

Contextualising Indicators for SDG 11: The GLOSSA Approach to Impact Assessment of Local Plans

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1 Introduction

The United Nations' 2030 Agenda emphasises the need to make cities and human settlements inclusive, safe, resilient and sustainable – an objective enshrined within Sustainable Development Goal (SDG) 11. At the urban scale, assessing the impacts of planning and territorial transformations and measuring progress towards sustainability are critical factors to support decision-makers in evaluating the effectiveness of adopted solutions [1, 2], providing the opportunity to redefine strategies. In this context, Neighbourhood Sustainability Assessment Tools (N-SATs) have gained increasing prominence as impact assessment and monitoring systems, enabling a systematic evaluation of multidimensional aspects of sustainability, ranging from environmental performance to social inclusion [3, 4]. In particular, the urban decision-making context needs more data-driven approaches based on evidence to support transition processes through Integrated Impact Assessment [5–7]. In this perspective, N-SATs can be conceived as multicriteria methodologies that integrate qualitative and quantitative indicators to measure and compare ex-ante and ex-post neighbourhoods sustainability levels. The assessment protocols, indeed, can provide DMs with powerful indicators to measure the impacts of urban policy and design strategies at a local scale when implemented by spatial Geographic Information Systems (GIS) analysis [8]. This contribution tries to foster the thesis that a crucial element for the success of N-SATs is the localisation of indicators with respect to specific context, as demonstrated by some recent developments of these tools, which prove that the selection of indicators has to reflect local priorities and urban landscape features [9, 10].

Identifying Key Performance Indicators (KPIs) capable of capturing the valued components from regional to local scale enables tackling complex assessments even in contexts where data availability is not guaranteed. Two illustrative examples of this approach can be found in the work of Sutherland (2016) and de Castro-Pardo (2023). The first study proposes an approach that begins with the definition of *values*, fundamental, shared principles that reflect what matters most to a community or system. These values are then linked to *valued components*: concrete, observable, or tangible attributes that represent the chosen values. Indicators are subsequently selected to monitor these components,

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following a process that emphasises transparency, traceability, and stakeholder participation [11]. The second study adopts a very similar framework, though it employs a more technical and operational terminology. It starts by identifying the dimensions of sustainability, which serve as the guiding "values" of the assessment process, along with their related sub-dimensions, specific aspects contributing to the definition of each dimension. These are then translated into KPIs, which represent the measurable elements [12]. The authors thus construct a *tree-structured indicator system*, where the KPIs are logically and functionally connected to the selected dimensions.

In this way, not only is the measurement of SDG 11 made more effective, but the adoption of measures that are both practically feasible and beneficial to the affected communities is also encouraged [3, 13]. The approach of localisation, often referred to as *contextualisation*, thus becomes essential for providing tailored responses to challenges such as reducing land consumption, improving sustainable mobility, promoting social inclusion, and safeguarding cultural heritage [14]. The scientific literature fosters the continuous development of new indicators, assessment methodologies, and classification systems that reflect urban and social changes [15]. On the other hand, NSATs can be essential for identifying KPIs capable of capturing the territorial values and valued components suitable for assessing urban-scale sustainability. However, although they are based on assessment protocols that illustrate specific indicator calculation processes, it is not always possible to adapt these processes to different territories [16]. In such contexts, the GIS environment allows for the definition of "proxy" variables that can be used as ancillary data to measure or estimate other variables that are more difficult to calculate directly due to practical limitations or unsustainable costs, by utilising heterogeneous data from various sources [17].

Moreover, the application of geospatial technologies - particularly those based on GIS – has been increasingly opening up advanced prospects for assessing urban planning actions, integrating the N-SATs into Spatial Decision Support Systems (SDSSs) for impact assessment in urban settings. Indeed, spatial data enable decision-makers to better understand the social and economic dynamics of cities, supporting the design of more effective urban policies which can improve the multidimensional impacts of urban infrastructures [18], allow to highlight critical areas of environmental protection [19], and improve the involvement and understanding of decision-making choices by stakeholders and local community [20]. Currently, the most established methodologies tend to prioritise the environmental aspect, yet SDG 11 demands that factors such as safety, resilience, and inclusivity have also to be included in the evaluation [21, 22].

This contribution is part of the National Interest Project (PRIN) GLOSSA - GLOcal knowledge System for Sustainability Assessment of urban projects - funded in 2022 by the Italian Ministry of Education and coordinated by the Politecnico di Torino (POLITO) in collaboration with the *Università di Napoli Federico II* (UNINA) and *Università di Cagliari* (UNICA). The fundamental aim of GLOSSA is to define a knowledge system based on SDG11 indicators that supports PAs in decision-making processes focused on territory monitoring, the selection of sustainable urban transformation projects, and the assessment of the impact of plans and policy. The principal tool developed by the GLOSSA research team is the Indicators-Based Tool (IBTool), a decision support system (DSS) capable of integrating NSATs at both the neighbourhood and building scales into

multi-criteria decision-making processes to support PAs during the key phases of project evaluation and territory monitoring.

