata* and Claudia Yamu

Chiara Garau
University of Cagliari, Department of Civil and Environmental Engineering and Architecture, 09123 Cagliari, Italy, cgarau@unica.it

Alfonso Annunziata*
University of Cagliari, Department of Civil and Environmental Engineering and Architecture, 09123 Cagliari, Italy, annunziata.alfonso@yahoo.it
*Corresponding Author

Claudia Yamu
University of Groningen, Department of Spatial Planning and Environment, 9747AD Groningen, The Netherlands, claudia.yamu@rug.nl

Abstract: The global trend towards the growth of urban population poses the issue of the public space influence on outdoor practices of different subjects. Given that the urban public space is the carrier of an ever-increasing number and density of users. Walking, both as a form of transportation and as a vector to physical activity and social interactions, emerges as a fundamental category of behaviour. The proposed research develops a theoretical and methodological framework for assessing the walkability of the urban space. Building on concepts of capability and affordance, walkability is herein conceptualised in terms of the effect of affordances incorporated into the built environment on individuals' propensity to walk for different purposes. The methodological framework aims to capture the characteristics of walkability across scales as the product of the intrinsic and extrinsic properties of an urban setting.

Keywords: Walkability, Space Syntax, Multi Criteria Analysis, Iglesias

1 Introduction

The global trend towards the concentration of population in urban areas poses the issue of whether and to what extent the characteristics of the public space incorporate opportunities for the functional, recreational, and social practices of different user groups. Within this context, the individuation and assessment of the characteristics of the built environment that are conducive to walkability emerge as a central issue. According to Giles-Corti et al. (2005), walking is a fundamental category of behaviour, involving a utilitarian dimension as well as a recreational and social dimension (Blecic et al., 2015; Gehl, 2013;).

Consequently, there is a wide consensus about the beneficial effects of walking in terms of quality of life and well-being. The proposed research aims to develop a theoretical and methodological framework for assessing the walkability of the urban space. Walkability is defined as the potential of the built environment to support different forms of walking. The theoretical framework is based on the concepts of capability and affordance (Sen, 1993; Gibson, 1979; Heft, 1988; Kyttä, 2002).

As a result, the relationship between the built environment, human behaviour and well-being is conceptualised in terms of the effect of the different affordances incorporated into the built environment on individuals' well-being. Specifically, this refers to the extent to which these affordances enhance individuals' capability to walk for different purposes and to different destinations.

Building on the existing literature regarding how street segments of the built environment correlate with walkability, the proposed methodological framework aims to capture the characteristics of walkability across scales as the product of the intrinsic – the visible geometric– and extrinsic – the invisible structural – properties of an urban setting. The methodological framework therefore incorporates the measurement of configurational factors, investigated through the techniques of the syntactic analysis of spatial structures (Hillier 1996; van Nes and Yamu, 2018), of contextual factors related to land-use distribution and density, and of site-specific compositional factors, understood through quantitative and qualitative indicators of urban design quality. The resulting Walkability Assessment Tool (WAT) is applied to the analysis of a sub-set of the most-connected urban spaces across the historic district of the city of Iglesias, Sardinia, Italy.

The objective of the research is the creation of a methodological framework that supports the urban planning process by enabling the individuation of critical conditions limiting walking behaviours, and by identifying potentially high-leverage interventions of regeneration of the physical environment to increase inclusivity and usability.

The paper is divided into six sections. Section two presents a review of the literature on how the built environment correlates with walkability follows the introduction, and includes a discussion of the theoretical foundation of the proposed WAT. The third section discusses the methodological framework. The fourth section presents the results obtained from applying the WAT to a sub-set of pedestrian routes across the historic district of the city of Iglesias. These results are comprehensively discussed in section five. Finally, the Conclusions section summarises the fundamental findings of the study, outlines their implications, and makes practical suggestions for their implementation.

2 Literature review

As observed by Giles-Corti et al. (2005), the study and evaluation of environmental factors influencing human practices requires a precise definition of the considered activity. In this respect, walking emerges as a multi-dimensional behavioural category that intersects different aspects of urban practices, and involves a utilitarian dimension (walking as a necessary activity), a leisure dimension (walking as an optional activity or as a vector to physical and recreational activities), and a social dimension (walking as a vector to contact and interactions among individuals). More precisely, walking as a means to recreational and social activity (Gehl, 2011) can be conceptualised as both a product and a pre-condition of the diversity of practices across the urban space (Gehl, 2013; Jacobs, 1961). In this sense it encourages physical activity and engenders socio-economic benefits, thereby improving public health and individual well-being (Xue et al., 2018; Calvert et al., 2019; Credit and Mack, 2019; Ferdman, 2019). The complex relationship between the spatial and immaterial aspects of the built environment, patterns of activity, and well-being is best understood via the concepts of affordance and capability.

In Sen's words (1993), capability can be defined as the ability of an individual to achieve a specific condition or "functioning" – a "doing" or "being" part of the state of that person – considered as valuable. Nevertheless, Sen also intends the concept of capability as the alternative sets of attainable functioning from which a person can choose one combination. In this sense, the concept of capability, while accounting for achievements, incorporates the intrinsic significance, in terms of an individual's well-being, of freedom and of the act of choosing per se.

Furthermore, the concept of capability implies the relevance of external conditions, including opportunities and constraints, as a factor that influences the combinations of alternative attainable functioning. This opportunity dimension hence includes the social and spatial structures that affect the transactions among individuals and spaces, and is more comprehensively understood through the concept of affordance. Introduced by Gibson

(1979) and developed by Heft (1988) and Kyttä et al. (2018), the concept of affordance refers to the set of functional, social, and emotional opportunities and constraints emerging from the relationship between the social, spatial, and immaterial characteristics of the environment and individual knowledge, intentions, abilities, body morphology, and physiology. These sets of opportunities and constraints influence the pattern of actions, of an individual, across a setting, through processes of direct perception and actualisation (Kyttä et al., 2018; Raymond et al., 2018).

The concept of affordance is multi-dimensional and includes a functional significance, which incorporates constraints and opportunities for meaningful actions, an emotional dimension, related to conditions conducive to the experiencing of positive or negative emotions, and a social dimension, which refers to conditions enabling or preventing meaningful or negative contact between individuals. In particular, emotional affordances refer to opportunities for feeling safe, for experiencing liveliness or quiet, conspicuous and legible environment. On the other hand, social affordances refer to opportunities for meeting friends, making new friends, for interaction among outdoor spaces and indoor spaces, and for interacting with people of different age. Finally, accessibility is conceptualised either as potential for interaction or as the actual freedom to participate to different activities. It is herein defined as the ability to access and benefit from opportunities embodied in public spaces. Accessibility derives from a city's configuration of the spatial layout and is interdependent with land-use patterns (Blecic et al., 2015; Hillier, 1996; van Nes and Yamu, 2020).

Yet, beyond the perceivable qualities of the individual space (Raymond et al., 2018; Kyttä 2002; Heft, 1988), constraints and opportunities affecting human behaviour are influenced by contextual factors, including land-use patterns, density, and configurational properties of the structure of public spaces (Moura et al., 2017; D'Acci, 2019; Wang and Yang, 2019; Jabbari et al., 2018). Spatial configuration refers to a set of relations among parts, such as urban streets that interdepend in an overall structure. Configurational properties thus refer to the topology of a complex structure (Hillier et al., 1987; Hillier, 1996; Yamu, 2014). In particular, connectivity, integration, and betweenness of public spaces influence patterns of movement, co-presence, and co-awareness across the urban space. Co-presence refers to the simultaneous presence of people that may not know each other within a space; co-awareness refers to a group of people who are aware of one another using and sharing a space. These two patterns are the raw material for the emergence of meaningful social contacts. Furthermore, patterns of natural movement are observed to affect the distribution of land uses (Hillier et al., 1993) and the multi-scale structure of pervasive centrality across the urban space (Hillier, 2012; Yamu, 2014).

The complex of social, emotional, and functional opportunities and of accessibility conditions incorporated into the configurational, compositional, and material properties of the built environment determine the potential of walkability of the public space. Walkability can therefore be defined as a measure of the built environment's potential to enable walking, and as a predictive indicator of human physical activity and active travel (Frank et al., 2006). In other words, it can be seen as an indicator of the extent to which the built environment is friendly to people who walk in order to travel, for leisure or recreation, for exercise, or to access services (Leslie et al., 2007; Saelens and Handy, 2008; Blecic et al., 2015).

As a consequence, the theoretical model embodied in the methodological framework operationalises walkability in terms of a synthetic index measuring the extent to which the affordances incorporated into the built environment improve residents' wellbeing. Specifically, this refers to improvements in wellbeing resulting from walking and outdoor practices. Thus, by individuating and analysing the intrinsic and extrinsic properties of the built environment conducive to people's propensity to walk, the WAT operationalizes the opportunity dimension for achieving and actualizing central capabilities, including affiliation (being able to live with others) , bodily health (being able to have good health) and integrity (being able to move freely from place to place), being able to play, control over the environment, and the ability to have attachments to people, objects, and places (Nussbaum, 2001).

