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Towards a SDGs Based Neighborhood Sustainability Evaluation Framework: A Tool for Assessing Sustainability at the Urban Micro-Scale

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Abstract In light of the rapid growth of the built environment and its attendant climate, ecological, social and economic impacts, neighborhood is recognized as an effective level to address many sustainability objectives, according to the Sustainability Development Goals (SDGs) of the 2030 Agenda. However, there is no simple way to define an index for neighborhood sustainability assessment that can be used as a suitable tool for evaluating and monitoring interventions at this scale. The paper introduces a neighborhood sustainability evaluation framework based on SDGs that allows to analyze and measure the performance on different goals and map the results via a Geographic Information System. This architecture is useful to merge data from a variety of open sources and to obtain a significant spatial representation of potentials and problems on different thematic issues of a specific neighborhood or urban area. Due to its sensitivity—both in relation to the spatial and environmental structure and the socio-functional organization of the neighborhood micro-scale that are analyzed—the proposed evaluation framework can serve as an important planning and design tool to guide and inform strategies, policies and urban transformation interventions aimed at improving urban sustainability.

Keywords 2030 agenda · SDGs localization · Urban sustainability · Neighborhood level · Evaluation models · Sustainability index

1 Introduction

Today 55% of the world's population live in urban areas, so that «Cities are increasingly the home of humanity. They are central to climate action, global prosperity, peace and human rights. (...) To transform our world, we must transform its cities» (UN Secretary-General, Secretary-General's message on World Cities Day, 2016). Cities can play the role of “massive agents of positive change” [34] only if these will be well equipped to address many sustainability challenges, according to the integrated approach adopted by the UN 2030 Agenda, one of the most important global action plans for sustainable development which calls for evidence-based and measurable goals for all policies and actions [33]. Through the Sustainable Development Goals (SDGs) framework, in fact, the 2030 Agenda clearly defines some development targets for 2030 which cities must reach through their “Voluntary Local Review” (VLR) provided by article 47 [15, 19, 23]. This implies the collection of urban data to understand the status of each city in terms of SDGs performance and identify, evaluate and prioritize actions and investments needed to improve their performance. Indeed, this knowledge allows to plan and design interventions that have a significant impact, certifying its contribution in achieving SDGs. Furthermore, SDGs define a common language and agenda among different urban realities useful to share knowledge and better practices.

In this context, the development of sustainable neighborhoods is one of the major issues of urban sustainability and a key action for the SDGs localization process because, as highlighted by Choguill «no single city can contribute to overall sustainability if its own component parts are found not to be sustainable» [11]. At this level, according to the SDG 11, the main goal is to create inclusive, safe, resilient and sustainable neighborhoods in which people can live healthy and happy lives without affecting the climate and the environment. This is very relevant due to the fact that a large number of measures necessary to reach the SDG 11 have an impact on all the other SDGs or, in other words, almost all SDGs are relevant to building and urban planning [31]. For this reason, decision-makers, local public administrations and stakeholders involved in neighborhood development should start considering and incorporating the evaluation of SDGs in the early stages of the planning process, so they can work together to share knowledge, design strategies and measures, and establish good practices.

1.1 Urban and Neighborhood Sustainability Assessment and SDGs

The importance of urban sustainability at a local level had been growing since the last decade of the twentieth century as a result of the launch of Local Agenda 21, “the action plan for sustainable development” for local authorities adopted at the Earth Summit in Rio de Janeiro in 1992 [27].

Thus far, several tools have been developed for evaluating the effectiveness of new development or regeneration projects at the neighborhood scale and their sustainability performance such as rating tools, certification systems, indicator frameworks and assessment tools [21, 26, 28]. Among these the American LEED (Leadership in Energy and Environmental Design) for Neighborhood Development; the Japanese CASBEE (Comprehensive Assessment System for Built Environment Efficiency) for Urban Development; the French HQE2R (Haute Qualité Environnementale et Economique Réhabilitation); the English BREEAM (Building Research Establishment Environmental Assessment Method) for Communities; the German DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen: the German Sustainable Building Council) for Urban District, and the Italian ITACA (Italian Institute for Innovation and Transparency in Procurement and Environmental Compatibility) for Urban areas.

In last years, some of these tools (i.e., NSA tools) have been starting to encourage the achievement of SDGs through their certification systems, like the “City prosperity Index” and the “SDG Cities Certification” developed by the United Nations and, at the neighborhood scale, BREEAM Communities and DGNB System for districts.

The City Prosperity Index (CPI) was created by UN-Habitat in 2012 as a tool to measure sustainability at the urban level, after a survey conducted in 54 cities from the developing world to conceptualize prosperity and identify its most critical components. After numerous requests from local authorities and central governments asking for the estimation of their respective prosperity indexes, in 2013 UN-Habitat transformed the City Prosperity Index into a global initiative known as the City Prosperity Initiative [32]. Today more than 400 cities across the world use the CPI as a monitoring framework. The CPI has been recently proposed to serve as a global architecture platform for monitoring and comparing the progress towards SDG 11 and a selected number of other SDG indicators that have an urban component. The 2020 UN-Habitat Report highlighted that 23% of all SDGs targets measurable at the local level are covered by the CPI [29].