The work presented here aims to contribute to the debate on a consistent methodology for assessing the sustainability impacts of individual plan actions portfolios at both municipal and neighbourhood levels, by proposing an operational framework for indicators measurement that, based on a set of 27 SDG11 indicators selected within the GLOSSA project and stored within the IBTool software, aims to produce spatial mapping of impact indicators linked to the *valued components* of the urban context of Bacoli, a municipality within the Metropolitan City of Naples. The research seeks to address: i) the need to contextualize sustainability indicators derived from the scientific literature within real urban contexts; ii) the possibility of defining an operational workflow for measuring proxy variables for these indicators within a GIS framework; and iii) the future implementation of a SDSS through the definition of a structured decision-making process.

2 Case Study: The City of Bacoli

The case study presented in this contribution aims to build a spatial mapping of impact indicators to support the GLOSSA project in terms of making operational the application of the IBTool in the city of Bacoli. The goal is to assess the impacts of the projects planned by PAs through the proposal of an evaluation framework able to highlight areas of concerns and potentials for the management of the territory (Fig. 1).

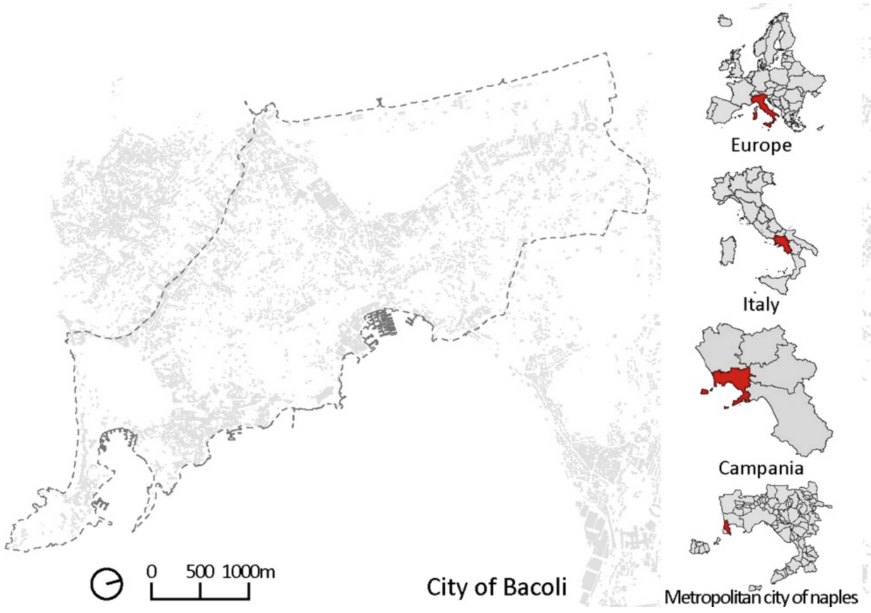

Fig. 1. The city of Bacoli in its territorial framework

The city of Bacoli is part of the Metropolitan city of Naples (Italy). Located to the west of Naples, it is part of the geological complex of the "Campi Flegrei", characterized by a volcanic field which has been active for more than 80.000 years. According to the census data provided by the Italian National Statistics Institute (Istat, 2021), the city is inhabited by 25.410 people, distributed on an surface of 13,47 Km^2, subdivided into 10 municipalities. The first findings suggest that the city of Bacoli saw its first development with the Romans, following the Greek city of Cuma. The thermal area of Baia attracted even the Roman Empire, who built their villas in this area, suggesting an environmental value which has been remaining relevant during the time. The urban layout was not subject to heavy transformation up until the end of the Second World War and during the 1980s, when heavy expansion concerned the city. This expansion was partially regulated by the general urban development plan of 1972, which was focused on the preservation of the ancient centre and the development of areas of new urbanization, as well as the expansion of the road layout. Constraints to further constructions were applied in 1976, with the variant to the general urban development plan, and in 1999 with the landscape plan of the "Campi Flegrei". In spite of them, abusive expansions determined the formation of new and informal agglomerations. To this day, unregulated building stands as a pressing issue: more than 5000 building amnesty applications have been received by the local administration. The main problems the city faces today are related to the seasonal tourism flow. During the summer months, congestion of the road network causes a real issue for the inhabitants of the city. Furthermore, this poses risks regarding air quality, heavily impacted by gases released by thermal motors. The state of the public transport, which is not sufficient to answer the demand, poses as one of the issues that need to be faced by the PAs, also with regards to the need for immediate evacuation of the city in case of seismic or volcanic events. With regards to public services, the main registered deficits regard the lack of green areas for leisure and parking spaces for private vehicles.

3 Materials and Methods

The methodological process was addressed to lay the foundations of a SDSS based upon the three decision-making phases which Simon has identified as: Intelligence, Design, and Choice [23].

As shown in Fig. 2, the proposed methodological framework has focused on the Intelligence phase, in which the problem to be faced was structured to identify *valued components* and linked impact indicators for the case study of Bacoli.

The Design phase was oriented to data gathering and selection to build spatial indicators contextualised to the focus area.

The Choice phase - whether not discussed in this contribution - relates to future developments of the SDSS for developing impact assessment of project portfolios using GIS-MCDA scenarios maps.