2.1 Existing methodologies for the assessment of walkability

The existing literature proposes different approaches to the analysis of walkability. As observed by Moura et al. (2016), four approaches to the assessment of the walkability of the public space can be distinguished: (1) Web-based tools such as 'Walkscore', 'Walkshed', or 'Walkonomics' (Blecic et al., 2015), focusing on quantitative evaluations of macro-scale factors, such as intersection density, population density, and distance from amenities; (2) multi-criteria evaluation models, which combine spatial information and evaluation of micro-scale urban design features (Moura et al., 2016; Jabbari et al., 2017); (3) audit tools, assessing urban design micro-scale features of route segments (Pikora et al., 2000; Clifton et al., 2007; Saelens et al., 2006); and (4) questionnaires, reporting pedestrians' perceptions and preferences related to spatial, environmental, and social properties of urban spaces (Rosenberg et al., 2009).

From a multi-criteria analysis perspective, the precise nature of the evaluation methodology depends on the definition of categories of environmental variables.

Solid contributions are represented by the '3Ds' layout introduced by Cervero and Kochelman (1997), including density, diversity, and design, and reconfigured by Ewing et al. (2013) as a 5-dimension layout, adding distance to transit and destination accessibility (Su et al., 2019). The '5Cs' layout proposed by the London Planning Advisory Committee relates the walkability of the pedestrian environment to the attributes of connectedness, conviviality, convenience, comfort, and conspicuousness (Moura et al., 2018). Moura et al. added to these categories the dimensions of commitment and coexistence. This '7Cs' layout was used by Garau et al. (2018) to structure a methodological framework for assessing built-environment factors conducive to children's independent activities. In our research, the affordance categories introduced by Kyttä et al. (2018), reflecting the functional, emotional/contextual, and social implications of the concept of affordance, and the seven dimensions introduced by Moura et al., are adapted to structure a methodological framework for measuring the walkability of the built environment, the WAT, which is presented in the following sections.

3 Methodology

The proposed methodological framework combines multi-criteria analysis and space syntax techniques to determine a measure of walkability of public spaces, the Synthetic Index of Walkability of public spaces (I_{SWAT}). The integration of quantitative and qualitative indicators related to micro-scale compositional characteristics, and of quantitative indicators related to contextual and topological factors, reflects a conceptualisation of walkability as the product, across scales, of intrinsic and extrinsic properties of spaces.

The methodology for the assessment of the usefulness of the public space is conceived as a procedure articulated in seven stages: (i) selection and characterisation of the case study; (ii) an extensive literature review for individuating relevant environmental criteria and sub-criteria, selection of pertinent, valid, representative indicators, and definition of the layout of the tool for the analysis of environmental correlates of walkability; (iii) definition of functions and selection of algorithms for the calculation of quantitative indicators; (iv) definition of scales for the evaluation of qualitative indicators; (v) definition of threshold values and of fuzzy-logic functions for the normalisation of results and for the aggregation of individual indicators; (vi) data collection, evaluation of indicators, and calculation of the I_{SWAT} of public spaces; (vii) rendering of the gradient of walkability levels across the set of selected public spaces.

More precisely, with respect to the first stage, the case study is defined by selecting a sub-set of segments with the highest local through movement potentials in terms of pedestrian's route choice for the historic district of the city of Iglesias, Italy. Streets and public spaces comprising the most accessible segments are hence identified as the unit of analysis. A street segment is defined as the section of axial line or street or path between two intersections. Most accessible segments were identified computing local normalised angular choice (NACH) for the street network applying a 400 m radius representing a 5-minute walk. This radius is also known as the 'pedestrian shed'. Street segments with a numerical value >1.23 on a scale ranging from 0 to 1.54 were chosen. This threshold for each street segment, taking into consideration the top 20% values, corresponds to the highest potential of pedestrians' route choice from origin to destination. Normalised angular choice is a measure of potential trough movement and measures the least angular path between from all spaces to all other spaces in an urban network. It measures a route hierarchy of the urban street network.

Angular segment choice is calculated by counting the number of times each street segment falls on the shortest path between all pairs of segments within a selected distance, termed the radius. The shortest path refers to the least angular deviation through the system (Hillier and Iida, 2005, p. 475). Choice *C* of a street axis *i* measures the degree of through movement as follows (Rashid, 2017, p. 64):

$$C_i = \sum_j \sum_k g_{jk}(i)/g_{jk}(j < k)$$

Where $g_{jk}^{(i)}$ is the number of shortest path between segment *j* and k containing *i*, and g_{jk} is the number of all shortest paths between *j* and *k* (Rashid, 2017, p.64). The normalisation of angular choice (NACH) for an urban system is as follows (Hillier et al., 2012, p. 191):

$$NACH = \frac{\log(Choice\ (r) + 1)}{\log(Total\ depth(r) + 3)}$$

In the following, we discuss the layout of the assessment tool which includes four categories: (i) functional affordances, (ii) accessibility, (iii) emotional affordances, and (iv) social affordances (See Table 1).

Insert table 1

Table 1. Indicators incorporated into the WAT tool.

Affordance	Environmental features	Indicator	Subindicators
Functional affordances			
Walking, running, cycling, playing ball	Compositional properties of pedestrian facilities	Quality of pedestrian facilities	Barriers; effective width; condition of pavements; longitudinal slope
Seating	Position and distribution of seats	Availability of resting/sitting features	Presence; distance; distribution of seats; condition; comfort; cleanliness; coverage; position; view
Crossing roads	Organization and use destination of the road-space	Barrier effect	Crossing type, desire lines; coexistence (number of lanes AND speed limit); parking regulation
Resting	Alignment and design of edges	Configuration of edges	
Basic physical needs	Presence and condition of public Lavatories	Usability of Lavatories	Presence; proximity to the most disadvantaged point; condition; cleanliness; accessibility
Following, catching, caring for	Presence of vegetation	Nature situations	Trees coverage
Emotional affordances			
Feeling safe	Natural control of the POS	Eyes on the POS	Visibility of nearest buildings; Interactivity of façades; residential density; presence of activities with extended service hours; social incivilities; unpleasant/scary people/antisocial practices; prospect; refuge; boundedness
Pleasant place	Conspicuousness	Imageability of the POS	Distinctive natural, artificial structures (public art, ruins, geological/vegetation formation); distinctive buildings (historical/ not regular profile); major landscape feature (visible); distinct landscaping elements present along street edges; outdoor activities; cleanliness
Quiet	Acoustic environment	Quality of the acoustic environment	
Lively	Activities along the edges of the POS	Density of retail activities and services	
Social affordances			
Meeting friends	Meeting places; to – movement potential of spaces	Significance of the POS as a destination	Segment angular integration $r = n$; Presence of distinctive building or functions
Interaction among outdoor spaces and indoor spaces	Spatial and functional continuity between the street and the surrounding building and space	Level of integration of interiors and outdoor spaces	
Being with adults	Intergenerational activities	Presence of intergenerational activities	Co-presence of users of different age
Make new friends	Anchor places	Presence of anchor places within a 400 m buffer (sports facilities, educational institutions, shopping malls)	

(*Continued*)

Table 1. Continued.

Affordance	Environmental features	Indicator	Subindicators
Accessibility			
Decision among alternative routes	Connectivity	Axial connectivity	
Access to collective transport	Distribution of collective transport nodes	Distance from collective transport nodes	Maximum complement of normalized cost value for transport nodes
Access to local destinations	Distribution of amenities	Distance from services and amenities	Average complement of Normalized Cost value for *i*-destinations from *j* types of amenities
Access by walking	To – movement potential of spaces	Segment angular integration *r* = 400 m	

Environmental features and attributes associated with functional, emotional, and social affordances are then individuated according to the existing literature on walkability and place experience:

(i) Functional affordances are related to compositional and functional properties of individual spaces, including width, slope, condition of surfaces, presence of barriers along pedestrian facilities, barrier effect, availability and usefulness of formal and informal seats, configuration of edges, tree coverage, and usability of public lavatories.