SDG Cities Certification was developed by the United Nations within the flagship programme “SDG Cities”, the global initiative that aims to realize the potential of cities as drivers for the achievement of the SDGs during the Decade of Action (2020–30) and recognize their efforts through a prestigious certification [31]. UN-Habitat, UN and other partners involved in the programme support the building of city capacities in key areas of policy, planning, governance and local financing, whereby each city is encouraged to create an urban lab to develop SDGs oriented projects. This would allow the production of reliable and comparable evidence for the identification of strategic actions aimed at accelerating SDGs achievement. One of the main objectives is the monitoring and certification of projects, processes and initiatives of excellence and the alignment of funding to sustainable urban transformative actions [30].

BREEAM Communities is one of seven schemes developed by BRE Group (Building Research Establishment). In 2018 BREEAM schemes were reviewed to verify their applicability to the SDGs at an indicator level [9, 10]. The deep analysis conducted by BRE shows the correlations between SDG targets and key performance

indicator, both directly and indirectly. By mapping each of the schemes to the SDG, BRE demonstrates that a large part of their schemes is already aligned with the SDGs.

DGNB System for sustainable districts is a globally recognized planning and optimization tool developed by the German Sustainable Building Council (DGNB) in 2012 and updated in 2020. In this latest version of the DGNB district certification, all criteria are analyzed in relation to their contribution to the achievement of the SDGs. This like-for-like comparison between all system criteria and the SDG targets has consequently made them certifiable and, therefore, each DGNB certified project receives a statement on how much it has contributed to achieving the SDGs [14]. Furthermore, the system provides an additional incentive—the “Agenda 2030 bonuses”—awarded in selected criteria for projects that make a particular contribution to climate action and the implementation of the other UN sustainability goals (DGNB).

The limitations of these two neighborhood assessment tools are related to their private nature that limits their applicability to selected projects and urban areas, besides the high economic cost of the certification [6]. For example, to date only 13 urban districts have been certified through the DGNB system [13]. Additionally, these tools are not based on Geographic Information Systems (GIS) which support multicriteria analysis by allowing data collection and analysis, and the automatization of the calculation of related indices and measurements.

At the same time many studies employed GIS methodology to evaluate sustainability and SDGs but these previous works focused only on the SDG 11 targets or on a small subset of SDGs [1, 16–18]. Therefore, the main purpose of this paper is to propose a SDGs based Neighborhood Sustainability Evaluation Framework, designed to overcome the limitations mentioned above.

The paper is organized as follows: after this introduction where the current problems in the analysis of sustainability at the urban micro-level were presented and an overview of the existing literature was provided; in Sect. 2 the study methodology and data collection processes are exposed; Sect. 3 highlights the main characteristics of the proposed framework through its application to a case study of a neighborhood in the city of Cagliari (Italy). Finally, in Sect. 4 we illustrate the implications of our approach and discuss the main limitations and future research areas.

2 N.SDGs Framework: Analysis and Evaluation of Sustainability at the Urban Micro-Level

2.1 N.SDGs Methodology

We propose a multicriteria evaluation framework that merges several dimensions of urban sustainability into a composite framework—the Neighborhood SDGs-based Assessment Framework (i.e. the N.SDGs Framework)—which allows to evaluate sustainability at both global and thematic level, by relating each criterion with

specific SDGs. The process of definition and design of the N.SDGs Framework was subdivided into three phases:

1. Structure of the Framework: We analyzed a selection of relevant neighborhood sustainability assessment tools currently in use with the aim of identifying evaluation topics relevant to urban design interventions, the key performance areas and the associated sub-areas of analysis [25].

2. Sustainability Indicators based on SDGs: This phase consisted of two interwoven sub-phases. First, we have selected a set of indicators that provide information on specific sustainability sub-areas. More specifically, the indicators we have chosen allow us to assess the current situation and identify which areas need most interventions. In the second phase, we associated these indicators with the SDGs “urban targets and indicators”, namely the targets and indicators of the SDGs framework that are potentially relevant to the project at the neighborhood scale [22, 24]. Note that we attempted to achieve all SDGs, except the SDG 17 as explained in the next text below.

3. Validation. The framework was tested and validated by applying it to a case study in the city of Cagliari. This experiment has allowed us to verify whether the data used for the evaluation of each indicator are easily available and analyzable; the final selection of indicators, as well as their hierarchy and prioritization, was carried out taking these results into consideration. We used a Geographic Information System (GIS) platform that allows the analysis and visualization of spatial data, and the efficient management and monitoring of individual indicators, thematic indices and synthetic index of sustainability.

2.2 N.SDGs Structure and Indicators

As highlighted in the previous Section, we used a Geographical Information System (GIS)-based platform to collect, manage, analyze and geographically display the data used for the evaluation of the N.SDGs Framework indicators within the four key performance areas which are: (1) Mobility and Accessibility, (2) Vitality and Attractiveness, (3) Equity and Social Inclusion, and (4) Environment and Well-being (see Table 1 and Fig. 1).

