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Evaluating Urban Quality: Indicators and Assessment Tools for Smart Sustainable Cities

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Abstract: The analysis of urban sustainability is key to urban planning, and its usefulness extends to smart cities. Analyses of urban quality typically focus on applying methodologies that evaluate quality objectives at environmental, urban, and building levels. Research has shown that a system of indicators can be useful for developing qualitative and quantitative descriptors of urban environments. The first step in this study was to formulate a methodology to measure the quality of urban life based on investigative checklists and objective and subjective indicators, aggregated to develop an index to evaluate a city's level of smart urban quality. The second step was to apply this methodology to evaluate the city of Cagliari (Italy) at the neighbourhood scale, which is considered by literature the most suitable as a self-sufficient spatial unit for showing redevelopment results. In addition to sharing its research findings, this study aims to verify whether the methodology can be applied to similar urban contexts. The main outcomes of this research pertain to opportunities to numerically measure both objective and subjective aspects that affect urban quality. In this way, the most critical areas to be requalified have been highlighted in order to prepare policies congruent with the local context.

Keywords: urban sustainability; smart cities; urban quality assessment; indicators; smart governance

1. Introduction

The concept of smart cities has attracted significant attention in the context of urban development policies. Although there is not a general consensus on what the concept of a smart city is, at its core, the notion is premised on the networking of human capital, social capital, and information and communications technologies (ICTs). It is, moreover, supported by the level of infrastructure needed to promote sustainability challenges (economic, environmental, and social development) and lead to a better quality of life [1–3]. Scholars started to consider the term "Smart Sustainable Cities" [4], so as to incorporate the different aspects of sustainability in the classical "smart cities" paradigm. In fact, literature tends to consider as a sustainable city a place that have a strong environmental focus [5] with a balance within the city between infrastructures, ICT, smart technologies, and urban metabolism—sewage, water, energy and waste management [6]. In addition, interpretations of urban sustainability have promoted an anthropocentric approach that encourages cities to respond to people's needs by designing sustainable solutions to mitigate social and economic weaknesses [7–9]. Ensuring liveable conditions in the context of rapid global urbanisation demands a deeper understanding of the smart city concept, and many cities are finding smarter ways to manage them. So, what makes a city 'smart' and 'sustainable' is the capacity to systematise processes that, thanks to ICTs, optimize the functionality of the city in all sectors, by protecting the environment, by stimulating economic growth in the local context, and by improving the quality of life of people.

In the urban planning field, the notion of a smart sustainable city is often treated as an ideological dimension dependent on strategic directions, in order to find a good balance between territories and human societies via ICT and behavioural changes [10]. Cities have recently become aware of this concept, by producing data particularly in terms of energy [11] and transport [12] and developing smart management strategies for using the cities' resources more effectively and for decreasing the costs and waste that urban living generates [10], also in term of wellbeing and inclusion. Giffinger and Gudrun [13] rely on traditional and neoclassical theories of urban growth and development to evaluate criteria for ranking smart cities, and include an assessment in the quality of life in their ranking. Many researchers [4,14–22] argue that the quality of life may not represent a separate dimension of a smart sustainable city, given that all the actions undertaken in the other areas of city management should also have the objective of raising the quality of life and urban competitiveness. Ibrahim et al. [4] underlines as "a smart sustainable city is evolving as an urban space that tends to solve urban problems and improve quality of life of citizens, making urban development more sustainable" (p. 530).

According to Fleischmann and Heuser [23] and Chourabi et al. [24], the transformation of an ordinary non-smart city to a smart city also entails networking its technological components with its political and institutional components.

Public actions, administered in a discretionary manner, have been used to manage critical planning issues that include the depopulation of historical centres, the deterioration of suburbs, mobility problems, difficulties inherent in managing public property, the incoherent super-positioning of spreading cities, and a loss of interest in social places [25]. Governments at all levels are now embracing the both notion of sustainability and smartness, by developing specific policies and programs that target sustainable development, economic growth, a better quality of life for citizens, and the creation of happiness [14]. Several cities—including Barcelona, Amsterdam, Berlin, Manchester, and Edinburgh—have undertaken transformation projects and smart city initiatives to better serve their citizens and enhance their quality of life.

Until now, researchers have used two basic approaches to examine the quality of urban life: the objective approach, which is typically confined to analysing and reporting secondary data—usually aggregate data that are mainly available from official government data collections, including the census, at different geographic or spatial scales—and the subjective approach, which uses social survey methods to collect primary data at the disaggregate or individual level, and focuses on peoples' behaviours and assessments, or their qualitative evaluations of different aspects of urban life [26].

Since 2014, 34 Organisation for Economic Cooperation and Development (OECD) countries have attempted to collect data about people's well-being several times a year. Comparisons have been made using nine criteria—these include access to services, civic engagement, the environment, individual incomes, employment, and education—with open data being made available to researchers and citizens [27].

Also in Europe, different organisations are now trying to identify the best indices for quantifying/evaluating urban smartness. For example, the Finnish Technical Research Centre has created the CITYkeys project (2015–2017) [28], funded by the European Union HORIZON 2020 programme [29], which is developing performance indicators and data collection procedures to monitor and compare smart city solutions across European cities. Research institutes including VTT (coordinator, Finland), AIT (Austria), and TNO (Netherlands) have cooperated with five cities—Rotterdam, Tampere, Vienna, Zagreb, and Zaragoza—and EUROCITIES to define needs, analyse results, and develop recommendations for the use of performance indicators. Given this dynamic evolutive background, it has become necessary to understand and evaluate how cities and territories are changing. The city must become a powerful generator of value, beginning with its own spatial, social, cultural, and relational resources. The new creative city has to provide opportunities for real development that are not only quantitative but also increasingly qualitative that positively influence the domains of collective assets and economic and social capital [30]. This research aims to document an accurate and flexible procedure for evaluating the urban quality of medium-density neighbourhoods, using an approach that combines both objective and subjective approaches, because the authors consider it imperative that both dimensions of urban quality be considered simultaneously [14,31–35].