(ii) Accessibility is herein conceptualised as a characteristic of spaces incorporating a transport component and a land-use component. More precisely, the land-use component is associated to access to local destinations. Access to local destination is operationalised in terms of metric distance from a set of proximate urban functions, and angular segment integration, within a 400-metre radius. Moreover, the transport component is related to the configuration of the urban spatial layout and it is operationalised in terms of axial connectivity, determining opportunities for choice among different routes, angular segment integration and access to transit. Normalised segment angular integration (NAIN) is a measure of the distance of a space to all other spaces, conceptualised in terms of the sum of angular changes that are made on each route. NAIN represents to-movement. It allows to understand the most central space represented by accessibility. Considering a set of spaces within a 400-metre radius is instrumental to underlining the potential of a space as a destination, with respect to patterns of pedestrian movement (Hillier and Vaughan, 2007). Angular integration yields (Rashid, 2017, p. 66): The angular integration of a segment *x* yields (Rashid, 2017, p.66):

$$AI_x = \frac{1}{n}\sum_{i=1}^{n} d_\theta(x, i)$$

Where n is the number of segments and $d\theta$ is the angle between any two segments on the shortest path on segment *x.* When adding the length l for of a segment, we get following equation for angular integration of a street segment with segment length l.

$$AI^l_x = \frac{\sum_{i=1}^{n} d_\theta(x, i)\, l\,(i)}{\sum_{i=1}^{n} l\,(i)}$$

Angular segment integration (NAIN) is normalised as follows (Hillier et al., 2012, p. 191):

$$NAIN = \frac{\sqrt[1.2]{Node\ count\ (r)}}{Total\ depth\ (r) + 2}$$

(iii) Emotional affordances are associated with natural control of the public space, also coined ‘natural surveillance’ (Jacobs, 1961), determining affordances for feeling safe, the imageability of a setting, associated to the opportunity for experiencing a place as conspicuous and legible, (Ewing and Handy, 2009), the density of retail activities along the edges of the public space, determining opportunities for experiencing liveliness within the public space (Gehl, 2013), and the acoustic environment (Garau and Annunziata, 2019), related to the affordance for experiencing quietness. The affordances for experiencing a safe public space are associated with structural, social, compositional, and configurational aspects of a street (See table 1). More precisely, structural factors include the visual and functional continuity between the outdoor space and the buildings forming its edges (Gehl, 2013). Configurational properties refer to the normalised angular choice, at radius n, measuring the global through-movement potential of a space, and hence representing system-wide movement patterns in relation to the area of study, herein, with a focus on their effect on pedestrian activities. (Hillier and Sahbaz, 2011). Compositional factors include prospect, presence of refuge space, and boundedness. These factors measure the ability to see from any point to any other point within a space, the presence of elements affording refuge, and the degree of enclosure of a space, including the distribution of access points, which affects the possibility to escape, respectively (Loukaitu-Sideris, 2011).

(iv)Lastly, social factors refer to signs of neglect and abandonment and to the presence of "social milieu fragilities", considered as a proxy of anti-social practices (Jamme et al., 2018, p.130). These attributes are considered as factors that affect patterns of co-presence and the natural surveillance of a public space, which in turn determine the perception of an open space as safe and inclusive. Finally, opportunities for social contact and interaction are associated with the potential of a public space as a meeting place, distance from anchor places, presence of intergenerational activities across a setting, and functional and spatial continuity between a public open space and the buildings constituting its edges (Blecic et al., 2015). The potential of a space as a meeting place is conceptualised in terms of its to-movement potential, and of the presence of distinctive buildings and/or urban functions.

Indicators based on topological, angular, or metric analyses of a segment map, and/or of an axial map, are analysed using Depthmap X software. If a space is intersected by multiple segments, Indicators related to segment analysis are measured by considering the mean of values calculated for each segment, provided the longest dimension of the space is more than 70 metres; otherwise, the value of the indicator is determined considering the segment with the highest value among those intersecting the considered space. The 70-metre measure is derived from Gehl (2013) and is considered a relevant social distance.

Indicators measuring distances from individual spaces to destination points representative of urban functions, transport nodes, and basic services are calculated using the network analysis processing tools incorporated into the QGIS suite. Cost variables representative of distances from retail activities, transport nodes, and anchor places are calculated using the shortest metric path-point to layer function. For each category of urban functions, a layer containing destination points is structured by aggregating data collected from informative systems imagery services (Google Maps, Google Earth), and validated via internet-based street level imagery services (Google Street View). To determine the point of origin, the mean coordinates algorithm is used to compute a point layer with the centre of mass of geometries representing each individual public open space.

Individual quantitative indicators are normalised via value functions and according to the concept of fuzzy logic, which defines the membership grade of an element to a set, representative of a condition or attribute, as a value ranging from 0.0 (certain non-membership) to 1.0 (certain membership) (Jabbari et al., 2018).

For indicators for access to collective transport nodes urban functions, cut-off values are set to truncate corresponding value functions to minimum and maximum values. The minimum value is set to 50 metres in order to compensate for different factors: (i) errors in defining the position of destination points on the map; (ii) tolerances set for the elaboration of the graph representative of the structure of urban spaces and for the calculation of lowest-cost routes between origin and destination points; and (iii) definition of origin points of the centre of mass of segments constituting individual public open spaces. On the other hand, the maximum radius value for measuring and investigating patterns of pedestrian movement is set at 800 metres. Furthermore, in determining the normalised value for the access to local transport nodes and access to urban functions, the condition of proximity of the space, *i,* to the destination, *j*, is conceptualised as the complement of the cost variable of the corresponding route, representative of the distance from the origin point to the destination point.

Qualitative indicators are normalised via binary evaluation, hence excluding intermediate values, or via scales, where significant intermediate conditions are formalised by values comprised between 0.0 and 1.0. For multi-dimensional indicators, incorporating different sub-indicators, an aggregate value is determined via addition of partial results, determined for individual sub-indicators, and formalised by a score ranging from 0.1 (least condition) to 1.0 (optimal condition). The resulting value is then normalised via a sigmoidal function. Values of sub-indicators are defined by determining a score for conditions observed on an ordinal scale for qualitative sub-indicators, or related to intervals of values on an interval scale for quantitative sub-indicators. The potential of a space as a meeting place is calculated as the product of the normalised value of the segment angular integration indicator and of a value, equal to 1 or to 0.1, determined via binary evaluation, indicative of the presence or absence of distinctive urban functions, buildings, or artefacts (see Table 2).

Insert Table 2

Category indexes are then determined as the mean value of the pertinent normalised individual indicators. Functional index, emotional affordances index, social affordances index, and accessibility index are therefore calculated in terms of a value ranging from 0.0 (marginal positive influence of environmental variables on walkability) to 1.0 (optimal influence of environmental variables on walkability). Category indexes are then summed to determine the value of I_{SWAT}, expressed as a score ranging from 0.0 to 4.0, where 0.0 is representative of environmental spatial and material properties preventing pedestrian movement, and 4.0 indicates a built environment conducive to pedestrian outdoor practices. For each index, measures of central tendency (mean and median) and measures of dispersion (standard deviation, inter-quartile range, skewness, and kurtosis) are calculated (See Table 3).

Insert Table 3

Reasons for selecting Iglesias as a case study are presented in the next section, and the results from the application of the WAT are presented and discussed in sections 5 and 6.

3.1 Selection of the Case study

This methodological framework was used to assess a sub-set of connected routes across the historic district of the city of Iglesias, in Sardinia, Italy (see Figure 1). This was selected for its demographic and socio-economic conditions. The specificity of the city of Iglesias is related to three factors: (i) an ageing population, in which residents aged more than 65 years represent 23.9% of the population, compared to a national average of 22.6% and a regional average of 23.2%; (ii) trends towards depopulation, underlined by the loss of 204 inhabitants in 2017(-0,8%) and of 269 inhabitants in 2018 (-1%); and (iii) economic stagnation, measured in terms of difference in GDP per capita between the city of Iglesias and the national and regional average. In 2016, the GDP per capita of Iglesias was €19200 per year, compared to a national average of €26,000 per year and a regional average of €20,600 per year (Eurostat, 2016a; Eurostat 2016b; Il Sole 24 ore, 2016). These phenomena call for actions aimed at increasing the usefulness of the public space from the point of view of vulnerable users, by designing open spaces to prioritise outdoor practices and pedestrian movement. Furthermore, a highly walkable environment supports a vital micro-economy in line with Hillier's theory of the natural movement (economic) process (Hillier et al., 1993).