From an operational point of view, the proposed index supports the development of:

- *slow-modes-oriented neighborhoods* linked to the quality of public transport, active mobility and multimodal transport options that improve equal access to essential services, activities, and jobs for all citizens;
- *high-quality neighborhoods* with a high degree of land-use mix, rich in open public spaces such as community gardens, parks, outdoor sports areas and play areas, where different people want to spend time and can build friendships and share time together;

Table 1 N.SDGs framework structure. *Source* [24]

Performance areas	Sub-areas	SDGs targets related
I1. Mobility and accessibility	I. Public transport	3.4. Promote mental health and well-being
	II. Walkability	3.6 Reduce road traffic accidents
	III. Ciclability	7.2. Increase substantially the share of renewable energy
	IV. Intermodality	7.3. Double the global rate of improvement in energy efficiency 8.4. Reduce the built environment's footprint and decouple economic growth from environmental degradation 9.1. Develop quality, reliable, sustainable and resilient infrastructures 11.2. Provide access to safe, affordable, accessible and sustainable transport systems
I2. Equity and social inclusion	I. Urban equity	1.4. Provide equal access to basic services
	II. Social support	3.4. Promote mental health and well-being
	III. Participation	4.7. Promote education for sustainable development and lifestyles
	IV. Awareness	5.5. Ensure full participation in leadership and decision-making 6.b. Improve participation 10.2. Empower and promote the social inclusion 10.3. Ensure equal opportunities 11.1. Ensure access for all to adequate, safe and affordable housing and basic services 11.3. Enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management 12.8. Improve information and awareness for sustainable development and lifestyles 13.3. Improve awareness-raising and planning capacity on climate change mitigation and adaptation 16.7. Ensure responsive, inclusive, participatory and representative decision-making at all levels

(continued)

Table 1 (continued)

Performance areas	Sub-areas	SDGs targets related
I3. Vitality and attractiveness	I. Functional diversity	2.3 Double the agricultural productivity and incomes of small-scale food producers 4.4. Increase technical and vocational skills, for employment, decent jobs and entrepreneurship 8.9. Promote sustainable tourism that creates jobs and promotes local culture and products 11.7. Provide universal access to safe, inclusive and accessible, green and public spaces 12.b. Develop/implement tools to monitor sustainable tourism
	II. Economic vitality	
	III. Touristic attractiveness	
I4. Environment and well-being	I. Urban naturalness	1.5. Improve the resilience to natural disaster and extreme weather of the vulnerable people 3.4. Promote mental health and well-being 3.9. Reduce air, water and soil pollution and contamination 3.d. Strengthen the capacity for early warning, risk reduction and management of health risks 11.4. Protect and safeguard the world's cultural and natural heritage 11.5. Reduce the deaths and the people affected by disasters 11.6. Reduce the adverse environmental impact of cities 11.7. Provide universal access to safe, inclusive and accessible, green and public spaces 13.1. Improve resilience to natural disasters and extreme weather 13.2. Integrate climate change measures into planning 14.1. Prevent/reduce marine pollution from land-based activities 15.3. Combat desertification, restore degraded land and soil 15.9. Integrate ecosystem and biodiversity values into planning
	II. CO ₂ reduction capacity	
	III. Environmental well-being	
	IV. Environmental safety	

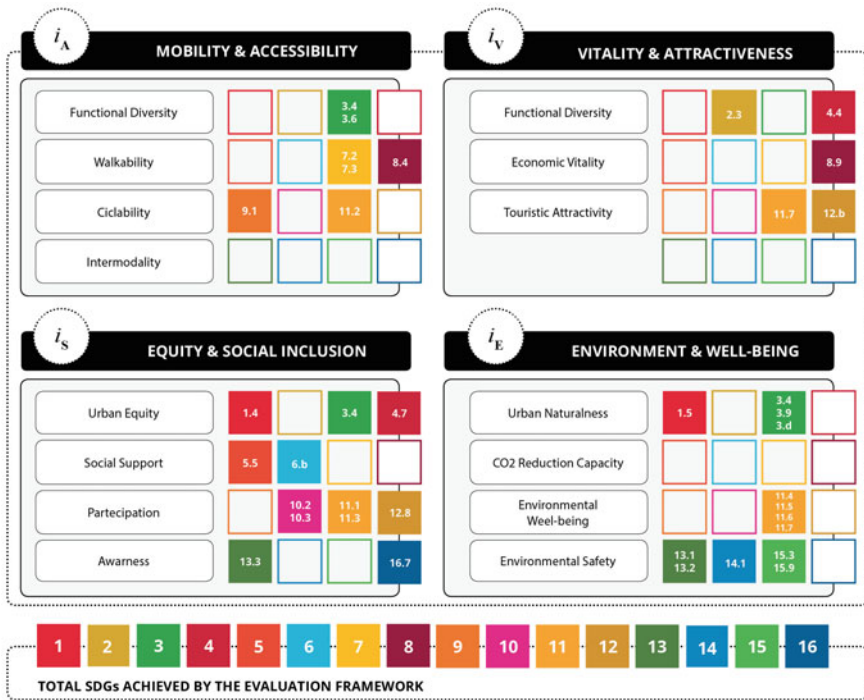


Fig. 1 N.SDGs framework: the four key performance areas cover an wide spectrum of SDGs

- *inclusive neighborhoods* that support life opportunities for all and enable people to access the services they need, especially those with disabilities and vulnerable individuals such as children, the elderly and lower socioeconomic groups;
- *low-carbon and climate-resilient neighborhoods* that promote biodiversity and soil quality, reduce the extent of urban warming and minimize emissions and risks through the design of quality public spaces and street networks, not just for the ecological restoration and protection but also to promote human health and well-being.