This paper is organised into three sections. The authors begin by evaluating urban quality concepts under the smart sustainable paradigm, the objectives of this research, and the evaluation framework on which it is premised. Second, we introduce the tools—including indicators and checklists—useful for policy makers' quantitative and qualitative analyses of urban spatial features. We specifically consider the definition of an Indicator of Smart Urban Quality (I_{SUQ}), which refers to the neighbourhood, prioritises existing problems, and proposes regeneration interventions aimed at improving the neighbourhood's urban quality. The third part develops the concepts presented earlier and applies the evaluation methodology developed in a case study of the city of Cagliari, Sardinia, Italy. The paper concludes by evaluating the results of the case study analysis and exploring the model's possible relevance for other similar contexts.

2. Methods

2.1. Methodology and Objectives of Urban Quality Evaluation

The methodology developed in this study synthesises theoretical and conceptual aspects of urban quality under the smart sustainable paradigm. Most of the dimensions that affect citizen satisfaction are determined by state policies, and regional planners need best practices to facilitate local planning and management [36]. Marsal-Llacuna et al., (2015) [5] and Ahvenniemi et al., (2017) [4] underline that urban monitoring started in the 1990s thanks to the indicators of Local Agenda 21, able to monitor sustainability of urban areas. Subsequently, the Economist Intelligence Unit's quality of life index [37] started to analyse the quality of life, followed by Mercer's annual quality of life survey [38] and by the most famous ranking of quality of life Index (Monocle's Most Livable City [39] and the one of International Living [40]. Over the years, different urban sustainability assessment tools measure sustainability from different angles. Well-known neighborhood sustainability rating tools, such as LEED, *(Leadership in Energy and Environmental Design)*, *BREEAM (Building Research Establishment Assessment Method)*, CASBEE *(Comprehensive Assessment System for Building Environmental Efficiency)* and Green Star NZ analyzed for example by Doan et al., (2017) [41]. In addition, different tools—that use indicators—are developed to help city planners to assess different approaches of a smart sustainable city, from the energy efficiency of a detailed city plan to transportation network's field. However, this versatility can be useful for a holistic assessment framework for steering integrated challenges, such as the smart sustainable paradigm.

Regional planners lack yet valid scientific tools that would enable them to assess conditions in urban areas and how local inhabitants perceive their environment.

The key objective of this study was to develop a new scientific methodology that can be used to support cities' transformation into smart sustainable cities and to evaluate the validity of this performance measurement framework for monitoring and comparing the implementation of smart city solutions. Though performance measurement is a key component of both planning and implementing smart city solutions [30,42], cities have not yet widely adopted or implemented performance measurement systems.

This study aimed to develop a measurement framework that can be used to interpret and integrate aspects of citizens' urban life quality by interpreting interactions between urban and environmental systems, and between critical resources and their influences on the environment. According to Dotti [27], a key question that remains unanswered pertains to how the numerical results of indices can be correlated with how citizens perceive their quality of life. Thus, our primary objective was to develop a set of indicators and an index that can be used to measure urban aspects and their influence on the quality of urban life.

The evaluation of urban quality of life can be undertaken at various scales [43], from the city level to the neighbourhood or building level, thus enabling the integration of different aspects. Indicators should monitor progress over time [44]. For this reason, city indicators should be formulated in such a way that they can be easily incorporated into a city's on-going programme of gathering statistics, and their measurements should be summarised and integrated into the city's planning processes.

The proposed evaluation framework will enable smart cities to strengthen their strategic planning efforts and measure their progress [45]. Under this framework, a city's quality of life will be evaluated, findings compared over time, and its progress toward smart city goals monitored in relation to the extent to which its policy goals have been achieved. In addition, when used with care, city-level indicators may be used to compare cities. A smart city evaluation framework should encompass different sectors rather than focus on only one, and impact categories should be subdivided to allow for more flexibility [46]. These indicators and indices will allow us to identify homogeneous areas that experienced significant differences in the quality of services provided in various urban areas, as well as differences in their environmental aspects.

Many factors must be considered, including the following: better public transportation, protection of the environment, improvements in housing conditions, improved health and well-being, digital infrastructure and e-services, better city governance, and the protection of natural resources. To be a useful tool, outputs of a monitoring framework must consider all city stakeholders' priorities. For citizens, useful means a better environment and quality of life; in practice, it means better and more efficient services, tackling social and economic challenges, and focusing on innovation and job creation. For cities, useful means tackling social issues while making the city more efficient and sustainable, as well as more competitive and financially robust [28].

According to Bosch et al. [28], useful can be further developed by highlighting aspects of smartness. A smart city is a city that mobilises and uses available resources to improve its inhabitants' quality of life, significantly improves its resource-use efficiency, reduces its demands on the environment, builds an innovation-driven and green economy, and fosters a well-developed local democracy [28]. Given that we are designing indicator lists in this context, we have begun by identifying those indicators that will be useful and feasible for evaluating actual levels of urban quality. By definition, smart cities can be expected to offer better services for city users, have fewer negative impacts on the environment, have more responsive administrators, be more informed and educated, and encourage citizen participation [11,24,47–49].

In the following section, we describe the selection of the indicators of urban quality and how the Indicator of Smart Urban Quality was created in relation to the development of our case study.

2.2. Designing of the Indicators Criteria

Nowadays, it is important to evaluate the quality of urban life, in order to define public intervention priorities, and to evaluate problems to ensure that the policies developed are compatible with the local context. Citizens and stakeholders have high expectations, both in terms of quality and quantity, and city decision makers need to monitor the impacts of their smart city strategy over time while reflecting on how the city can become smarter. In particular, more emphasis must be given to three objectives that affect them directly: improving the quality of life, providing better services to the citizens, and creating an environment that fosters innovative jobs [28]. Assessing the quality of urban spaces involves documenting current conditions and then applying methodologies aimed at achieving the city's urban and environmental quality objectives. Doing so involves initiating a methodological process that begins with a site analysis, during which critical aspects are highlighted [50].

According to Gehl [51], urban density is key to understanding how cities function. Density is closely related to urbanisation, which will influence how our cities may evolve in the future. However, density is a slippery concept. When density is measured over metropolitan areas that vary in size from city to city, it does not provide very meaningful data [52].