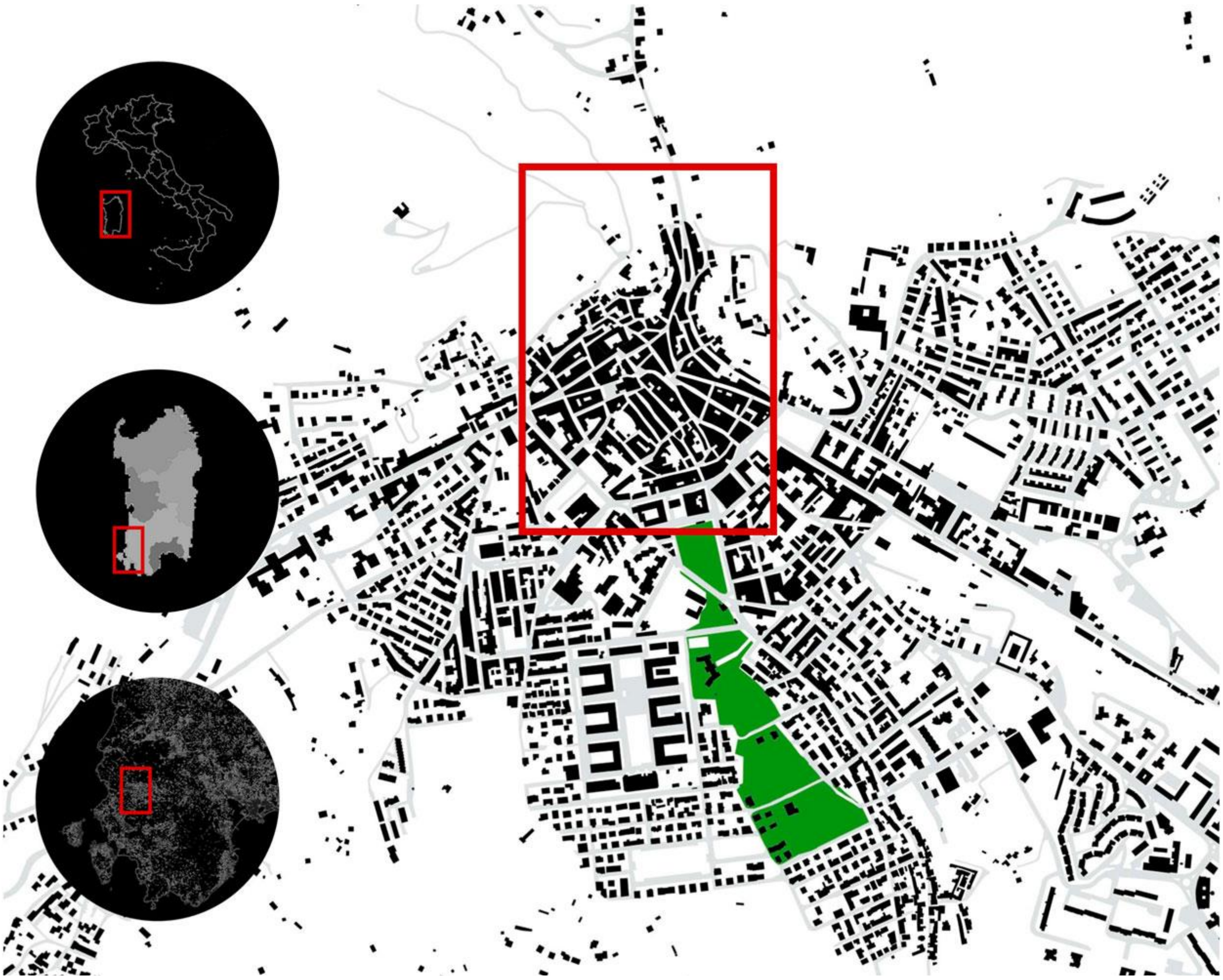

Figure 1. Selection and characterisation of the area of study: The city of Iglesias, in Sardinia Italy.

The examples from Finland (Verma and Taegen, 2019) underline that interventions of regeneration and renewal of the public space, aimed at improving walkability and accessibility, are instrumental in fostering independence and control over one's life, retaining homeowners, thus driving local economy and reversing trends towards depopulation. Finally, reasons for the analysis of spaces within the historic district are related to its configurational, compositional, and social attributes that positively affect walkability. These attributes include mixed uses, continuity of the network of pedestrian and limited traffic routes, and an integrated spatial structure (Garau et al., 2019).

In the following section, the results of the assessment of the sub-network of the most accessible routes are presented, and the walkability of the selected public spaces is analysed.

4 Results

The application of the WAT to the analysis of the system of spaces within the historic district of Iglesias underlines fair levels of walkability (see Figure 2). Values calculated for the I_{SWAT} index range from a value of 1.89 for Pescivendoli Street, corresponding to an inadequate level of walkability, to a value of 3.11 for Matteotti Street, representative of significant usability (see Table 4).

Figure 2. Distribution of I_{SWAT} values across a sub-network of integrated spaces within the historic district of the city of Iglesias, Italy.

Table 4. Values of the I_{SWAT}, I_f, I_e, I_s and I_a indexes for the selected area of study.

	Indexes of walkability and of categories of opportunities				
Urban public space	I_{SWAT}	I_f	I_e	I_s	I_a
Gramsci Street	2.65	0.43	0.55	0.87	0.81
Azuni Street	2.61	0.39	0.60	0.93	0.70
Martini Square	2.09	0.38	0.55	0.47	0.70
Martini Street	2.20	0.39	0.61	0.52	0.68
La Marmora Square	2.96	0.53	0.75	0.98	0.71
Canelles Street	2.18	0.36	0.42	0.68	0.73
Cavour Street	2.10	0.36	0.54	0.52	0.68
degli orti Street	1.90	0.36	0.44	0.47	0.63
Manno Street	2.19	0.37	0.45	0.64	0.73
Repubblica Street	2.59	0.45	0.51	0.95	0.69
Dritta Street	2.00	0.52	0.43	0.47	0.58
Sassari Street	1.95	0.36	0.46	0.46	0.66
Sarcidano Street	2.66	0.40	0.73	0.92	0.62
G. Pichi Square	2.83	0.52	0.75	0.91	0.65
Verdi Street	2.35	0.36	0.57	0.77	0.66
Dei Pescivendoli Street	1.89	0.30	0.44	0.47	0.68
Cagliari Street	2.75	0.41	0.68	0.90	0.76
G. Matteotti Street	3.11	0.52	0.75	0.98	0.87
Sulis Street	1.92	0.31	0.40	0.52	0.69
Mean value	2.36	0.41	0.56	0.71	0.70
Standard deviation	0.39	0.07	0.12	0.21	0.06
Interquartile range	0.66	0.09	0.24	0.45	0.05

Analysis of the central tendency reveals a mean value of 2.36, indicating an average level of walkability for the system of spaces within the historic district, and a median of 2.20. The measures of dispersion indicate a standard deviation of 0.39, and an interquartile range of 0.66, from 2.00 to 2.66. Consequently, 50% of the analysed spaces are characterised by a fair level of walkability, 25% are characterised by an inadequate level of walkability, and the remaining 25% comprises spaces significantly conducive to outdoor activities.
A more comprehensive understanding of the extent to which the compositional, configurational, and material attributes of spaces enable walking is supported by the values calculated for the category indexes for functional affordances (I_f), accessibility (I_a), emotional affordances (I_e), and social affordances (I_s). With respect to I_f, the mean value for the set of the analysed spaces is equal to 0.41 and the median is 0.39, suggesting that the sub-network of spaces is characterised by a low availability of opportunities for meaningful actions (Fig. 3). Values of I_f range from a low of 0.30, measured for Pescivendoli Street, to a high of 0.53 for La Marmora Square; 15 different spaces are inadequate for enabling meaningful actions, while four spaces are adequate.