All these objectives and related neighborhood project actions have an impact on the indicators and targets outlined in the 2030 Agenda, making the proposed evaluation framework very effective in achieving all SDGs. We have analyzed this potential correlation in previous studies and reported these results in Table 1 and Fig. 1 which graphically synthetizes the correlations between neighborhood-scale project interventions and SDGs Targets reported in Table 1 (for a detailed analysis, see: [24]).

In order of impact, the performance area “Equity and Social Inclusion” have potential correlations with ten SDGs (1, 3, 4, 5, 6, 10, 11, 12, 13, 16), “Mobility and Accessibility” with seven SDGs (3, 4, 7, 8, 9, 11, 12), “Environment and Wellbeing”

with seven SDGs (1, 2, 3, 11, 13, 14, 16), “Vitality and Attractiveness” with five SDGs (2, 4, 8, 11, 12).

All Goals are included in our evaluation framework, except for the SDG 17 “Partnership for the Goals” that does not address specific policy tasks but has cross-cutting and cross-sectoral links and effects that make them crucial for the achievement of the other SDGs.

2.3 Mobility and Accessibility Sub-Index

Given the limited space available in this paper, the following description is focused on the “Mobility and Accessibility” key performance area which exemplifies the approach and the methodology conducted for the other three key areas. Table 2 shows the structure of this area, highlighting the sub-areas and the evaluation elements.

Indicators and modelling. The N.SDGs Framework brings together quantitative and qualitative indicators. The former is related to traditional evaluation methods based on per capita data or on the percentage of land area with a specific destination/use. Among these, the percentage of public space or green area within each neighborhood is one of most used indicators in all NSA tools and urban sustainability certification systems. The latter, on the other hand, propose a high fidelity evaluation approach in order to consider the differences in the intrinsic quality of a specific service or activity and their real accessibility by the inhabitants or users of the neighborhood [7]. This second type of indicators evaluates the distance of certain destinations for different neighborhood inhabitants by assuming that each building constitutes a

Table 2 The N.SDGs framework: the structure of “mobility and accessibility” key area

Key area	Sub-areas	Evaluation elements
Mobility and accessibility	I. Vehicular mobility	Street network, street junctions, street areas, vehicular areas, area 30
	II. Parking	Roadside parking, parking areas (formal and informal)
	III. Public transport	PT network, bus stops
	IV. Walkability	Pedestrian network, sidewalks, crosswalks, pedestrian areas
	V. Ciclability	Cycle network, cycle lane, cycle crossing, bike parking, bike sharing
	VI. Intermodality	Meeting points between bicycle or car sharing points, bus and train stops, parking stations
	VII. Destinations	Buildings (origin of the movement); Land use, public open spaces, activities, services, public green spaces

possible starting point. This method, which we described in our previous research [4, 8], produces highly detailed and spatially granular evaluations.

Dataset implementation. The proposed framework considers: (1) the physical characteristics of mobility infrastructures and services relating to motorized mobility, walkability, bikeability and public transport; (2) the potential destinations to which the inhabitants or users of the neighborhood can reach; and (3) the different categories of users/inhabitants that can be associated with different needs.

Therefore, we use different data sources collected and made available by the Italian National Institute for Statistics (ISTAT), Sardinia local and regional planning authorities—such as the Autonomous Region of Sardinia (RAS) Database, the Municipality of Cagliari Geo-Portal (CGP)—and those offered by free and open web platforms such as Open Street Map (OSM) and Google Maps (GM) and Sardinia Open data (SOD). Other data not available in these databases are manually digitalized (MD). In Table 3 we report a sample of 17 datasets that we have identified and collected, and Fig. 2 shows the high level of detail of our analysis.

The “street areas” shapefile contained in the RAS database served as a basis for analyzing the public road space between different modes of mobility. After having manually mapped the road areas dedicated to cycle paths and lanes reserved for public transport and collected the inventory of the sidewalks, by overlapping these three layers was possible to obtain, by subtraction, the vehicular areas dedicated to both transit and parking areas. The inventory of the distribution of public parking lots along the street is a crucial information that allows us to understand the amount of public space left to private cars, mostly free of charge. This data also requires manual digitization, which makes it possible to detect the number of parking spaces available and the areas where the cars are parked even though there are no official parking spaces.

While a street network shapefile is available, the pedestrian network was traced manually through GIS software starting from the sidewalks and pedestrian areas layers contained in the RAS database and the crosswalk layer manually digitalized through site inspection and consultation of Google Maps. The tracing of a pedestrian network is a time-consuming phase because government administrations often do not hold such data in their databases and at most only provide technicians with a shapefile of the road network.