Starting from the selection and validation of the 27 indicators proposed by GLOSSA, the proposed methodological framework was addressed to operationalize and contextualize impact indicators linked to 6 valued components for the testing phase of the IBTool in the case study of Bacoli. The following sections explore the tools and methods used to structure the SDSS for Bacoli.

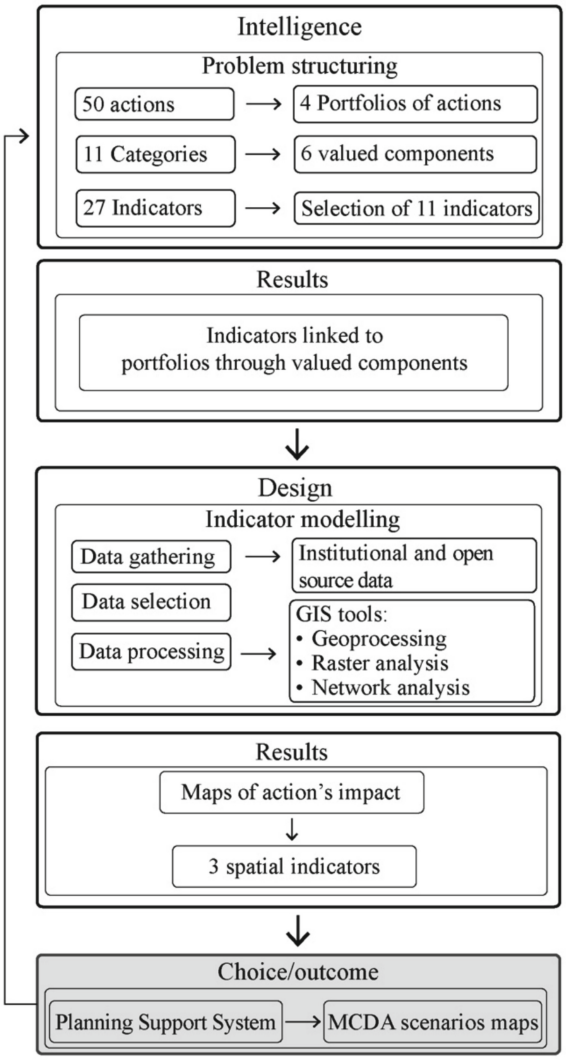

Fig. 2. The methodological workflow

3.1 Intelligence: Identification of Portfolios, Valued Components, and Linked Indicators

The intelligence phase, fundamental to the structuring of the decision-making problem, was divided into three main steps:

- the analysis of all the plan actions provided by local authorities and their classification into four portfolios;
- the clustering of indicator categories - derived from Glossa - into six groups, associated to each valued component;

- the identification of existing relationships among indicators and plan actions.

This phase made it possible to structure the decision-making problem of the impact assessment by integrating the processes of selecting and validating the SDG 11 indicators identified within the GLOSSA project by contextualising and linking those indicators to the primary features of the study area. This process has allowed to foster a strong coherence between the valued components identified and the effects of the plan actions on the territory.

3.1.1 Structuring Portfolios of Actions

Firstly, a qualitative content analysis was performed to organise the actions into four portfolios [24]. The aim was to group into the following 4 portfolios the 50 actions planned by the local authorities, based on their similar scope.

- *Environmental and cultural redevelopment and enhancement interventions*, which includes 8 actions aimed at improving the quality and accessibility of natural and cultural assets. These actions are: 1A_Redevelopment and completion of the east-side cycle-pedestrian path (from Vanvitellian Park to Quarantine Park); 1E_Redevelopment of the Quarantine Natural Park, with pedestrian connections to the dune system and the sea, and the creation of a research center on the biodiversity of the lake-dune system; C1_Equipped sports park in Cuma, enhancement of the columbarium on Via Virgilio; C2_Enhancement of the columbarium on Via Scamardella and the route leading to the Tomb of Agrippina, pedestrian connection between Villa Ferretti, Baia Castle up to Via Ortenzio, and redevelopment of the road section; C3_Redevelopment of the cycle-pedestrian connection between the Theater, the Sacellum of the Augustals, the Dragonara Cave and pedestrian square of San Sossio; E2_Redevelopment of pedestrian paths between the Tomb of Agrippina (Odeion) and the Piscina Mirabilis; F2_Enhancement of the Baths of Baia and creation of a new entrance route from Piazza De Gasperi; F4_Enhancement of the system of archaeological sites in Bacoli (Odeion, Centum Cellae, and Piscina Mirabilis) and in Miseno (Theater, Sacellum of the Augustals, and Dragonara Cave).
- *Restoration and safety interventions for the historical and infrastructure Heritage*, which contains 9 actions focused on the conservation, structural rehabilitation, and safety upgrading of historical buildings and existing infrastructure. These actions are: D_Completion of the park around Lake Miseno with the redevelopment of the cycle-pedestrian path; 1B_Restoration of the thermal archaeological sites known as 'Grotte dell'acqua'; A1_Safety measures and usability improvements for Villa Ferretti.A2_Safety measures for the seafront of Villa Ferretti; A3_Safety measures for 101 housing units; A4_Safety measures for the 'Marconi' school complex; C1_Consolidation and repair of the bridge of Casina Vanvitelliana; E1_Reuse of the decommissioned tunnel of the Cumana railway line from Piazza De Gasperi to Sella di Baia and its enhancement as an exhibition-informative space; F1_Completion of the Baia Castle Museum, including the restoration of the Cavaliere bastion and the creation of an urban park around the castle.
- *Infrastructure interventions for mobility and road networks,* which regards 32 actions encompassing projects to improve urban mobility and accessibility through