Density and compactness are two closely related but different criteria, and both are relevant to sustainable urban development and the transformation of cities. While a high degree of compactness is desirable, too great a population per unit area can be detrimental to liveability, health, and urban well-being [53]. Approximately 2000 inhabitants is considered an optimal value [54], referred to as the number of people who inhabit a given urbanised area. It is considered ideal, especially for evaluating the urban quality of medium-density neighbourhoods.

As a consequence of the urban and functional analyses, a case study should have between 4000 and 10,000 inhabitants. This has been considered the optimum dimension as it can include housing, collective spaces, and services [55]. This study focuses on the neighbourhood planning processes, since they represent an intermediate urban scale, larger than a single building and its immediate surroundings but smaller than an entire town or city—in other words, a spatial unit that is self-sufficient and characterised by social interactions between residents. A neighbourhood is a small but relatively independent area of dwellings, employers, retail, and civic places, and its residents and employees identify with their immediate environment in terms of social and economic attitudes, lifestyles, and institutions [56]. The methodology adopted should consider the real needs of city users, and involve all interested social parties. Proven investigative urban checklists and environmental indicators should be used in a city's transformation process.

The selection of appropriate indicators included research and exploration, evaluation, and selection of relevant databases. Thanks to these, adequate indicators of measurement (as a basis for determining the level of the city performance development and consequently a useful tool for ranking of comparable cities) was obtained. Different types of indicators exist. To evaluate the progress of a city of asset in achieving goals, the primary focus is on impact indicators. Often, various indicators are available to assess the progression towards a certain goal.

The indicator selection process reliese on a set of general selection criteria against which indicators can be evaluated [57].

To arrive at a shortlist of indicators, a set of criteria can be used, such as the one based on the CIVITAS [58] framework and the one based on the Citykeys one. Starting from the analysis of the criteria used by these two frameworks, the authors have constructed the list of criteria for the selection of the indicators that they consider most effective for their study. Following these considerations, indicators in the study were selected on the basis of following criteria: *objectivity* (clear, easy to understand, precise, and unambiguous); *relevance*, *measurability*, and *reproducibility* (quantitative, systematic observable); *validity* (with the possibility of verification and data quality control); *representativeness* (at the city level); *comparability* (over time); and *accessibility* (available databases, use of existing data). According to Delsante, Bertolino, Bugatti, and Cristina [59], the set of indicators used should include references to housing, social, and collective services at the neighbourhood scale, as well as references to the landscape and its environmental features. As previously stated, this procedure should comprised both quantitative and qualitative indicators that can be adapted to different urban settlements. These indicators must encompass more than density and green surfaces—such as how effectively maintenance services are provided, how homogeneous the distribution of services is, and the relative quality of public spaces, in terms of furniture and lighting, for example [59]. The choice of a shortlist of quantitative and qualitative indicators is a delicate process that first requires the identification of the case study, because the indicators are strictly connected with the territory. For that reasons, authors describe the case study, which in this case is the historic centre of Cagliari and its peripheral areas.

2.3. The Case Study of Cagliari (Italy)

Cagliari is the capital city of the Sardinian Region in Italy. Located on the southern coast of the Island of Sardinia, it is considered the island's political, economic, cultural, and tourism centre.

The city covers 85 km^2, has a population of 154,460, and has a population density of 1817 people per square km [60]. A value of urban density of approximately 2000 inhabitants is considered an optimal value [54], and Cagliari was selected as the case study for this research due to its urban density value, referred to as the number of people who inhabit a given urbanised area. It is considered ideal for evaluating the urban quality of medium-density neighbourhoods.

As previously mentioned, a case study should have between 4000 and 10,000 inhabitants.

Following these considerations, for the development of our case study, two neighbourhood were taken into account, located in two different areas: the first area is the city's historic centre, the neighbourhood called 'Villanova', and the second is in the city's peripheral area, the neighbourhood called 'Sant' Elia' (Figure 1).

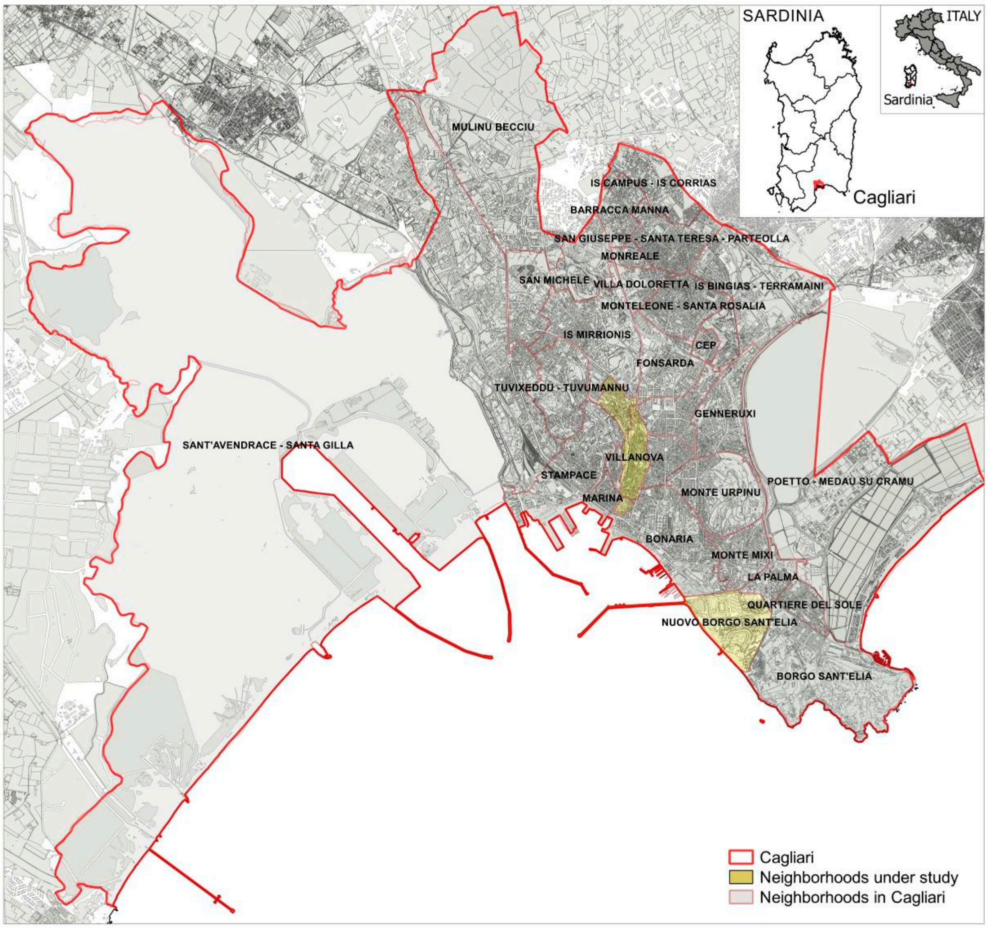

Figure 1. Cagliari and its neighbourhoods (in yellow the neighbouhoods under study [Villanova and Sant'Elia]).