In the GIS database, through OSM open-source data and Google Maps consultation several attributes were manually associated with each layer. For example, non-permanent or permanent obstacles were detected for the pavement segments, such as parked cars, light poles, large trees and kiosks which reduce space for pedestrians and in some cases represent a real impediment. Also, the presence of lighting and facilities for people with disabilities such as ramps was considered, as the absence of these elements makes the sidewalks unsafe, less attractive and, in some cases, inaccessible to certain categories of pedestrians. For those attributes that indicate the presence or absence of a specific element, values within the range of [0–1] have been assigned. For example, in the case of public transport stops, if a bus shelter is

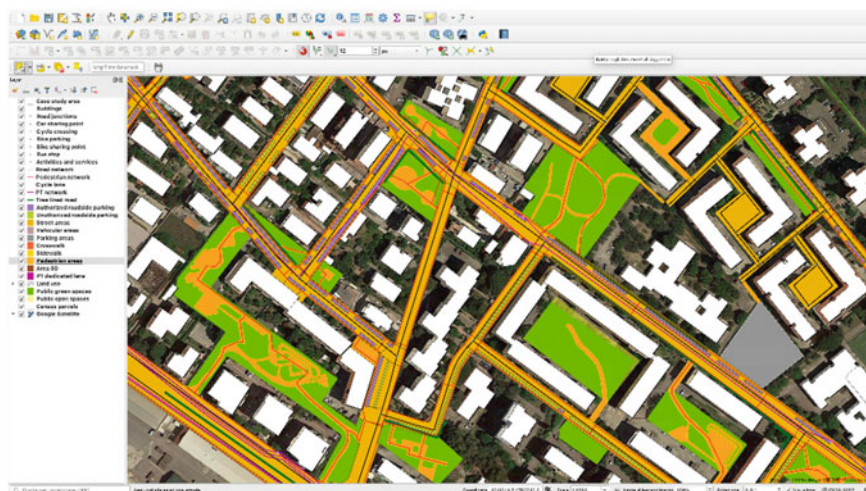
Table 3 The dataset used for the “mobility and accessibility” key performance area

Dataset	Source	Year	Feature	Description	Open data
Street network	RAS	2020	Line	ID, name, width, length, ranking, pavement, direction, speed limit, restrictions, sidewalk, PT dedicated lane	Yes
Street junctions	RAS	2007	Point	ID, number of streets, number of crosswalks	Yes
Street areas	RAS	2007	Polygon	ID, area	Yes
Vehicular areas	RAS	2007	Polygon	ID, area, pavement, speed limit	Yes
Roadside parking	MD	2021	Polygon	ID, area, width, type, number of parking spaces, disabled parking, loading–unloading parking	No
Parking areas	MD	2021	Polygon	ID, area, type, pavement	No
Car sharing points	SOD	ND	Point	ID, number of cars	Yes
Pedestrian network	MD	2021	Line	ID, length, type	No
Sidewalks	RAS	2007	Polygon	ID, area, width, length, pavement, lighting, obstacles	Yes
Crosswalks	MD	2021	Polygon	ID, type, lighting, obstacles, signposting	No
Pedestrian areas	RAS	2007	Polygon	ID, area, pavement, opening time, lighting, furniture	Yes
Cycle network	CGP	ND	Line	ID, length, type, direction	Yes
Cycle lane	MD	2021	Polygon	ID, area, width, type, pavement, direction	No
Cycle crossing	MD	2021	Polygon	ID, type, signposting	No
Area 30	MD	2021	Polygon	ID, area,	No
Bike parking	MD	2021	Point	ID, number of parking spaces	No
Bike sharing point	SOD	ND	Point	ID, number of bicycles	Yes
PT network	SOD	ND	Line	ID, length, line name, PT dedicated lane, destinations	Yes
Bus stops	SOD	ND	Point	ID, name, code, destinations, real time timetable, bus shelter, bench, lighting	Yes
Buildings	RAS	2007	Polygon	ID, type, category	Yes

(continued)

Table 3 (continued)

Dataset	Source	Year	Feature	Description	Open data
Land use	RAS	2007	Polygon	ID, type, category	Yes
Public open spaces	RAS	2007	Polygon	ID, area, type, pavement, opening time, lighting, furniture	Yes
Activities—Services	GM, OSM	2021	Point	ID, type, category, opening time	Yes
Public green spaces	RAS	2007	Polygon	ID, area, type, pavement, opening time, lighting, furniture	Yes
Tree lined roads	MD	2021	Line	ID, length	No
Census parcels	ISTAT	2011	Polygon	ID, total population, women, 0–14 y/old, 15–34 y/old, > 65 y/old, foreigners	Yes

**Fig. 2** The GIS platform: the high level of detail of the evaluation implemented in our study

available in close proximity of the stop, the “*bus shelter*” attribute takes on the value of 1, 0 vice versa.