the upgrading of road infrastructure, the enhancement of public transport facilities, and the development of sustainable mobility solutions, these actions are: A_Redevelopment and enhancement of the Vanvitellian Historical Park, the Casina, and other 18th-century buildings (Ostrichina, Casone, fishermen's buildings, mussel farmers' buildings); 1A_Redevelopment and completion of the east-side cycle-pedestrian path (from Vanvitellian Park to Quarantine Park); B1_Cycle-pedestrian path on the west side of Lake Fusaro and F4b interchange parking; B2_Restructuring of the square on Via Bellavista (Church) for bus interchange; B3_Expansion of Via Risorgimento between the Via De Curtis intersection and the Municipal Villa, including a roundabout at the intersection with Via De Curtis; B4_Roundabout at Miseno; B5_Roundabout at Miliscola; B6_Roundabout at Fusaro; C3_Redevelopment of the cycle-pedestrian connection between the Theater, the Sacellum of the Augustals, and the Dragonara Cave; pedestrian square of San Sossio; E2_Redevelopment of pedestrian paths between the Tomb of Agrippina (Odeion) and the Piscina Mirabilis; G1_New connection between Via di Cuma and Via Spiaggia Romana with the East-West Naples Ring Road, including a bypass of the Old Felice Arch and the creation of interchange parking lots; G2_Redevelopment and expansion of Via Spiaggia Romana, level crossing, and roundabout on Via Giulio Cesare; G3_Relocation of the Cumana Station at Torregaveta and connection between Via Papinio Stazio and Via Servilio Vatia (Gavitello); B_Redevelopment and completion of the west-side cycle-pedestrian path of Lake Fusaro (from Quarantine Park to the Cuma Amphitheater) and construction of the F4b interchange parking lot; C_Redevelopment of the connection between the Baths of Baia and the Vanvitellian Park with a cycle-pedestrian path; E_Construction of an internal service road in the area between Lake Miseno and the beach, and enhancement of the existing road into a cycle-pedestrian avenue with connections to the path around the lake; T1_Completion of the 'Cumana' Baia railway station; T2_Extension of the Cumana Line from Torregaveta to Bacoli center; F4a_Construction of Scalandrone interchange parking; F4b_Construction of Cuma interchange parking; F4c_Construction of Torregaveta interchange parking; F4d_Construction of Cappella interchange parking; F4e_Construction of Via Bellavista interchange parking; F4f_Construction of Baia - Castle interchange parking; At-P_Creation of a waiting/parking area as per the municipal civil protection plan – 2016_ Pi1_Construction of Sella di Baia interchange parking; Pi2_Construction of Fusaro interchange parking; Pi3_Construction of Baia - Cantieri interchange parking; Pi4_Construction of Torregaveta Station interchange parking; Pi5_Construction of Center interchange parking; Pi6_Construction of Lido Fusaro interchange parking; 1C_Expansion of the Pi7 service parking.

- *Creation and enhancement of sports and urban spaces*, which includes 5 actions for the development, renovation, or expansion of sports facilities and urban recreational areas, these actions are: C1_Equipped sports park in Cuma; C2_Construction of an equipped sports park; C3_Pedestrian square of San Sossio; F3_Enhancement of the lower city of Cuma; F_Recovery of the 'Cinque Lenze' complex on Lake Miseno and connected areas for tourism, hospitality, and leisure activities.

The classification has highlighted the strategic dimensions on which the city of Bacoli relies for sustainable urban planning and transformation. From this classification, it is

possible to understand that the issues of mobility, accessibility, and local public transport represent the dominant issues dealt with by the local administration.

3.1.2 Identification of Valued Components

The next step involved the reframing of the thematic categories proposed by GLOSSA according to the identification of specific *valued components* common to the selected indicators. As shown in Table 1, six different components were thus identified, referred to as: Housing, Infrastructure and mobility, Environment, Culture and heritage, Risk, and Waste. In addition, the corresponding NSAT - from which the computation method and the indicator meaning has been derived - is specified for each indicator. The Housing component expresses values linked to the quality of the living environment and access to affordable and sustainable housing solutions. It is articulated into 2 categories: Housing Liveability and Housing Affordability. Within these categories, 5 distinct themes were found: overcrowding, outdoor spaces, costs, energy efficiency, and network, which are explored through overall 7 indicators. These indicators range from the percentage of people living in overcrowded homes, to aspects such as housing cost overload, energy efficiency, and the availability of common spaces.

The Infrastructure and mobility component highlights the value of accessibility and sustainable transport, both at the individual and collective level. It was structured into 3 categories: Accessibility and connection presence, Type of vehicles used, and Quality of public transport. The themes related to this component are the following: connections, parking areas, and sustainable organisation, supported by 6 indicators. These include, as an example, the level of bicycle and public mobility, presence of interchange points, incentives to use bicycles, and the maximum parking capacity available.