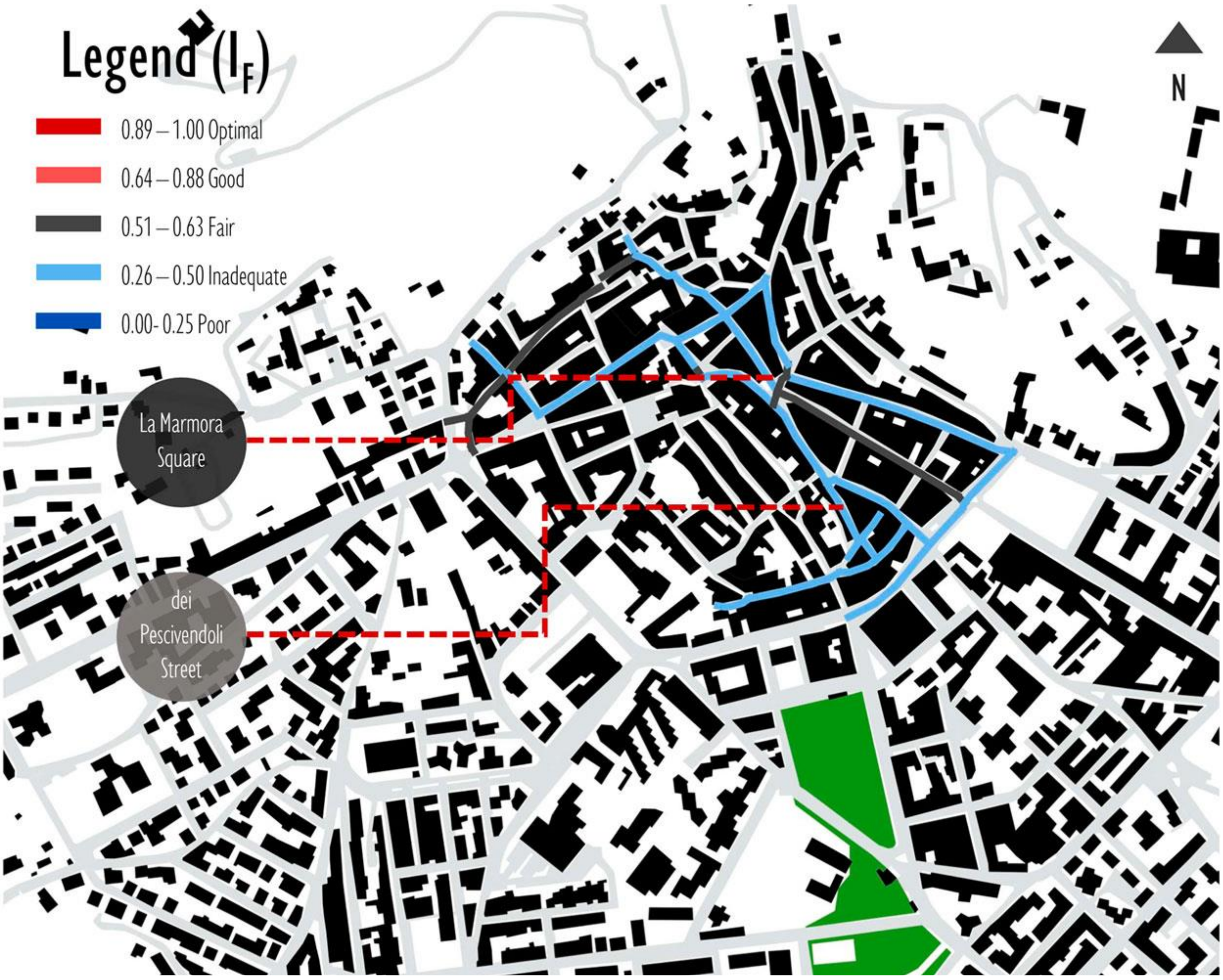

Figure 3. Variation of I_f values, measuring the availability of functional opportunities embodied in the built environment

With respect to dispersion measures, standard deviation is equal to 0.07 and the interquartile range equal to 0.09, from 0.36 to 0.45. These values denote a homogeneity of spatial, morphological, and material conditions across the analysed spaces, affecting the availability of functional opportunities.
The mean calculated for I_a is 0.70 and the median is 0.69, indicating good levels of accessibility of the analysed spaces (see Figure 4). I_a values range from 0.58, calculated for Dritta Street, to 0.87, measured for Matteotti Street. The measures of dispersion indicate a standard deviation of 0.06 and an inter-quartile range of 0.05, from

0.66 to 0.71. These values indicate a low variability of the configurational and contextual correlates of accessibility.

Figure 4. Variation of I_a values, measuring the accessibility of open spaces

Values for I_e on the other hand reveal that the built environment embodies adequate opportunities for positive and meaningful emotional experiences (Figure 5). The mean value is 0.56 and the median is 0.55, and the values observed range from 0.40, measured in via Sulis, to 0.75, measured in Pichi Square, La Marmora Square, and Matteotti Street.

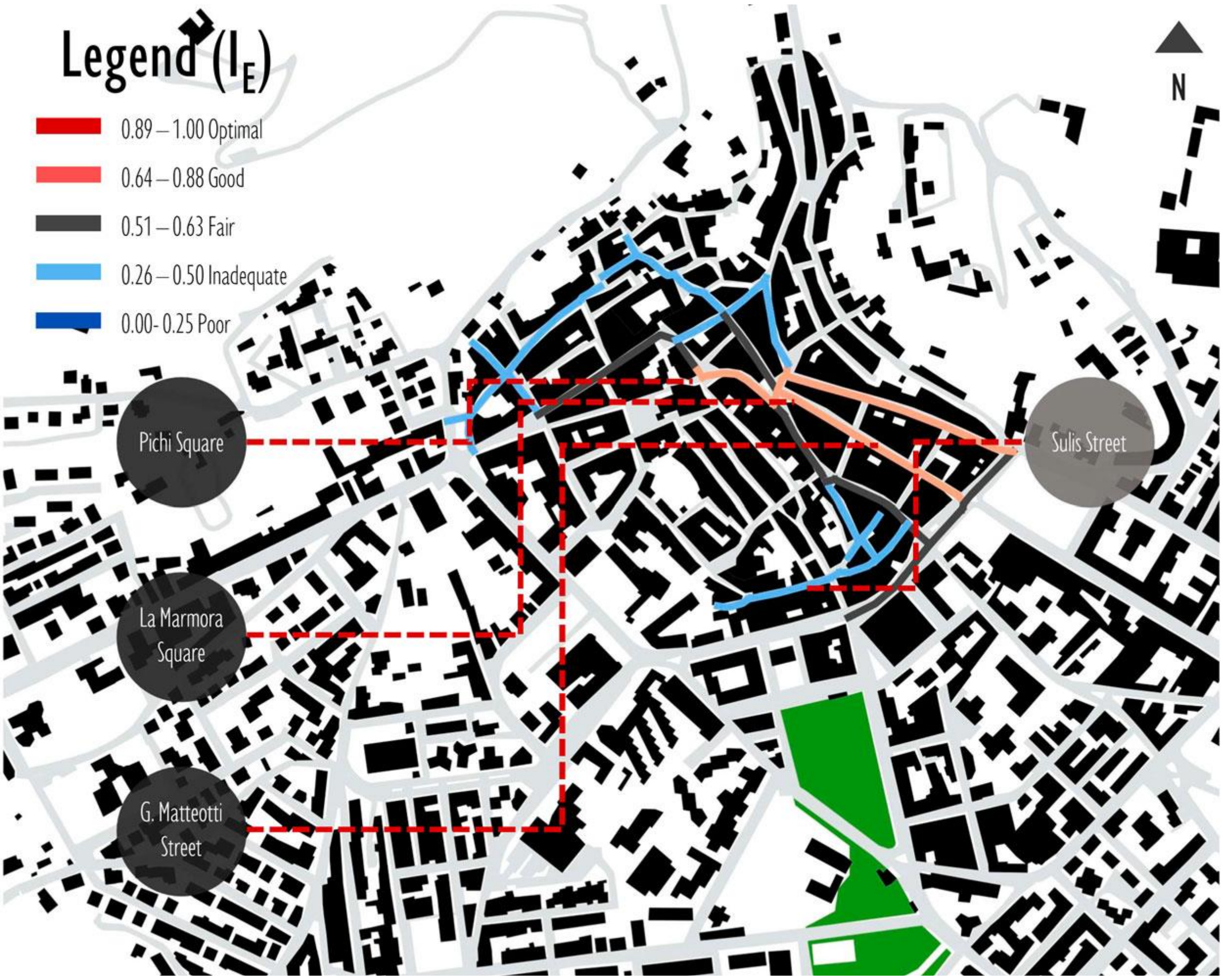

Figure 5. Variation of I_e values, measuring the availability of opportunities for meaningful emotional experiences embodied in the built environment

More precisely, seven spaces are characterised by an inadequate availability of emotional affordances, seven spaces by adequate emotional affordances, and five by reasonable opportunities for emotional experiences. Intrinsic and extrinsic spatial properties and social conditions, measured by the Natural Control of Public open spaces (POSs) indicator, suggest an average perception of spaces as safe. The mean is equal to 0.71, and values range from 0.48, measured in via Sassari, indicating an inadequate quality of outdoor space, to 0.98, measured in Matteotti Street, representing optimal quality in terms of actual and perceived safety. Measures of dispersion related to the Natural control of POSs indicator reveal that 25% of selected spaces have values greater than 0.82, representing good to optimal safety-related conditions. Lastly, measures of dispersion related to I_a denote a modest standard deviation, equal to 0.12, and an inter-quartile range of 0.24, from 0.44 to 0.68.

Values for I_s denote a significant availability of opportunities for social interactions (Figure 6). The mean is equal to 0.71 and the median to 0.68, with values ranging from 0.46, measured in via Sassari, to 0.98, indicating optimal quality of the public space, observed in Matteotti Street and La Marmora Square. Five spaces incorporate scarce opportunities for meaningful social interactions, three spaces are identified by adequate availability of social affordances, four spaces are reasonably conducive to contacts and interactions among individuals, and seven spaces incorporate optimal conditions for enabling meaningful social activities.