One of the problems encountered with regard to pedestrian paths was the identification of the real walkable portion of the sidewalk and of the buffer zone where trees and street furniture are located, since the latter considerably reduces the portion of the walkable area and, if not considered, involves an overestimation of the data. About the different neighborhood “destinations” we considered both the land use, that allows to measure the area occupied by each category of services and activities

in square meters, and their punctual localization. The manual geolocation and classification of these destinations took place by consulting different databases (Google Maps, OSM, RAS database). The classification used was as follows: commercial, education, place of worship, recreation, public office, health, services, tourism.

Finally, the socio-economic characteristics of the inhabitants of the district were analyzed through the data provided by ISTAT and referred to as the minimum territorial unit represented by the census parcel. Census data allow specific social groups (women, children, elderly people, ethnic minorities) to be taken into account in evaluating accessibility to urban spaces and services [5, 35]. Thanks to their periodic updating, census data can also provide a chronological evolution of the socio-economic system. They are usually proxied by the centroid of each polygonal section which represents the entire population living there. Currently, these data are available as polygonal shape files referring to the year 2011, as the 2021 data have not yet been published. It should be pointed out that in order to obtain a more precise distribution of the population, it would be advisable to have additional ancillary data, such as land-use maps containing information about residential areas, which public administrations do not always possess or make available. Through these data, in fact, it would be possible to evaluate the number of people living inside each residential area as a percentage of the number of people living inside the entire census parcel [3].

3 An Exploratory Case Study

To demonstrate the potential of the methodology and show how the wealth of information allows an in-depth assessment of sustainability at the neighborhood scale through the N.SDGs Framework, we present the preliminary results of a case study in Italy. In particular, we analyzed the “Quartiere del Sole—La Palma” neighborhoods, two adjacent residential areas located on the south-east side of the city of Cagliari which border on two sides by the Molentargius Park (one of the largest urban wetlands in Europe) and on the others by the Viale Poetto, a four-lane urban road that connects the study areas with the beach and the city center, and Via Tramontana, a two-lane road that connects them with the main urban centers of the Cagliari hinterland (Fig. 3). These predominantly residential neighborhoods are largely built in the 1960s under the INA-Casa and PEEP public housing plans, characterized by the presence of several green spaces and open public areas and services, with mid-level residential buildings and independent houses [20].

The socio-economic analysis conducted by the demographic data provided by ISTAT (the Central Italian Institute of Statistics) highlights the distribution of specific social groups to whom the evaluation of accessibility and quality of the public space can be expressly addressed (see Table 4). Within the city of Cagliari, the inhabitants of the neighborhood under analysis represent about 4% of the total population. The neighborhood has a population made up of more than 50% of women. An important share is represented by the elderly population, which corresponds to about 30%,



Fig. 3 The “Quartiere del Sole—La Palma” neighborhoods

while children make up 11% of the total inhabitants. On the other hand, foreigners do not constitute a relevant segment of the population. Furthermore, a significant portion of the total population (46%) commute daily toward their workplace/study place. The latter data highlights how the issues of mobility and accessibility to the neighborhood affect a significant portion of the population.

Then, we have analyzed the “Mobility and Accessibility” performance of the case study neighborhoods reporting two examples that show both the quantitative and the qualitative analysis. In the first, the different layers assigned to each means of transport (walking, cycling, private vehicle, and public transport) have been overlapped in order to isolate and evaluate both the pedestrian environment and the areas dedicated to vehicles transit and parking areas (Table 5). From the data analysis, it emerges

Table 4 Socio-demographic characteristics of “Quartiere del Sole—La Palma” neighborhoods

Demographic data	N	%	Source	Year
Total population	5.514	–	ISTAT	2011
Women	2.979	54		
Children (<14 years old)	600	11		
Young people (15–34 years old)	869	15,8		
Elderlies (>65 years old)	1640	29,7		
Foreigners	122	2%		
Inhabitants commuting daily	2.560	46%		

Table 5 The transportation layout of the neighborhood

	SQM	%
Total Publica Area	200.497	100
1. Street areas	145.416	73
2. Public open spaces	55.081	27
Street Area	145.416	100
1. Vehicular areas	84.683	58
2. Roadside parking	Authorized	7.588
	Unauthorized	7.288
3. Sidewalks	33.680	23
4. Cycle lanes	917	0,6
5. PT dedicated lanes	6.405	4,5
6. Accessory road elements	4.855	3
Public Open Spaces	55.081	100
1. Pavement public areas (squares, widenings, small open spaces, pedestrian paths)	12.312	22
2. Urban green areas (parks, neighborhood gardens, small green areas)	39.984	73%
3. Public areas used for parking	2.785	5%

that the public space of the district is largely dedicated to vehicular traffic (73%), while 27% is reserved for green areas, squares, or other open areas. It is interesting to observe that parking spots along the road occupy more than 15% of the surface dedicated to vehicles, a portion of public land that the administration leaves to private occupation without monetizing this resource or regulating its use but also taking it away from all other categories of public space users.