Once the case study has been identified, it is necessary to identify the most significant list of indicators for our area of intervention.

2.4. Identification of a Shortlist of Indicators

The choice of indicators is closely related to the achievement of the desirable goals for smart cities, referred to its six components: smart living, smart economy, smart environment, smart mobility, smart governance and smart people.

A smart and sustainable city has goals to be achieved in an adaptable, scalable, accessible way, such as improve quality of life of its citizens; ensure economic growth; improve well-being of its citizens by ensuring access to social and community services; establish an environmentally responsible and sustainable approach to development; ensure efficient service delivery of basic services and infrastructure such as public transportation, water supply, telecommunication and other utilities; and provide an effective regulatory and local governance mechanism ensuring equitable policies [61].

In order to arrive at a shortlist, it necessary to develop firstly a longlist of indicators that directly link to the goals, to make a first selection of indicators by type, and after to make a second selection by taking into account the criteria for indicators. Once the set of indicators has been determined, it is important to thoroughly describe each indicator; to which goal it refers, why this indicator was selected, how it has to be calculated and where data can be gathered. This approach will ensure consistency in the evaluation process in the years to come.

The final goal is to improve quality of life and find new and better relationships between urban quality and wellness perception by renewing existing neighbourhoods and through cost-benefit effects. Findings related to quality of life can be used to diagnose previous policy strategies and design future planning policies.

The selected indicators are sub-divided into sub-indicators that correspond to detailed elements of the evaluation, each of which is described in written form, along with references to specific projects and sites. Some of these indicators already exist in the literature (Agenda 21, CRISP—Construction and City Related Sustainability Indicators Network funded by EU in FP5, Living Places: Caring for quality (UK), 4 OECD indicators), while some are referred to indirectly in the established indicators.

In order to increase the effectiveness of the interventions, it is necessary to start by evaluating local characteristics while considering the needs of citizens expressed at the local level.

A series of checklists specific to the investigation are used to conduct a critical analysis of the area's context, which involves defining the qualitative and quantitative aspects of some features of the urban space, such as accessibility, comfort, safety, attractiveness, health and well-being, environmental safeguards, and management. The results of this evaluation are summarised using interpretative categories defined by perceptions of the area. Taken together with the quantitative factors and indicators characteristic of planning and urban design disciplines, it is evident that there are innovative methods for undertaking qualitative analyses of the territory [59].

Particular attention is given especially to developing processes of smart city strategies, in order to develop the categories for organizing indicators.

Smart cities are developed urban areas designed with a perspective of creating high quality of life and sustainable economic development by through advancement in several key sectors including environment, mobility, people, economy, government and technology.

The growth of urban areas is taking place due to the presence of better infrastructures, healthcare, quality of knowledge communication, social infrastructures and safety and security.

In light of this consideration, the indicators are grouped into six categories (Table 1): the Use and Fruition group is related to accessibility, the quality and presence of services, the infrastructure, and mobility; the Health and Well-being group represents the area's quality of life, citizens' priorities, needs, and levels of satisfaction; the Appearance group refers to architectural and environmental values; the Management group considers the efficiency with which maintenance activities are undertaken; the Environment group is linked to the quality of the landscape and the environmental system; and the Security group relates to perceptions of personal safety and security. Assessing the level of urban quality involves a thorough and critical analysis of the context and is conducted using a series of checklists that represent the investigation's specific requirements (Table 2; Figures 2 and 3).

Regarding the category Use and Fruition, the aspects analysed include accessibility, the presence of services, and mobility. In particular, accessibility refers to people's ability to access desired goods and activities. It generally refers to physical access to particular destinations and is usually described by people as transportation. In pedestrian planning and facility design, accessible design refers to facilities that accommodate people with disabilities. Because transportation and land use planning decisions often involve trade-offs between different forms of accessibility, accessibility has been evaluated from various perspectives, including the needs of particular groups, different modes, locations or activities, and considering direct and indirect impacts. The quality (speed, convenience, comfort, and safety) of various transport options—including walking, cycling, and public transport—are considered.

The smart planning paradigm requires a more comprehensive accessibility analysis. The ability to evaluate accessibility is improving as transportation and land use planners are developing better tools for quantifying accessibility impacts—including multi-modal level-of-service indicators and models that measure travel distances, travel times, and travel costs for users who access various types of services and activities.

The category related to Health and Well-being is aimed at analysing quality of life as well as citizens' priorities and needs. It combines measurable spatial, physical, and social aspects of the environment and individuals' perceptions of these aspects. These perceptions are related to objective environmental characteristics, as well as to personal and contextual aspects of health and liveability.

The concept of quality of life includes different components such as health, personal development, the physical environment, natural resources, security, comfort, the personal satisfaction of individuals with their living environment, and their feelings with regard to life. Quality of life in cities of course depends on the presence and distribution of spaces, services, and activities [62]. Many conventional approaches to assessing quality of life measure the distribution, density, and distances of different opportunities in space. If we want to reason in terms of capabilities, we should also take into account the quality of accessibility and urban opportunities. The mere presence of opportunities, places of interest, and services in space, apart from their mere distance, becomes relevant if they can also be reached on foot or by bicycle, if connective pedestrian routes are pleasant and spatially integrated with the surroundings based on good urban design, if the area is replete with urban activities, if it is well maintained and perceived as secure, and if it is not subordinate to car traffic, either by design or in response to predominant social practices. Ultimately, the presence and distribution of services and activities are not sufficient criteria for defining urban quality of life, for it depends also, perhaps above all, on the relationships between those places and the likelihood that inhabitants use them to develop their well-being [62].