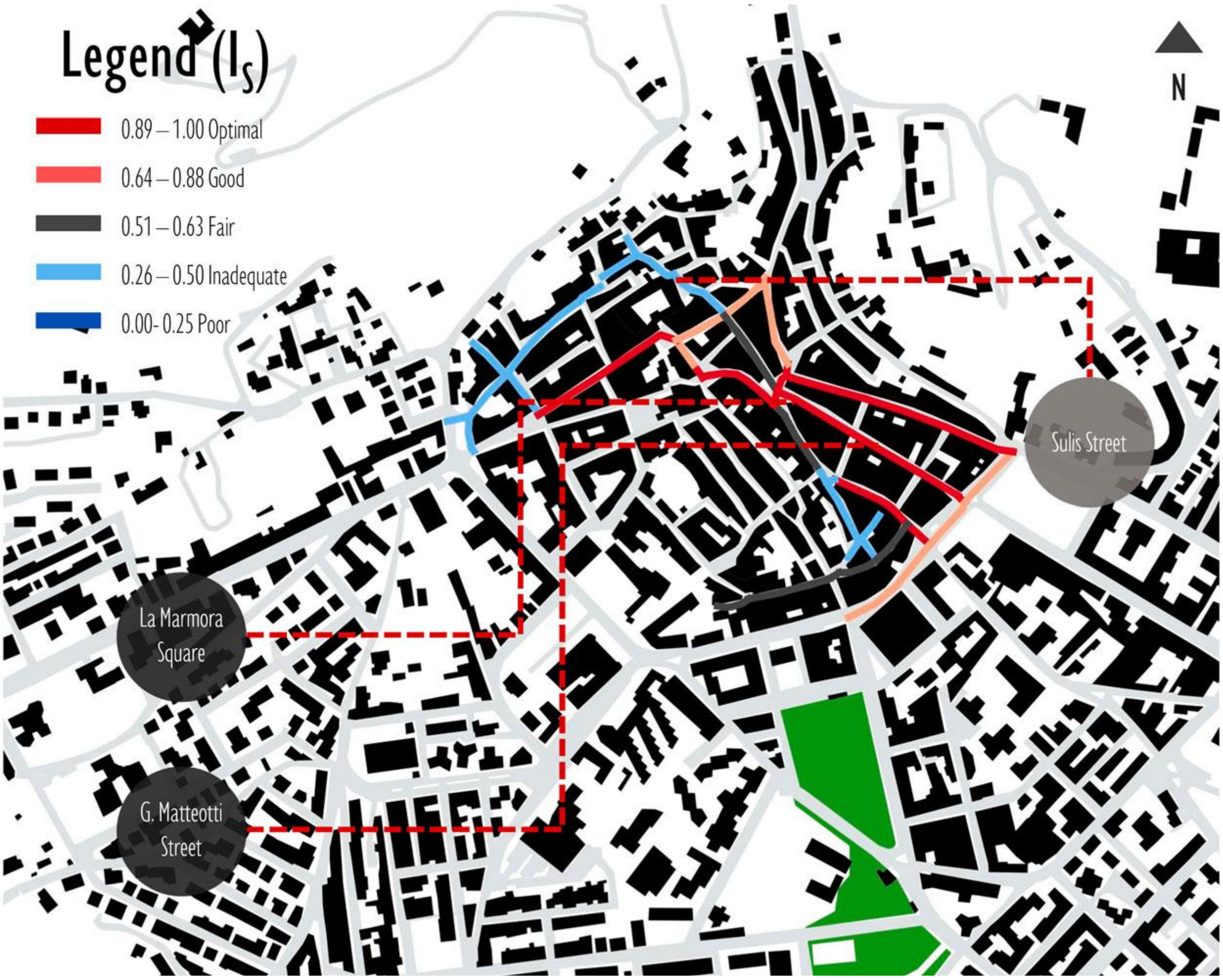

Figure 6. Variation of I_s values, measuring the availability of opportunities for social contacts engendered by the configuration, land-use patterns, and morphology of the built environment

Measures of dispersion related to I_s denote a significant standard deviation, equal to 0.21, and an interquartile range equal to 0.45. These values indicate a significant variability of spatial, social, and topological properties of spaces associated with the emergence of social activities.
The results presented in this section, and their implications in terms of perspectives for regeneration and renewal of the public space, are comprehensively analysed and discussed in the subsequent section.

5 Discussion

The results obtained via the application of the WAT highlight a number of factors that negatively affect walkability. The main concerns are the low diversity and the inadequate availability of opportunities for meaningful engagement with spaces and objects. This constrains spatial appropriation and engagement with public spaces while reducing the conditions of comfort.
More precisely, the dispersed, aligned, frontal, and concave arrangement of seats limits interactions and the differentiation of spatial propinquity among individuals, thus not allowing them to adapt their behaviour to social activities. Furthermore, the lack of public toilets can hinder the conditions of comfort of the public space and its usability from the elderly's viewpoint. The presence and availability of clean, well signed, and accessible public toilets, in proximity of walkways and pedestrian spaces, in fact, is identified as a central aspect for reinforcing social participation of the elderly within age-friendly and health promoting environments (WHO, 2007).

Finally, the lack of vegetation limits the functional opportunities for spatial appropriation and to meaningful engagement with the material environment, particularly for children. Meaningful engagement can in turn engender significant experiences of enchantment (Pyyry, 2017), as well as affective atmospheres constitutive of relational bonds among individuals (Giusti et al., 2018; Witten et al., 2017).
A further factor concerns spaces characterised by low levels of perceived safety. This condition is particularly associated with the irregular morphology of spaces, limiting individuals' ability to observe any point from any other point within the same open space, the absence of activities with extended service hours, and the presence of signs of neglect determined, in particular, by the significant number of abandoned buildings. The latter, in particular, is perceived as a manifestation of a lack of engagement and investment, and can diminish perceptions of safety by highlighting the incivilities and fragilities of the social milieu. Further factors relate to the inadequate imageability of the selected spaces. Only Gramsci Street, La Marmora Square, Pichi Square, Sarcidano Street, Cagliari Street, and Matteotti Street are characterised by distinctive and unique elements, reinforcing the imageability and visual richness of the public space. Furthermore, the low diversity and density of uses results in similarly low levels of activity in the public space. Amenities are concentrated in central integrated nodes (Pichi Square and La Marmora Square) and in adjoining connecting routes (Cagliari Street, Matteotti Street, and Sarcidano Street). Finally, the competition for space between vehicular flows and pedestrian movement and practices further limits walkability. In particular, the utilisation of streets for residents' parking significantly reduces the opportunities for recreational and social activities, thus limiting pedestrians' engagement with the public space.
These factors urge for urban design interventions aimed at increasing the complexity of the organisation of the public space. Complexity refers to the articulated combination of different scales, patterns, materials, and details in the organisation of the space, incorporating different levels of significance and function. Complexity entails an inclusive and unifying structure of the public space that encompasses contradictory and heterogeneous practices while engendering images vividly individuated, firmly structured, and functional of one's environment (Venturi, 1977; Lynch, 1960). Thus, complexity implies a conceptualisation of the public space as the realm of heterogeneous practices and experiences, of the exposition to diversity, and of the production of different ideas, subjects, and identities (Secchi, 2013; Zampieri, 2012).
An additional factor affecting the relevance and validity of the index of walkability, as well as its convenience in terms of conducting the study, concerns the quality of available data. Data referring to the city of Iglesias, collected from open-source databases, are incomplete, heterogeneous, and inaccurate. A thorough process of validation and integration is therefore necessary, based on information collected from internet-based street level imagery services (Google Street View) and territorial imagery services (Google Maps, Google Earth, Bing Maps), or from direct on-site observation. This aspect urges the involvement of private and public bodies, including professionals, academic and research institutions, and local authorities in a shared effort aimed at improving the currency, consistency, completeness, and accuracy of databases. The availability of consistent, accurate and comprehensive data is central to enabling thorough analyses of the different aspects, across scales, of the built environment, which in turn support planning processes in addressing inequality, precariousness, exclusion, and segregation.

6 Conclusion

This paper describes the theoretical and methodological framework for the development of an analytic tool for assessing the walkability of the public space, the WAT, and illustrates the results of its application to a case study of the city of Iglesias.
Consistent with the theoretical perspective embodied in the Smart-city paradigm, this study underlines the relevance of developing analytic tools that support the planning process by enabling the understanding of the built environment, in terms of incorporated opportunities and limits influencing human behaviour. This aspect is central to the decision-making process, helping to orientate design interventions towards the organisation of public space that enables social participation, inclusion, and sustainable ways of life, while affording multiple and varied experiences.

Furthermore, the application of the WAT to the case study illustrates that the proposed methodological framework can support the urban planning process in the individuation of factors of the built environment that negatively affect people's propensity to walk and to engage with the urban space. Moreover the characteristics of measurability, reproducibility, validity (related to verification and data quality control); comparability (over time); and accessibility (including availability of databases) of the indicators comprising of the WAT, enable two further ways of utilizing the methodology, within the planning process: (i) the evaluation of different scenarios of urban renewal and regeneration in order to identify high-leverage interventions; and (ii) comparison over time for monitoring and evaluating the consequences of actions of urban renewal and regeneration.

With respect to its theoretical framework, the study investigates the operationalisation of the concepts of capability and affordance in terms of a set of indicators aggregated into a synthetic index, expressing the potential of the public space to affect human behaviour and well-being.