The Environment component captures the values placed on land preservation, ecological quality, and the condition of public spaces. It encompasses three categories: Land Consumption, Presence and Quality of Green or Public Areas, and Decay. These categories are further developed into 4 themes: land preservation, building renovation, green, and decay, through 7 related indicators. These cover issues such as soil sealing, environmental remediation, green space distribution, and dissatisfaction with the landscape of the living space. The Culture and Heritage component reflects the value of community participation, cultural accessibility, and heritage protection. It is divided into 3 categories: Participation in urban Planning and management, Presence and quantity of cultural goods or services, and Quality of cultural goods. There are four themes: participation, heritage, inclusion, and building accessibility, represented by 5 indicators. These indicators explore both the level of citizen involvement and the presence of cultural and landscape heritage, as well as universal accessibility. The Risk component refers to the vulnerability of the population to natural hazards. It includes only 1 category, Population at Risk, and 1 theme, Natural Disasters, which is detailed through 2 indicators: population exposed to flood risk and population exposed to landslide risk. Finally, the Waste component addresses the value associated with recycling and sustainable resource management. It is represented by a single category, Quantity and recycling of waste, and 1 theme, Waste, described by 1 indicator: level of recycled or recovered materials. Table 1 represents the database of the indicators which were clustered. While the first column

are the valued components identified in this paper, the remaining columns are based on the structure of GLOSSA indicators dataset.

Table 1. Valued components and indicators dataset

VALUED COMPONENT	CATEGORY	THEME	INDICATOR	NSAT
Housing	**H**ousing **L**iveability	**H1** - Overcrowding	**H1.1** - Percentage of people living in overcrowded homes	ISTAT 2023
		H2 - Outdoor spaces	**H2.1** - Common areas: relationship and common spaces	GBC 2016
	Housing Affordability	**H3** - Costs	**H3.1** - Housing cost overload	GBC 2016
			H3.2 - Housing typologies and social housing	GBC 2015
		H4 - Energy efficiency	**H4.1** - Energy sustainability	PINQUA 2022
			H4.2 - Energy efficiency	PINQUA 2022
		H5 - Network	**H5.1** - Utility	BREEAM 2012
Infrastructure and mobility	**A**ccessibility/**C**onnections presence	**I1** - Connections	**I1.1** - Bycicle mobility	PINQUA 2022
			I1.2 - Public mobility	PINQUA 2022
			I1.3 - Families declaring difficulties connecting to public transport in their neighborhood	ISTAT 2023
			I1.4 - Accessibility to public transport	ISTAT 2019

(*continued*)

Table 1. (*continued*)

VALUED COMPONENT	CATEGORY	THEME	INDICATOR	NSAT
	Type of **V**eichles used	**I2** - Parking areas	**I2.1** - Incentive to use bycicles	ITACA 2019
			I2.2 - Maximum parking capacity	BREEAM 2021
	Quality of **P**ublic **T**ransport	**I3** - Sustainable organization	**I3.1** - Interchange points	GBC 2015
Environment	**L**and **C**onsumption	**E1** - Land preservation	**E1.1** - Soil waterproofing from artificial cover	SNSvS 2022
			E1.2 - Buildings not used by state of use	ISTAT 2011
		E2 - Building renovation	**E2.1** - Environmental remedation	PINQUA 2022
	Presence and **Q**uality of **G**reen or **P**ublic **A**reas	**E3** - Green	**E3.1** - Green areas distribution	GBC 2015
			E3.2 - Green areas	SNSvS 2022
		E4 - Decay	**E4.1** - Dissatisfaction with the landscape of the living place	PINQUA 2022
Culture and heritage	**P**artecipation in **U**rban **P**lanning and **M**anagement	**C1** - Partecipation	**C1.1** - Involvement and opening towards communities	MIM 2021; SNSvS 2022
	Presence/**Q**uantity of **C**ultural **G**oods or services	**C2** - Heritage	**C2.1** - Safety towards inclusion	ISTAT 2023
		C3 - Inclusion	**C3.1** - Historical-cultural goods and landscape goods	ISTAT 2023

(*continued*)

Table 1. (*continued*)

VALUED COMPONENT	CATEGORY	THEME	INDICATOR	NSAT
	Quality of **C**ultural **G**oods	**C4** - Building accessibility	**C4.1** - Buildings equipped with specific measures to overcome architectural barriers	ITACA 2019
Risk	**P**opolation at **R**isk	**R1** - Natural distasters	**R1.1** - Population exposed to flood risk	Chao, 2022
			R1.2 - Population exposed to landslide risk	PINQUA 2022
Waste	**Q**uantity and **R**ecycling of **W**aste	**W1** - Waste	**W1.1** - Recycled/recovered materials	Battisti, 2023; ISTAT 2023

3.1.3 Selection of 11 Indicators Based on the Valued Components

The last step of the Intelligence phase was aimed to identify the relationships among GLOSSA indicators and the actions planned by local authorities of Bacoli, specifically to understand which of the 27 indicators should be used to monitor the impact of actions against SDGs 11 targets. This goal was achieved by consulting the sources of the indicators and calculation methods stored within the IBTool, to understand the methods of calculations, and comparing them with the actions planned by the PAs. As a result, 11 cross-cutting indicators were selected which can be associated with the four identified portfolios. This made it possible to define a basic set of indicators through which the impact has been evaluated in a spatial GIS environment.