Our analyses need to consider more than the presence of urban services and understand their characteristics—whether they are able to serve different categories of individuals; whether their relevance is at the neighbourhood, urban, or metropolitan level; and whether there are possibilities for making choices between two or more relevant places [63].

With regard to the category Appearance, we referred to analyses of architectural and environmental values. It takes into account parameters such as the quality of urban design, housing, the urban-aesthetic character of the built environment, whether there are well-defined streets and open spaces and a well-structured building layout, the presence of green areas throughout the neighbourhood, value placed on restoration and preservation, the state of conservation, and safeguards implemented to protect cultural heritage and make positive contributions to improving the quality of the urban landscape [64].

Design values affect indoor and outdoor physical environments, as well as social environments, and subsequently can contribute to ensuring a healthy living environment.

The category Management takes into account the efficiency with which urban maintenance services are provided and, in particular, project management, as well as maintenance and repair policies that ensure the neighbourhood's sustainability.

The category Environment is linked with the quality of the environmental system. It evaluates the respect shown for local landscapes, and how the local environment is treated. It investigates best practices for controlling and managing waste, the protection of cultural heritage and natural values, whether streets and public areas are cleaned, ease of access to clean water, the preservation of resources, and minimising the use of energy.

Finally, the category Security refers to perceptions of personal safety and security as well as attitudes about the risk of being involved in a traffic accident or being the victim of criminal offences, violence, or threats. In most cases, it is the latter type of risk that is most important to pedestrians and most influences their behaviour. Safety is a fundamental and essential need for humans—a need that is as important as the need for social interaction. As human beings, we are always interested in ensuring our own safety and the safety of those around us. Still, feeling safe is only one of our fundamental needs. Unsafe roads are often considered one of the main factors hindering cycling and walking. Another important factor that influences perceptions of safety is lighting, especially in the local night-time environment. Pedestrians feel more afraid at night than during the day. Unpleasant people and bad lighting conditions are the factors that contribute most to feeling unsafe at night.

The sub-indicators used in the methodology do not correspond to those used in the planning process, as they refer not only to quantitative but also qualitative dimensions. The set describes the urban context with completeness. A significant tool for assessment is represented by the information forms (Figure 3), one for each sub-indicator, filled with general descriptions, aiming to reduce subjectivity during the evaluation process. The categories and indicators are products of the sum of the sub-indicators, and each is expressed by a numeric value. The sum of the values of the aggregated indicators produce what we have called the Indicator of Smart Urban Quality (I_{SUQ}). The I_{SUQ} is based on a general layout (structure of the procedure) from which categories, indicators, and sub-indicators are created. This indicator I_{SUQ} is considered smart because it combines traditional aspects of urban quality with smart and sustainable aspects related to the quality of life, health, and well-being. It can be used to analyse the city of Cagliari from different perspectives since each variable comprises a sub-set of indicators.

These analyses were carried out using this type of quality rating, relative to every need, at the census area scale. The neighbourhood's I_{SUQ} was identified as being the average of the sum of the ratings of each census section. In summary, the I_{SUQ} is the sum of the ratings relative to the single categories:

$$I_{SUQ} = IQ_{USE} + IQ_{H\&W} + IQ_{APP} + IQ_{MAN} + IQ_{ENV} + IQ_{SEC}$$

The categories considered are summarised in Table 1 below.

Table 1. Categories table. For each sub-indicator, the calculation method and the relative unit of measurement are indicated in each information sheet.

Categories	Indicators	Sub-Indicators
Use and fruition	Accessibility	Traffic accessibility Pedestrian accessibility Accessibility for people with disabilities Sustainable walkability Ciclability
	Flexibility and functionality	Services for people with disabilities Multifunctional and sustainable urban equipment
	Minimum service provided	Availability of services and equipment Availability of waste container
Health and wellbeing	Emotional wellbeing	Presence of green areas Attractiveness of living place Quality of Street lighting Easy mobility services Environmental maintenance
	Quality of life	Urban traffic noise pollution Air pollution Housing Livability and sustainability of public spaces Presence of spaces, services and activities Sustainable daycare and healthcare services
	Social wellbeing	Spaces, services and activities suitable for children Provision of services or activities for particular group Economic opportunity and social inclusion Perception of security
Appearance	Environment characteristics	Quality of urban landscape Green maintenance
	Built environment characteristics	Urban design maintenance Quality of housing and urban-esthetic characteristics

Table 1. *Cont.*

Categories	Indicators	Sub-Indicators
Management	Efficiency of primary services	Waste management Efficiency of the urban maintenance services
Environment	Soil pollution	Protection of Cultural Heritage Respect of local landscape and environment Street and public areas cleaning Waste disposal provided and sustainable recycling solutions Access to clean water
Safety and security	Security systems	Lighting and security control
	Smart crime prevention	Social security level
	Risk of natural disaster	Probability of natural disaster

The pertinent indicators were identified for each category and then grouped into classes of sub-indicators. Sub-indicators were used to assess indicators and to facilitate an objective quantitative and qualitative assessment. This methodology anticipates the use of two types of information sheets: graphics sheets, which display the areas of intervention, and information sheets, which contain a series of tables that describe the conditions relative to each requirement analysed (Figures 2 and 3; Table 2).