Moreover, an unexplored aspect in existing studies on the usefulness of the public space is the interaction of intrinsic and extrinsic properties of a setting in determining patterns of activities. A review of the existing literature conducted across the Web of Science database, through the query (TS= ("space syntax" AND "walkability" AND "assess*")) reveals that only six articles consider the configuration of the urban structure as a relevant determinant of people's propensity to walk. The theoretical and methodological framework encompassed in the WAT addresses this issue by taking into account the synergy, in terms of walkability, of intrinsic micro-scale factors and extrinsic configurational properties, including betweenness and integration.

Nevertheless, two limitations emerge from this study, concerning the validation of results and the need to determine the relative importance of built-environment correlates of walkability according to contextual and individual factors.

In particular, Giles-Corti et al. (2005) underline the need to compare measures of behavioural outcomes and environmental variables to enhance the predictiveness of methodological frameworks for the analysis of the built environment. Consequently, the future development of this research should address these central issues. Firstly, the need to enhance the predictiveness of the WAT should be addressed through the investigation of the co-relation between measures of walkability and measures of actual patterns of activities across the urban space, derived from map-based surveys conducted via Public Participation Geographic Information System (PPGIS) and Volunteered Geographic Information (VGI) tools. Furthermore, Moura et al. (2016) and Battista and Manaugh (2018) observe that existing measures of walkability only marginally account for the effect of individual characteristics, including age, gender, abilities, needs and purposes, and contextual aspects, including socio-economic factors and cultural constructs, on people's experience of the public space. In this preliminary phase, which is primarily focused on the selection of indicators and on structuring the layout of the assessment tool, the same relative importance is attributed to the indicators encompassed in the WAT and a compensatory layout is selected (Jabbari et al., 2018; Garau and Pavan, 2018; Moura et al., 2017; Blecic et al., 2015). Consequently, the future development of the methodological framework will focus on investigating to what extent the weighting of indicators, according to the preferences of different stakeholders within a specific context, can increase the WAT predictiveness and its capacity to reflect specific perceptions of the built environment in different contexts. Consequently, the methodological framework embodied into the WAT will incorporate decision-making techniques based on the analytic hierarchy process (AHP) to support the Multi-Criteria analysis, by structuring group sessions involving different groups of stakeholders, including different categories of users and experts. The application of AHP will enable the weighting of correlates of walkability according to individual and contextual factors that affect the outdoor practices of different groups of users.

Finally, a further research direction concerns the issue of the usefulness of the public space, particularly from the point of view of vulnerable and/or marginalised groups of users, within the more general question of urban ethics. This concept refers to the ethical and moral implications of global processes of transformation of urbanised areas. Urban ethics brings together urban design, urban planning, politics, and ethics. This by advocating the agency of design practices as a force capable of orientating the urbanisation processes towards the shaping of a more ethical, and hence sustainable and just, urban future (Chan, 2019; Mostafavi, 2017). Within this perspective, the city emerges as a plausible source of mitigation, and, via conscious urban design, as a solution, to negative impacts derived from inequality and precariousness due to anthropic processes, including climate change (Tonkiss, 2013; Chan, 2019). The methodology encompassed in the WAT addresses the issue of

urban ethics by identifying criticalities reducing people's opportunities for walking, limiting their capabilities, achieving a just society and a sustainable urban environment. In particular, for children and the elderly, opportunities for walking are related respectively to the central capabilities of physical development and sustainment which also accounts for all five senses, playing, being independent, and of social connectedness. Nevertheless, further applications of the proposed methodology can focus on identifying degrees of socio-spatial and socio-economic relationships with regard to walkability and active land use for an urban area. Understanding these relationships and coupling them enables to identify the degree of spatial inequality and social injustice connected to opportunities for walking.
Consequently, the modular structure of the methodological framework, along with the utilisation of an analytic hierarchy process method for analysing complex decisions and map-based survey tools enabling public participation and validation of results allow for further adaption of the proposed methodology framework. This adaption does not only address the analysis of spatial practices of different user categories across different contexts, but also reinforces its objectivity, relevance, predictiveness, and validity of the walkability index. In this respect, an improved WAT tool could be a pertinent and relevant framework for strengthening urban policy, governance and planning actions related to the activity of creating and changing places. This by supporting decision-making processes and offering insight on the spatial, material and social conditions of the physical environment affecting behaviours and idiorrhythms of the subjects belonging to the different urban populations.

7 References

Blečić, I.; Cecchini, A.; Congiu, T.; Fancello, G.; Trunfio, G.A. Evaluating walkability: a capability-wise planning and design support system. International Journal of Geographical Information Science 2015, 29.8, 1350-1374, DOI: 10.1080/13658816.2015.1026824.

Calvert, T., Jain, J., & Chatterjee, K. (2019). When urban environments meet pedestrian's thoughts: implications for pedestrian affect. Mobilities, 14(5), 545-560.

Cervero, R.; Kockelman, K. Travel demand and the 3Ds: density, diversity and design. Transportation Research Part D: Transport and Environment, 1997, 2(3),199–219, DOI: 10.1016/S1361-9209(97)00009-6 .

Clifton, K. J.; Smith, A. D. L.; Rodriguez, D. The development and testing of an audit for the pedestrian environment. Landscape and Urban Planning 2007, 80(1-2), 95-110, DOI: 10.1016/j.landurbplan.2006.06.008.

Credit, K., & Mack, E. (2019). Place-making and performance: The impact of walkable built environments on business performance in Phoenix and Boston. Environment and Planning B: Urban Analytics and City Science, 46(2), 264-285.

D'Acci, L. (2019) Orientational versus esthetical urban street morphology parameterization in Space Syntax, Spatial Cognition & Computation, 19:3, 172-189, DOI:10.1080/13875868.2018.1564754.

Eurostat (2016)a. Real GDP per capita. Available on line: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=sdg_08_10 (accessed on 26 March 2019).

Eurostat (2016)b. Regional gross domestic product (PPS per inhabitant) by NUTS 2 regions. Available on line: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tgs00005&plugin=1 (accessed on 27 March 2019).

Ewing, R., Handy, S. (2009). Measuring the Unmeasurable: Urban Design Qualities Related to Walkability, Journal of Urban Design, 14:1. 65-84, doi: https://doi.org/10.1080/13574800802451155;

Ewing, R.; Connors, M.; Goates, J.; Hajrasouliha, A.; Neckerman, K.; Nelson, A.; Green, W. Validating urban design measures. In TRB 92nd Annual Meeting Compendium of Papers, Proceedings of the Transportation research board 92nd annual meeting, Washington DC, United States, January 13-17, 2013; 13-1662.

Ferdman, A. (2019). Walking and Its Contribution to Objective Well-Being. Journal of Planning Education and Research, 0739456X19875195.

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. Journal of the American Planning Association, 72(1), 75–87.

Garau, C., Annunziata, A. (2019). Smart City Governance and Children's Agency: An Assessment of the Green Infrastructure Impact on Children's Activities in Cagliari (Italy) with the Tool "Opportunities for Children in Urban Spaces (OCUS)". Sustainability, 11(18), 4848. doi: https://doi.org/10.3390/su11184848.

Garau, C.; Pavan, V.M. Evaluating Urban Quality: Indicators and Assessment Tools for Smart Sustainable Cities. Sustainability 2018, 10.3, 575, DOI:10.3390/su10030575.

Gehl, J. (2011). Life between buildings: using public space. Island press.

Gehl, J. (2013). Cities for people. Island press: Washington DC, United States, ISBN 9781597265737;

Gibson, J. J. The Ecological Approach to Visual Perception; Lawrence Erlbaum: Hillsdale, NJ, USA. 1979. doi: https://doi.org/10.2307/429816;

Giles-Corti, B., Timperio, A., Bull, F., & Pikora, T. (2005). Understanding physical activity environmental correlates: increased specificity for ecological models. Exercise and sport sciences reviews, 33(4), 175-181.

Gillette, H. (2010). Civitas by design: Building beter communities, from the Garden City to the New Urbanism. Philadelphia: University of Pennsylvania Press.

Giusti, M., Svane, U., Raymond, C. M., & Beery, T. H. (2018). A framework to assess where and how children connect to nature. Frontiers in psychology, 8, 2283.

Heft, H. Affordances of children's environments: A functional approach to environmental description. Children's Environments Quarterly 1988, 29-37.

Hillier, B., Hanson, J., and Graham, H. (1987), Ideas are in things: an application of the space syntax method to discovering house genotypes. Environment and Planning B: Planning and Design, v14, 363-385. pp. 363;

Hillier B. Space is the machine: a configurational theory of architecture. Cambridge, UK: Cambridge University Press. 1996.

Hillier, B. (1999), Centrality as a process: accounting for attraction inequalities in deformed grids. Urban Design International, 4 (3/4) 107 – 127. pp.107

Hillier B (2012) The Genetic Codes for Cities: Is It Simpler than We Think?. In Portugali J., Meyer H., Stolk E., Tan E (eds) Complexity Theories of Cities Have Come of Age. An Overview with Implications to Urban Planning and Design, Springer, pp. 129–152.