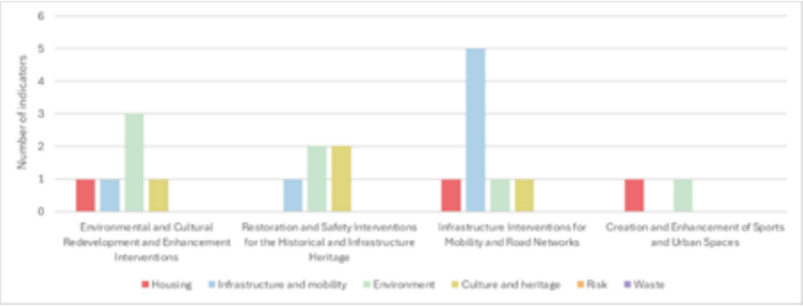

Fig. 3. Indicators linked to portfolios through valued components

As shown in Fig. 3, out of the four portfolios of actions identified, the one that can be monitored by the most number of indicators is "Infrastructure interventions for mobility and road network", it is also worth noting that the indicators of the valued components Risk and Waste are not found among the 11 indicators selected, highlighting a lack of actions impacting these domains.

3.2 Design: Proxy-Indicators Modeling

The second phase of the methodological process is the design phase, in which the focus is emphasized on the modeling of the indicators previously identified. This phase is subdivided into three steps: 1. Data gathering, in which data regarding the indicators was structured in a database to be further analysed; 2. Data selection, in which data regarding the four proxy indicators was filtered and refined; 3. Data processing, in which the data was processed through GIS to spatialize it and obtain the values of the proxy indicators.

3.2.1 Data Gathering

The first step of the design phase was to gather raw data to construct the indicators. The research of data ranged from institutional data to crowd-sourced data, because of a lack of availability. The research was based on the calculation methods of the indicators, which were found consulting the initial sources stored within the IBTool. As an example, indicator I 1.1 *Bicycle mobility* expresses the overall linear metres of the new project of cycle paths and was derived by Urban development plan. Given the spatial nature of the proposed DSS, the research focused on spatial data to be processed through GIS software, but also on statistics data available to the general public via institutional database. The main institutional sources consulted were: the Urban development plan (Piano Urbanistico Comunale), which contained information regarding the actions planned by local authorities, the Italian National Statistics Institute (Istat), which allowed for specific data on the population of the case study through the census of 2011 and 2021; the Military Geographic Institute (IGM), and crowd-sourced data from OpenStreetMap (OSM), which was used for the base map. The information collected from the identified sources and related to the indicators proposed by GLOSSA and previously selected were collected in Table 2.

Table 2. Data gathered

ID	NAME	UM	SOURCE	VALUE	YEAR
H1.1	Pop 2021	n	ISTAT	25410	2021
H1.1	Residing families - 6 and more components	n	ISTAT	156	2021
H3.1	Annual expenses of families for energy consumption	€	ISTAT	1242	2021

(*continued*)

Table 2. (*continued*)

ID	NAME	UM	SOURCE	VALUE	YEAR
I1.1	Length of bike lanes	km	Bacoli urban plan	4,4	2020
I1.2	Railway length	km	IGM	7	2020
I1.2	Number of commuters	n	ISTAT	5120	2011
I2.2	veichle fleet - all veichles	n	ISTAT	21318	2023
I1.2	veichle fleet - cars	n	ISTAT	15791	2023
I2.2	Public parking	m^2	OSM	77215	2023
I3.1	Interchange nodes - existing	n	Bacoli urban plan	2	2020
I3.1	Interchange nodes - projects	n	Bacoli urban plan	1	2020
W1.1	recycling rate	%	ORGR	66,46	2023
R1.1	Popolation exposed to medium hydraulic risk	n	Regional River Basin plan	7674	2019
R1.1	Popolation exposed to maximum hydraulic risk	n	Regional River Basin plan	3788	2019
R1.2	Popolazione esposta a rischio da frana medio	n	Regional River Basin plan	1164	2019
R1.2	Popolation exposed to high landslide risk	n	Regional River Basin plan	9833	2019
R1.2	Popolation exposed to very high landslide risk	n	Regional River Basin plan	5985	2019

3.2.2 Data Selection

In this step of the design phase, the objective was to select some indicators to be modeled into GIS environment to produce impact assessment maps. In this meaning, 3 indicators were selected and produced: bicycle mobility (I1.1), Accessibility to public transport (I1.4) and maximum parking capacity (I 2.2). The indicators are linked to the portfolio referred to as: "infrastructure interventions for mobility and road networks", which is the one that encompasses the most amount of actions planned, which in return are also the ones with the most amount of indicators that can monitor them. The selection phase was then focused on the dataset by specifically filtering and retaining the information directly relevant to the selected proxy indicators. This step involved removing redundant, inconsistent, or incomplete data points to enhance accuracy and relevance (Table 3).