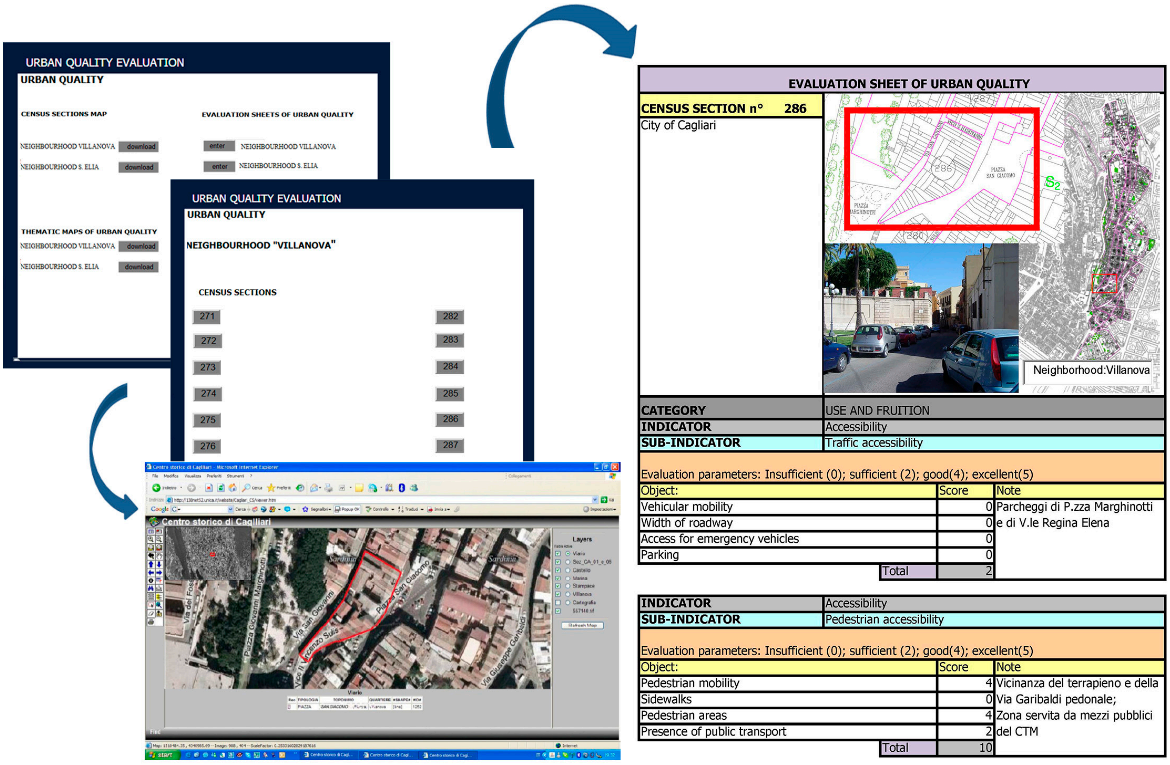

Figure 2. Graphics sheets.

INDICATOR	Accessibility		
SUB-INDICATOR	Pedestrian accessibility		
Evaluation parameters: Insufficient (0); sufficient (2); good(4); excellent(5)			
Object:		Score	Note
Pedestrian mobility			
Sidewalks			
Pedestrian areas			
Presence of public transport			
	Total		

Figure 3. Evaluation sheets.

Table 2. Information sheets. This table shows an example of the calculation method and the relative unit of measurement for the sub-indicator "Green space in urban areas".

Sub-Indicator	
Name	Green space in urban areas
Description	Public spaces like parks, gardens, squares and sport areas
Method of measurement	Calculation
Unit	square meters of green areas/total number of inhabitants
Category	Health and Wellbeing
Indicator	Emotional wellbeing

For all the categories identified above, each sub-indicator has been expressed with a numerical value and has been ultimately expressed in an evaluation sheet, with the relationships between qualitative evaluation parameters and the final score expressed in numerical values (Table 3; Figure 4). This score reflects the real conditions of urban settlements. The final output involves the computation of a number of scores corresponding to each sub-indicator, indicator, and category.

Table 3. The table shows an example of the attribution of scores to sub-indicators referring to indicators belonging to one of the categories. Their sum allows to obtain the scores relative to the single indicator and to the whole category. This work has been done for every single census section and for all categories. The sum of the values obtained for the individual categories of each census section gives us the value of the index I_{SUQ} for the single section analyzed.

Census Section	Category	Indicator	Sub-Indicator	Score Sub-Indicator	Total Score Indicator	Total Score Category
286	Use and Fruition	Accessibility	Pedestrian Accessibility	10		
			Traffic Accessibility	2		
			Accessibility for people with disabilities	4	30	
			Sustainable walkability	10		
			Ciclability	4		
		Flexibility and functionality	Service for people with disabilities	8		
			Multifunctional and sustainable urban equipment	14		
		Minimun service provided	Availability of service and equipment	24		
			Availability of waste container	6		

The point system used to define the rating is based on a system of a 5—point scale, that was set out as follows: 0 points are given for an insufficient quantitative assessment, 2 points are given for a sufficient quantitative assessment, 4 points for a good assessment, and 5 points for an excellent assessment.

The value of the I_{SUQ} index is scored by adding up the score on each item of sub-indicators.

A total of 760 points are available, representing the maximum value of the I_{SUQ} index. The quality relating to the census section under analysis is considered sufficient if the value of the calculated index is between 380 and 570 points. Below the average score of 380 points you have poor quality; between

381 and 570 sufficient quality; between 571 and 700 good quality; and over 700 excellent quality. For the assessed sections of poor urban quality it will be necessary to provide for redevelopment actions to be implemented in a short time.

The point-rating system was formulated by referring to indicators that meet the standards established by the master plan (e.g., social services are available for the resident population), and an in-situ neighbourhood analysis was conducted to acquire information on the area's conditions and gather supporting photographic documentation. In addition, online data available were examinated and evaluation questionnaires were given to citizens in order to understand their perception about the places in which they live and to collect reports of possible problems.

It is possible, therefore, to create a rating for each neighbourhood census area and identify aspects that present the greatest problems for each area, after which planners can design interventions aimed at improving the neighbourhood's environmental quality. This proposed model is a technical tool that will produce a concise evaluation of a neighbourhood's urban quality expressed as a numeric value. Because it is flexible, modifiable, and open, new or updated indicators can be added easily, and this evaluation model can be adapted to a single case study.

3. Results

The first step of analysis was to identify our case study on the basis of the previously listed criteria, that is values related to urban density and subsequently to the number of inhabitants per neighbourhood. So the city of Cagliari, in Sardinia, Italy, was selected due to its urban density value, equal to 1817 people per square km.