The results shown in Table 5 are plotted in Figs. 4 and 5. This cartographic representation makes it possible to instantly visualize those areas of the neighborhood in which vehicular mobility is privileged rather than active mobility, and constitutes a useful tool for planners and policymakers when deciding which infrastructural or legislative interventions aimed at discouraging the use of the private car need to be prioritized. Moreover, it allows to verify whether the layout of the streets that include services and activities serving the most vulnerable sections of the population (schools, health services) makes it possible to easily and safely access them.

The second example concerns the evaluation of the different levels of walkability by identifying the paths available for walking in the pedestrian catchment areas at 200 m–300 m–400 m for each building in the neighborhood [2]. We searched for all the activities and services (destinations) falling within these three catchment areas and then we computed the number of buildings (origins) that can access the different typologies of destinations (education, health, commercial, services). Figure 5 reports an example of the maps that can be obtained by the computation of the service areas:

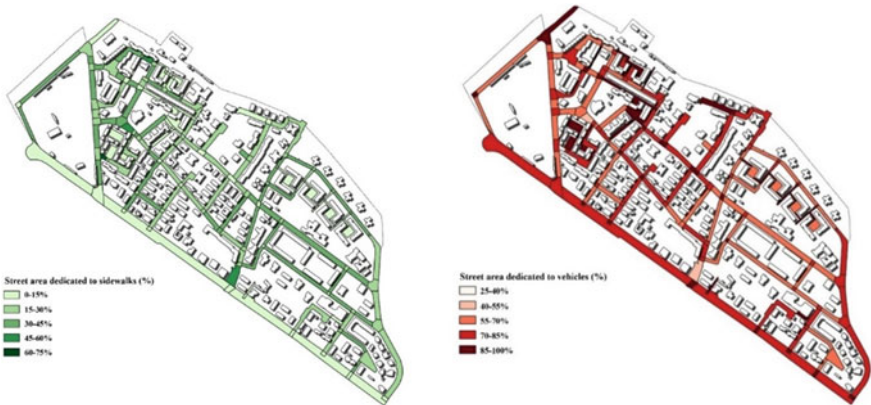


Fig. 4 Share of street areas dedicated to sidewalks and to private vehicles

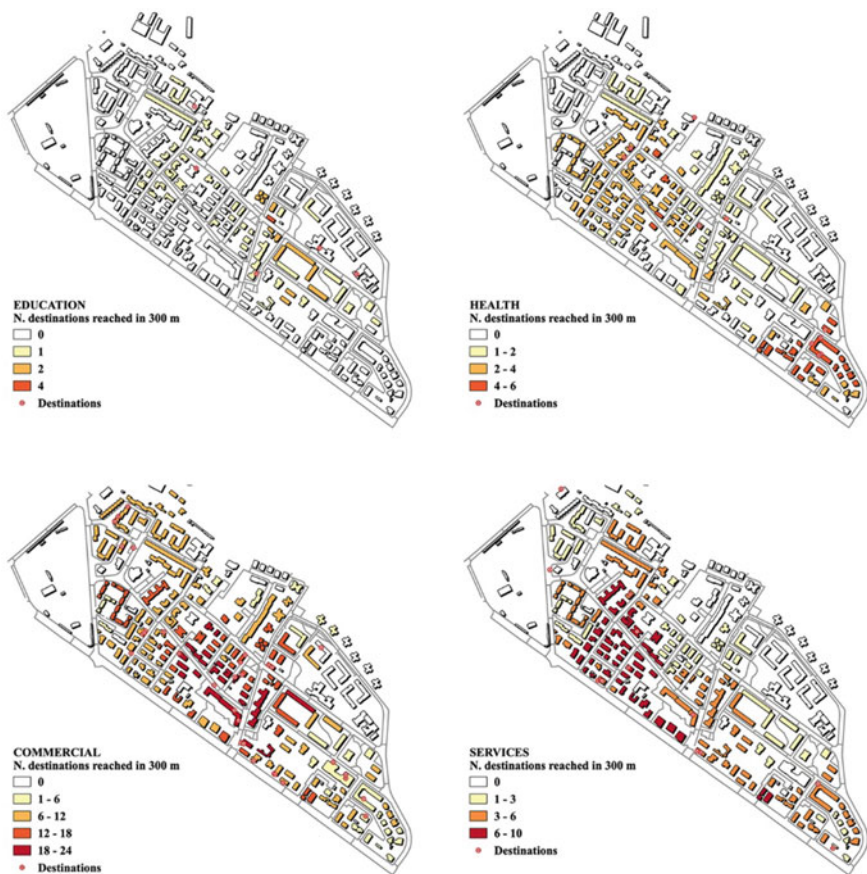


Fig. 5 Number of destinations that each residential origin can access by walking 300 m

in this specific case we reported the number of destinations that each residential building can access by walking 300 m.

In Table 6 we provided the share of residential origins in the neighborhood that can reach a certain destination for different walking distances, while in Table 7 we reported the average number of destinations accessible from each residential origin. In each table, we compare the results obtained using as a basis the pedestrian network we manually digitalized and the street network provided by the RAS. The main difference between the two networks is that the latter one does not consider paths along with parks and green areas and each road is considered as a single link of the network. Instead, in the pedestrian network crossing the road is possible only where a signalized pedestrian crossing exists.