3.2.3 Data Processing

All of the data collected and selected has then been processed with the use of GIS, to obtain KPI related to the actions planned. Three main processing tools were used, based on the extension of the data and the indicator needed to be calculated.

Proxy indicator 1 relates to the length of bike lanes. To obtain this indicator geo-processing tools for data analysis were utilized for deriving the segment length. Raster

Table 3. Data selected

ID	NAME	U.M	SOURCE	VALUE	SCALE	YEAR
I1.1	Length of bike lanes	km	PUC Bacoli	4,4	City	2020
I1.1	Length of informal bike lanes	km	PisteCiclabili.com	11,8	City	2024
I1.2	Railway length	km	IGM	7	City	2020
I1.2	Number of commuters	n	ISTAT	5120	City	2011
I2.2	Public parking	m^2	OSM	77215	City	2023

analysis was used to overlap the documents from the urban development plan in order to calculate the dimensions of project cycle paths. Proxy indicators 2 and 3 required more advanced spatial analysis tools. Specifically, proxy indicator 2, Maximum parking capacity, has required raster analysis to overlap the areas of future parking expected by the urban development plan. Consequently, each attribute table of each census tract of the city of Bacoli has been remodeled to gather information of the total sqm falling within each section. This value has then been divided by the area of each section to obtain a normalized index of sqm of parking area on sqm of census tract. For proxy indicator 3: accessibility index to railway service several steps were needed. First, service areas were constructed starting from existing stations and project stations, with timings of 10, 20 and 30 min at walking speed (considered to be 5 km/h). Subsequently, the attribute table of the 2011 census tract (as it is the last census available that contains the values regarding commuters) was updated to contain the information regarding the number of stations reachable at each time interval considered. These values were then weighed and summed, following formula (1),

$$I = (\alpha_{T3} * N_{T3}) + (\alpha_{T2} * N_{T2}) + (\alpha_{T1} * N_{T1}) \quad (1)$$

where α is the weight assigned to each time (1 for 10 min, 0,66 for 20 min and 0,33 for 30 min); N is the number of stations reachable from each section; and the subscripts (t1, t2, t3) are respectively equal to 10, 20, 30 min. The results of all these processes were action's impact maps, which allowed the visualization of impact derived from the actions planned by local authorities, which will be discussed in the next paragraph.

3.3 Choice: Towards a MCDA Scenario Maps for Impact Assessment

The last phase of the structuring process of the SDSS is the choice phase. Further development of the indicators modelled in the previous steps will enable the realization of MCDA scenarios maps, showing the different impact derived from different actions planned on the territory, with the aim of guiding local authorities towards structured decision making processes.

4 Results and Discussion

The three proxy indicators which represent the KPIs for Bacoli derived from GIS spatial analysis are presented as follows.

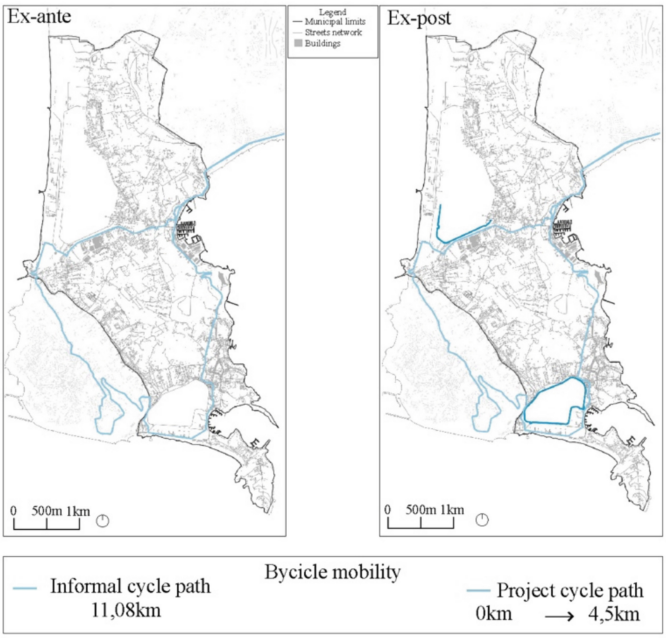

Fig. 4. Bicycle mobility

As shown in Fig. 4, *Proxy indicator 1 - bicycle mobility* highlights the length of bike lanes available in the city of Bacoli. This indicator was derived from the *PINQuA 2022* NSAT [25], in which it is defined as the "*expansion or new construction of cycle paths*", expressed in Kilometres. In current state, no bike lanes are present in the territory, thus, the indicator is expected to grow up to 4,5 km. In the indicator map, informal bike paths were highlighted, since these paths are generally followed by cycle-tourists. In this perspective, the urban development plan has integrated these paths into the city design project in which they were conceived as tourist paths crossing localities of lakes Miseno and Fusaro. Actually, these paths do not provide strategic connections for alternative transport modalities, but they facilitate the tourism activities.