Following this, the neighbourhoods have been chosen among those with the value between 4000 and 10,000 inhabitants, considered optimal for the analyzes to be carried out.

The attempt of this study was to measure the quality of urban life in the city of Cagliari. This study's results and findings will be useful for designing and implementing the city of Cagliari's future urban smartness policies.

In order to facilitate the transition to a smart sustainable city, the use of indicators and standards will be critical in analyzing the performance of urban areas and setting priorities and targets for change.

The application of the methodology proposed to our case studies, in relation to two different types of urban realities, the central neighbourhood of Villanova, the recent object of redevelopment policies, on the one hand, and the peripheral neighbourhood of Sant'Elia on the other, allowed to highlight the various problems present in the two areas.

The procedure was structured to synthesise through a numerical value the level of urban quality in the neighbourhoods of Cagliari. This made it possible to get an overview of the whole neighbourhood and its individual census sections, with opportunities to deepen the aspects that most affect urban quality. The attribution of the scores, to the individual items of the 38 sub-indicators considered, certainly allowed to delineate positive aspects or critical states for each single analyzed census section. It was possible, through the verification of the urban planning standards required by the masterplan of the city of Cagliari, to assign an assessment for quantitative sub-indicators. This analysis made it possible to highlight in some areas the deficiencies of some standards, such as the presence of green areas, services for disabled people, the availability of waste containers, which are not adequate to the needs.

With regard to qualitative indicators, the evaluation was done on several bases. First of all by observing the state of the places, by administering questionnaires to citizens in order to have an assessment of their perception of the neighborhood in which they live, and finally by analyzing the data available, in relation to aspects such as urban traffic noise pollution, air pollution, presence of services for health and well-being, of spaces and activities for children, of public transport, etc., easily consultable through a big data platform, which allows punctually to have access to many information on the services present in the city. The complete evaluation of single indicators gives as a result the sum of values synthesised in the Smart Urban Quality Index. When combined, all the assessments conducted for each category provide a numerical index for each of the neighbourhood's census areas. Therefore, the values obtained for the I_{SUQ} index of each census area have been represented in a thematic map that displays urban areas most in need of regeneration interventions aimed at improving their environmental quality (Figure 4).

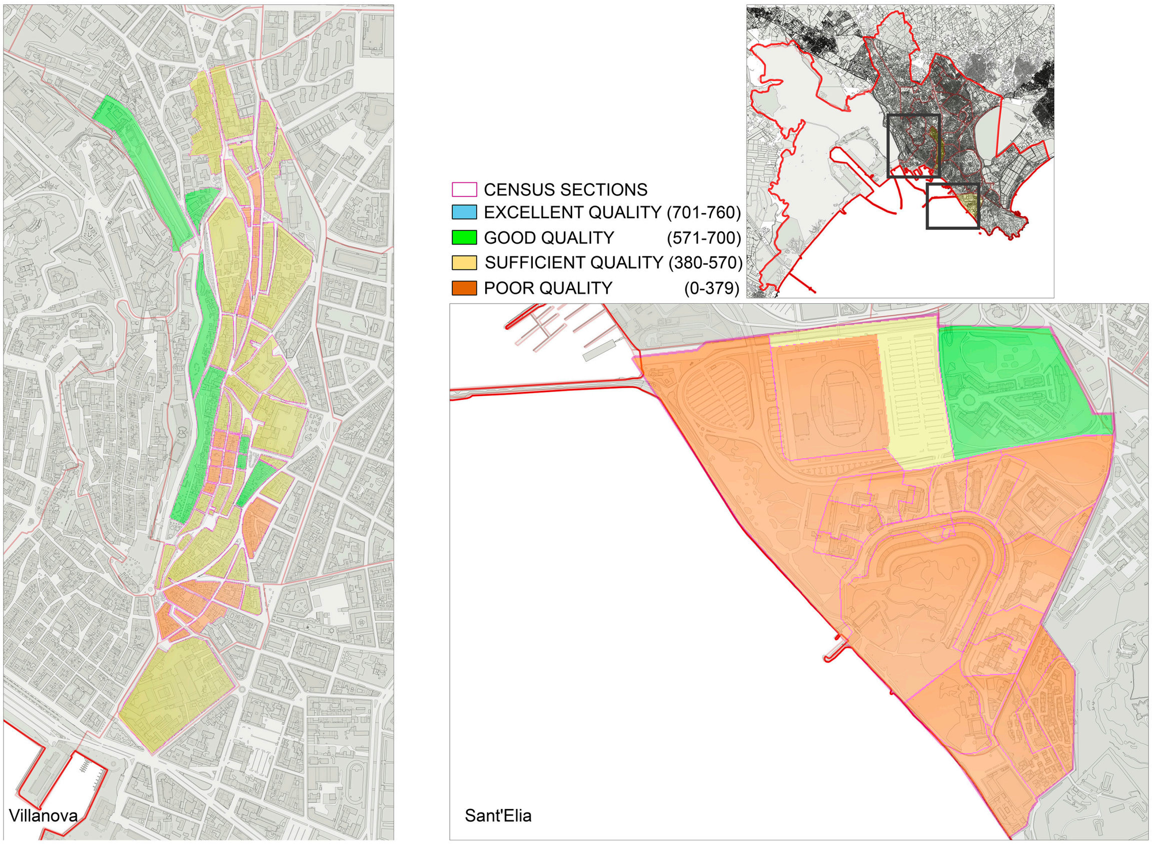

Figure 4. Thematic map. This figure shown the value of the I_{SUQ} index obtained for each census section. The value is given by the sum of the indices calculated for each categories, obtained in turn by the sum of the values attributed to each individual sub-indicator. The colours from orange to blue represent the level of urban quality found through the analysis of the values of the indices calculated for each census section. The legend shows the ranges of attribution of the ratings.

The evaluation process has shown that the overall smart urban quality index differs between the two neighbourhoods. The scores in some sections are similar, but that does not mean the scores are equally close to each other for each indicator, some of which scored very differently due to specific local features. The analysis of the single evaluation sheets allowed us to deepen the factors' influence on the total score. As can be seen, the majority of the census sections in the historic district of Villanova are of sufficient and good quality, and mostly poor in the peripheral area. No section reported an excellent evaluation. The problems encountered are obviously different in the two neighborhoods.