In general, it is apparent that the majority of origins can reach a commercial activity or a public or private service by walking at most 200 m. Around 30% of the origins have access to a school within 200 m. Only the 10% of the 200 m of services area include a recreational activity. These shares increase as the distances employed to compute the service areas increase as well. We can also observe that using the

Table 6 Share of residential buildings that can reach a certain destination for different distances

Network used to compute the service area	Distance (m)	Commercial activities (%)	Schools (%)	Recreational activities (%)	Health services (%)	Public/private services (%)
Pedestrian network	400	100.0	82.9	38.6	99.5	94.3
	300	96.2	59.0	23.3	97.1	80.5
	200	85.2	29.5	12.9	86.2	58.6
Street network	400	100.0	85.2	38.1	100.0	94.8
	300	97.1	59.0	25.7	97.6	83.3
	200	84.8	31.9	9.5	87.1	67.6

Table 7 Average number of destinations accessible from each residential building for different distances

Network used to compute the service area	Distance (m)	Commercial activities	Schools	Recreational activities	Health services	Public/private services
Pedestrian network	400	16.96	1.71	0.51	9.77	3.65
	300	10.77	0.96	0.31	5.83	2.36
	200	5.69	0.38	0.17	2.90	1.20
Street network	400	17.11	1.81	0.57	9.92	3.99
	300	11.00	1.02	0.36	6.03	2.62
	200	6.17	0.43	0.12	3.14	1.47

street network, on average, a higher number of destinations can be reached from the residential buildings of the neighborhood, though this difference is relevant only for the service areas within 200 m.

4 Discussion

The results of the case study application highlight the potential usefulness of the proposed evaluation method for urban planning and design at the neighborhood scale, and its contribution to the achievement of SDGs.

Regarding to the first outputs obtained from the N.SDGs Framework, the analysis of the neighborhood's walking accessibility allows to identify those areas with low levels of pedestrian accessibility for different categories of services and activity analyzed, highlighting not only a lack in their provision but also an inadequate pedestrian accessibility to reach them. The fine-grain analysis provided by the proposed methodology, in fact, allows to identify the presence of pedestrian barriers or poor sidewalks, that require infrastructural interventions to improve the neighborhood walkability. Indeed, the proximity and variety of different services and activities in a neighborhood is only one aspect of the accessibility problem: if individuals, despite having a large number of *opportunities* available in close proximity of their homes, encounter difficulties in obtaining them due to the poor quality of the built environment, we cannot guarantee that they will use active mobility rather than private car for their trips, both discretionary and for leisure.

This highlights the need for integrated actions on both the functional and physical subsystems to improve and increase the neighborhood's accessibility. The thematic maps developed by applying geospatial tools immediately show critical situations and allow to foresee how the value of different indicators change with different interventions and also to update the database each time an intervention is carried out. In the same time, these maps can show the impacts of a project in achieving of SDGs according to the correlations highlighted in Table 1 and Fig. 1.

It should be noted that within the study area some information, such as pedestrian networks or parking areas, is currently not available in open data format and requires manual mapping work to acquire the data. While nowadays there are various open-source street datasets at different scales and resolutions, such information is not always available and can be expensive to build for the purpose. This suggests that the data collection and index calculation can be conducted both by public administrations during the planning phase or by private actors during the design and development stage of a neighborhood regeneration project.

5 Conclusions

The present study introduces a sustainability evaluation framework that allows to obtain a significant spatial representation of potentials and problems on different thematic issues of a specific neighborhood or urban area also in order to analyze and measure the performance on the achievement of SDGs. The high level of detail of the analysis of the N.SDGs Framework allowed us to verify the impact of the interventions at the micro-urban scale, through strategic maps developed with the help of GIS software packages. In turn, these maps allowed the computation and spatialization of different sustainability indicators, providing useful information to policy makers, specifically for the planning of actions involving the improvement of the four key performance areas of analysis. Indeed, the most important capability of GIS in urban perspectives is model simulation, which can support planning and decision making. Furthermore, integrating GIS with other technologies and methodologies can provide a powerful tool for quantitatively measuring urban patterns on a spatial scale.

The methodology was implemented using open-source data so that our model is freely and easily usable:

- by public administrations to evaluate the level of sustainability of specific urban areas and decide which urban regeneration interventions should be prioritized;
- by planners to evaluate the contribution of urban regeneration projects in the transition process towards the sustainability of a city;
- by citizens to understand the potential and the problems of the neighborhood they live in and actively participate in the decision-making process for interventions, on which your quality of life depends.

Although findings of our case study confirm the applicability of the framework, at the same time it is important to highlight that we found some difficulties in data collection and representation at the neighborhood scale. These limitations must be recognized and overcome through the consistent involvement and engagement of different urban actors to optimize the efficiency of data collection and analysis process. Future research should focus on improving the attribution of the individual factors that determine the overall quality of each key performance area at the neighborhood level. Interviews should also be carried out with a sample of citizens to improve the reliability of the method and better understand how each factor affects mobility and accessibility at the neighborhood scale.

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