Proxy indicator 2 – maximum parking capacity provides a normalized index of the parking availability value related to the size of each Census tract. The source for this indicator is the *BREEAM 2022* [26] technical manual, in which the indicator is produced with a scenario measure unit, relating the parking's number to the number of users of the building. As shown in Fig. 5, it is possible to notice that a significant increase in parking spaces availability from the expected state will take place after planned actions, especially in the western side of the city of Bacoli, as well as in the southern area close to the city centre.

Proxy indicator 3 - accessibility to railway services contextualses the indicator I1.4, which refers to the accessibility to public transport. The source for this indicator is the 2019 ISTAT report [25]. The index discussed shows the level of accessibility to railway stations through the above-mentioned normalized index. The changes related to the projects expected are significant, as at the current state of the southern side of the city of Bacoli presents a zero value, indicating a serious inaccessibility to the railway services. The plan of Bacoli has expected to change this value presenting a project with an acceptable level of accessibility to the stations (Fig. 6).

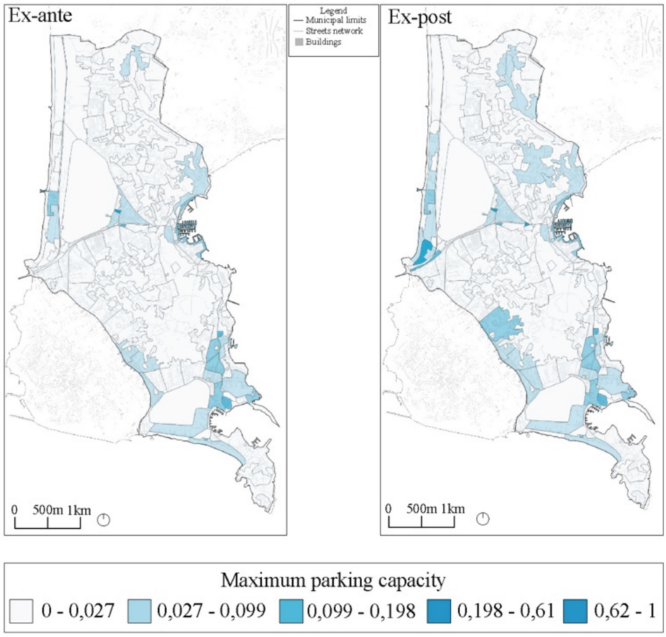

Fig. 5. Maximum parking capacity

5 Conclusions and Further Developments

This research has presented an operational framework aimed at contextualising sustainability indicators within the urban context of Bacoli, by applying a structured methodological approach grounded in the three phases of DSS: Intelligence, Design, and Choice. In the Intelligence phase, the valued components were identified and matched with corresponding SDG 11 indicators, enabling a coherent classification of local planning actions into thematic portfolios. The Design phase provided the selection and modelling of proxy indicators using geospatial data and GIS tools, demonstrating the practical feasibility of assessing urban impacts in a spatially explicit way. Although the Choice phase remains in development, the groundwork laid by the current research allows for future integration of MCDA to support scenario-based decision-making processes.

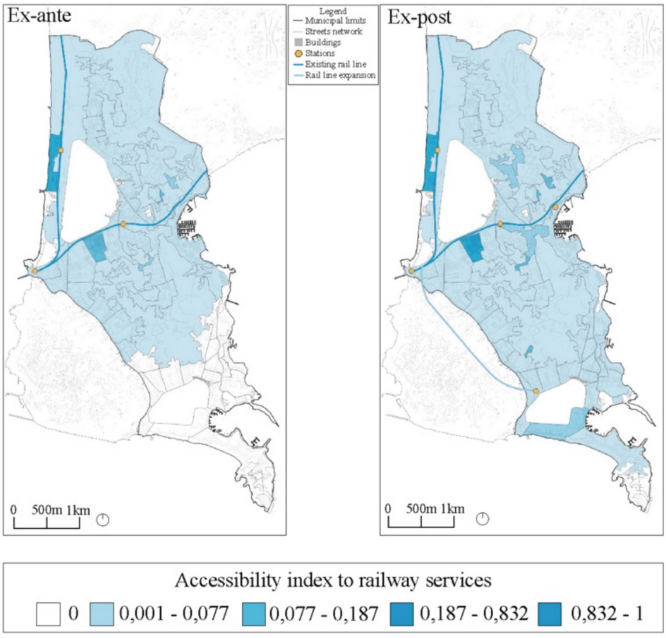

Fig. 6. Accessibility index to railway services

Despite the robustness of the approach, some limitations emerged during its application. Firstly, the availability and quality of data—especially at the local scale—posed challenges for the calculation of certain indicators. Moreover, while proxy indicators offer a pragmatic solution where direct measurement is difficult, they inevitably introduce a level of approximation that should be critically considered when interpreting results. Additionally, the lack of integration of spatial-temporal data restricts the ability to monitor changes over time, thereby limiting dynamic assessments.

Further developments of this research will be focused on the full implementation of the Choice phase through MCDA scenario mapping, allowing for the simulation of different planning alternatives and their relative impacts. Future work should also involve expanding the range of indicators to better capture social and cultural dimensions, integrating real-time data streams, and enhancing the participatory dimension of the tool. These steps would contribute to the construction of a fully operational SDSS capable of guiding municipalities in the evaluation and optimisation of their planning actions towards sustainable and inclusive urban development.

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