Despite of various projects of urban renewal and significant improvements have been made to the city in recent years, the results of our analysis show that the city can not yet be described as an example of smart sustainable city and urban best practices. The central neighbourhood Villanova has implemented different urban regeneration projects, and this has led to a clear improvement in the quality aspects.

Otherwise, the peripheral area of S. Elia still shows many critical aspects to be taken into account in future policy strategies. These include, in particular, problems related to social integration, justice and equity; equal access to affordable housing; economic activities, services, and facilities, reinforcing a safe environment; and improving the design quality of streets and buildings. Moreover, walking, and cycling have to be improved, as well as the quality of accessibility not only at neighbourhood-level destinations but also at the urban and metropolitan level.

In addition, with regard to both neighbourhoods, were reported problems of accessibility especially for people with disabilities, The advantages of the methodology are surely linked to the possibility of having an immediate picture of the areas that need more attention in the field of urban recovery policies. By consulting the thematic map it immediately becomes clear, for city planners, which areas to consider with greater attention. Then, the evaluation sheets allow an in-depth analysis, through the consultation of the individual scores attributed to each sub-indicator, which allows to identify in a precise way the critical elements.

On the other hand, the limits are primarily linked to the subjectivity of the assessments, in relation to the qualitative parameters, which are however partially mitigated by the questioning of more people, both technicians and citizens, which has allowed the attribution of average values to the evaluations of the individual parameters.

Another limit, to be deepened and developed during subsequent studies, is represented by the attribution of the same weight to all the indicators. In fact, also considering the various problems encountered through the analysis of the individual sections, it is understood that some parameters play an important role in the evaluation, such as, for example, the case of the categories "Health and wellbeing" and "Safe and security" in the neighbouhood S. Elia.

In our opinion, the choice of the shortlist of the indicators, in relation to the case study, was quite adequate, because it comprehensively analyzes the factors that most influence the urban areas analyzed.

The proposed methodology is a tool that is effective in evaluating urban environmental quality, as its outputs are expressed in numeric values. It reduces subjectivity in the evaluation process and, most importantly, can be related to other data (e.g., environmental, health, and well-being). The final outcome of the assessment procedure is meaningful for the disciplines of architecture and urban design. Although the methodology is meaningful for obtaining an overall Smart Urban Quality Index, what is important is not the numerical value in absolute terms but its progress over time and its comparison with other locations. Moreover, as smart urban quality is expressed through numerical values, it can be compared and monitored over periods of time. In fact, if scores are monitored over time, proper actions can be planned by Public Administration. In the context of the smart sustainable cities, urban planners now tend to lean towards an integrated approach, running cities as an integrated network rather than a set of individual sectors. The aim of increasing the quality of life of inhabitants is one of the key point of the new paradigm on the smart cities.

Literature converged on the belief that the subjective wellbeing of a society is a measure for its success. The rationale is that people move to and live in places where they perceive high levels of quality of life. Therefore, it becomes important to understand the nature of residents' happiness and to suggest smart policies to improve it [65].

For this reason, is important, in our opinion, for citizens to have access to all information through the online platform and to be constantly informed about the results of the analysis.

The selected indicators, according to the authors, fit quite well within the framework of smart sustainable cities. In fact, the following attributes of smart sustainable cities are observed: sustainability, quality of life and intelligence. Sustainability relates to governance, pollution and other factors. Quality of life is about emotional wellbeing. Intelligence is the ambition to improve economic, social and environmental standards.

Citizen engagement has a critical role to play. Public Administration should make space for citizen involvement in planning and responsive policies and in finding solutions and improving services. Public participation in decision-making processes represents an added value in the objective of increasing the efficiency and effectiveness of urban policies. It improves the quality of life and the wellbeing of its inhabitants and ensures higher standards of living and employment opportunities.

4. Conclusions

Quality of life in urban areas is becoming a strategic issue for city planners. In fact, cities can have excellent tools for the implementation of urban planning policies in terms of smartness, sustainability, in order to move toward a smart and sustainable urbanism. Assessments of the quality of urban life represent a multidisciplinary concept that encompasses environmental, social, and urban planning features, and a subjective estimation. The general objective of this paper has been to document a process that will standardise the evaluation of urban quality levels and contribute to the optimisation of its performance. The method used was based on six categories, classified by 11 indicators and 38 sub-indicators that represent a large number of variables characteristic of the urban contexts studied.

This research analysed the urban quality of life in the city of Cagliari by selecting appropriate indicators—summarised in the Indicator of Smart Urban Quality (I_{SUQ})—and then applied the described methodology to a case study. A description of urban quality of life is usually complex because it should include the essence of the subject, as well as all its relationships, dynamics, and the reticular relationships that exist between the various dimensions of this concept. It should be noted that urban quality of life does not refer to the quality of life in urban areas only as they are known conventionally but to all factors that, either directly or indirectly, affect citizens' quality of life.

Analysis was conducted by using checklists and questionnaires that made it possible to highlight the most critical aspects of the two neighbourhoods analysed. Moreover, use of the checklists and thematic maps enabled the assessment and individualisation of urban, environmental, and building problems, and made it possible to get an instant picture of the areas that need more attention from policy makers. These tools provide inputs that can be used to start the process of regeneration, improve smart urban quality, and design innovative policies and urban projects that promote quality of life, especially in peripheral urban areas.

The significant feature of this method is that it embeds the possibility of adaptation—such as changes to the number of indicators or their specific weights—while maintaining the structure of the procedure. The next step of our research is to see if it is possible to apply the methodology adopted to similar urban contexts. Moreover, it can be made into the city dashboard 'Km4city' to show the results of the processing data in real time [66].

This paper has shown that the methodology used can be applied to evaluate various elements of smartness—such as the health, well-being, environment, and governance of cities—to make life in the city easier, more convenient, and secure. The measurement of the level of smartness in the city allows public authorities and city planners to promote integrated urban governance by monitoring governance actions, and to assess the effectiveness of these interventions for improving the quality of life, which is the central theme of contemporary political development in the urban field of smart cities.

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