Hillier B and Iida S (2005) Network effects and psychological effects: A theory of urban movement, 5th International Space Syntax Symposium, proceedings, pp. 553–564

Hillier, B., Penn, A., Hanson, J., Grajewski, T., Xu, J. (1993): Natural movement: or configuration and attraction in urban pedestrian movement. Environment and Planning B: Planning and Design 20, pp. 29-66

Hillier, B., Sahbaz, O. (2011). Safety in numbers: high-resolution analysis of crime in street networks. In The urban fabric of crime and fear ; Ceccato, V., Springer: Dordrecht, Netherlands, 2011. 111-137.

Hillier, B., Yang, T., Turner, A (2012) Normalising least angle choice in Depthmap and how it opens nw perspectives on the global and local analysis of city space, Journal of Space Syntax, Vol3(2), p. 155-193.

Il sole 24 Ore (2016). La mappa dei redditi nelle città. Available on line: http://lab24.ilsole24ore.com/mappaRedditi/index.html (accessed on 27 March 2019).

Istat (2019). Popolazione residente per età, sesso e stato civile al 1° Gennaio 2018. Available on line: http://demo.istat.it/pop2018/index4.html (accessed on 26 March 2019).

Jabbari, M.; Fonseca, F.; Ramos, R. Combining multi-criteria and space syntax analysis to assess a pedestrian network: the case of Oporto. Journal of Urban Design 2018, 23(1), 23-41, DOI: 10.1080/13574809.2017. 1343087.

Jacobs, J. (1961). The death and life of great American cities. Random House: New York, USA; ISBN 978-067964433-0;

Jamme, H. T. W., Bahl, D., Banerjee, T. (2018). Between "broken windows" and the "eyes on the street:" Walking to school in inner city San Diego. Journal of Environmental Psychology, 55, 121-138. doi: https://doi.org/10.1016/j.jenvp. 2018.01.004

Kamel, M. A. E. Encouraging walkability in GCC cities: smart urban solutions. Smart and Sustainable Built Environment 2013, 2(3), 288–310, DOI: 10.1108/SASBE-03-2013-0015;

Kyttä, M. 2002. "Affordances of Children's Environments in the Context of Cities, Small Towns, Suburbs and Rural Villages in Finland and Belarus." Journal of Environmental Psychology 22 (1–2): 109–123;

Kyttä, M.; Oliver, M.; Ikeda, E.; Ahmadi, E.; Omiya, I.; Laatikainen, T. Children as urbanites: mapping the affordances and behavior settings of urban environments for Finnish and Japanese children. Children's Geographies 2018, 16(3), 319-332. doi: https://doi.org/10.1080/14733285.2018.1453923;

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., & Hugo, G. (2007). Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes. Health & Place, 13(1), 111–122.

Loukaitou-Sideris, A. Safe on the move: The importance of the built environment. In The urban fabric of crime and fear; Ceccato, V., Springer: Dordrecht, Netherlands, 2011. 85-110.

Lynch, K.: The Image of the city, 2nd ed.; MIT Press, Cambridge, United States, 1964; ISBN: 9780262620017.

Mostafavi, M. (2017). Agnostic Urbanism. In M. Mostafavi (Ed.), Ethics of the Urban: The city and the spaces of the political (pp.9-16). Zurich: Lars Muller.

Moura, F.; Cambra, P.; Gonçalves, A.B. Measuring walkability for distinct pedestrian groups with a participatory assessment method: A case study in Lisbon. Landscape and Urban Planning 2017, 157, 282-296, DOI: 10.1016/j.landurbplan.2016.07.002.

Nussbaum, M. C., & Glover, J. (Eds.). (1995). Women, culture, and development: A study of human capabilities. Clarendon Press.

Nussbaum, M. C. (2001). Women and human development: The capabilities approach (Vol. 3). Cambridge University Press, New York, USA, ISBN-13 978-0-521-00385-8;

Nussbaum, M. C. (2011). Creating Capabilities; Harvard University Press: Cambridge, MA, USA. ISBN 978-067407235-0;

Pikora, T.; Giles-Corti, B.; Bull, F.; Knuiman, M.; Jamrozik, K.; Donovan, R. Survey of the Physical Envi-ronment in Local Neighbourhoods SPACES Instrument: Observers Manual; The University of Western Australia, Nedlands, Australia, 2000. Available on line: https://activelivingresearch.org/sites/default/files/ SPACES_Observation_Manual.pdf (accessed on 12 April 2018).

Pyyry, N. (2017). Thinking with broken glass: making pedagogical spaces of enchantment in the city. Environmental Education Research, 23(10), 1391-1401. doi: https://doi.org/10.1080/13504622.2017.1325448;

Rashid M (2017) The Geometry of urban Layouts. A Global Comparative Study, Springer International Publishing Switzerland.

Raymond, C. M., Giusti, M., Barthel, S. (2018). An embodied perspective on the co-production of cultural ecosystem services: toward embodied ecosystems. Journal of Environmental Planning and Management, , 61(5-6), 778-799. doi: https://doi.org/10.1080/09640568.2017.1312300.

Rosenberg, D.; Ding, D.; Sallis, J.F.; Kerr, J.; Norman, G.J.; Durant, N.; Harris, S.K.; Saelens, B.E. Neighborhood environment walkability scale for youth (NEWS-Y): Reliability and relationship with physical activity. Preventive Medicine 2009, 49, 213-218, DOI: 10.1016/j.ypmed.2009.07.011.

Saelens, B. E.; Frank, L. D.; Auffrey, C.; Whitaker, R. C.; Burdette, H. L.; Colabianchi, N. Measuring physical environments of parks and playgrounds: EAPRS instrument development and inter-rater reliability. Journal of Physical Activity and Health 2006, 3(s1), S190-S207, DOI: 10.1123/jpah.3.s1.s190.

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: A review. Medicine and Science in Sports and Exercise, 40(7 Suppl), S550

Sen, A. Capability and Well-being. In The Quality of Life; Nussbaum, M.; Sen, A. Eds.; Clarendon Press: Oxford, UK, 1993; pp. 30–53;

Su, S., Zhou, H., Xu, M., Ru, H., Wang, W., & Weng, M. (2019). Auditing street walkability and associated social inequalities for planning implications. Journal of Transport Geography, 74, 62-76, DOI: https://doi.org/10.1016/j.jtrangeo.2018.11.003

Talavera-Garcia, R.; Soria-Lara, J.A. Q-PLOS, developing an alternative walking index. A method based on urban design quality, Cities 2015, 45, 7-17, DOI: 10.1016/j.cities.2015.03.003.

van Nes, A.; Yamu, C. (2018) Space Syntax: A method to measure urban space related to social, economic and cognitive factors. In *The Virtual and the Real in Planning and Urban Design*, Yamu, C.; Poplin, A.; Devisch, O.; De Roo, G. Eds. Routledge: London, UK, 2017; pp. 136-150.

Van Nes, A.; Yamu, C. (2020) Introduction to Space Syntax in Urban Studies. Dordrecht/London/New York: Springer.

Venturi, R. (1977). Complexity and contradiction in architecture (Vol. 1). The Museum of modern art.

Verma, I. & Taegen, J. (2019). Access to Services in Rural Areas from the Point of View of Older Population—A Case Study in Finland. Int. J. Environ. Res. Public Health, 16, 4854

Wang, H., & Yang, Y. (2019). Neighbourhood walkability: a review and bibliometric analysis. Cities, 93, 43-61.

Witten, K., Kearns, R., Carroll, P., Asiasiga, L. (2017). Children's everyday encounters and affective relations with place: experiences of hyperdiversity in Auckland neighbourhoods. Social Cultural Geography, 1-18.

Xu, M., Yu, C. Y., Lee, C., & Frank, L. D. (2018). Single-Family Housing Value Resilience of Walkable Versus Unwalkable Neighborhoods During a Market Downturn: Causal Evidence and Policy Implications. American Journal of Health Promotion, 32(8), 1714-1722.

Yamu C. (2014) It is Simply Complex(ity). Modeling and Simulation in the Light of Decision-Making, Emergent Structures and a World of Non-Linearity. *disP – The Planning Review*, 50(4), pp.43–53.

World Health Organization. (2007). Global age-friendly cities: A guide. World Health Organization.

Aknowledgement: This study was supported by the project "Space Syntax and Multicriteria Analysis for the Measurement of Walkability in the Build Environment", founded by the programme "Bando 2019 Mobilità Giovani Ricercatori (MGR)", financed by the Autonomous Region of Sardinia (under the Regional Law of 7 August 2007, n. 7 "Promotion of Scientific Research and Technological Innovation in Sardinia").

Author Contribution: This paper is the result of the joint work of the authors. In particular, “Methodology”, “Results”, and “Selection of the Case study” and “Discussion” were written jointly by the authors. C.G. wrote “Introduction” and “Methodological basis”. A.A. wrote “Literature review” C.Y. wrote “Conclusions”.