A Multi-dimensional Decision-Making Process for Regenerative Landscapes: A New Harbour for Naples (Italy)

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Abstract. The paper aims at testing an evaluative methodology for choosing the best-fit alternative of sustainable development for a complex urban context, stressing advantages and limitations in using Analytic Network Process (ANP) multi-criteria method to rank sustainability indicators, that have been conceived as the criteria - in meaning of control parameters - through which alternatives comparison has been carried out.

The proposed methodology highlighted the relationships between the Sustainable Development Goals (SDG) and the place-based issues in order to define a first step to operationalize the United Nation guidelines, adopting a cross-scale, multi-dimensional and goal-focused approach.

The methodology has been tested on the area of interest which is localized in the eastern part of the Gulf of Naples, in Italy, and falls within the VI District of the City, including "San Giovanni a Teduccio" neighbourhood.

The impact assessment that the design of new harbour will have on surrounding urban districts and the city, in social, economic and environmental terms, is the main issue underpinning the decision-making problem structuring.

Sustainability indicators have been selected from different sources recognized from literature and national and international databases. Thus, each indicator has been categorized, processed and assessed for the focus area by comparing the current scenario with two alternatives development strategies for landscape regeneration.

Keywords: Sustainability indicators · Analytic Network Process (ANP) · Multi-Criteria Decision Aid (MCDA)

1 Introduction

The 17 Sustainable Development Goals (SDGs) and 169 targets of 2030 Agenda for Sustainable Development inform decision-makers, stakeholders and specialists on consistent and generally accepted sustainability issues which needed to be considered when the assessment of best-fit development strategies for complex urban contexts are at stake [1, 2].

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While the SDGs depict a global to-do list and plan for the success of all human beings, the purpose of Agenda 2030 at regional scope involves balancing economic, social and environmental dimensions of development [3].

The challenges of the new paradigms of sustainability, afforded by the Landscape Sustainability Science (LSS) [4] and regenerative landscapes framework [5], deal with the research of "place-based" knowledge systems and developmental change methodologies in order to outclass the deterministic approach in favour of stochastic and holistic ones.

The Landscape Sustainability Science (LSS) is concerned with a practical field of application of sustainability theoretical principles. It has been defined as "place-based" and "use-inspired" science, which aims to understand and implement the dynamic relationships that exist between landscape and human activities, through the use of spatially explicit methods [6].

Within a cross-scale perspective for operationalizing sustainability targets, the regenerative development has been considered as developmental change methodology which is able to support the paradigm shift including the principles of LSS and regenerative design. Leveraging on interdependencies among different knowledge domains and interdisciplinary issues, the above-mentioned framework works on multiple scopes to assess development strategies [5, 7].

According to this theoretical background, two main issues addressed by the paper are concerned with:

1. How is the operationalization of the SDGs targets achieved in order to conceive more sustainable development strategies in urban planning and design?
2. Which indicators have to be selected and categorized as proxy parameters to put in practice the sustainability definition?

Moreover, a third question connected to the above-mentioned issues relates to the choice of suitable multi-criteria methods to compare the indicators each other and perform the alternatives' priorities.

When faced with strategies of economic development for the harbour and surrounded complex urban systems, it is necessary to evaluate alternatives in multidimensional terms, considering the interaction of multiple criteria within the decision-making problem structuring [8].

In this perspective, Multiple Criteria Decision Analysis (MCDA) provides a set of theory and methods that give support to structure and solve complex issues encountered in different disciplines and fields of human activity, in which incommensurate and conflicting criteria subsist [9].

Concurrently, the trade-off between economics and ecology is widely known in the Post-Normal Science field as well as many authors have been focusing on the complexity of performing objective evaluations when environmental conflicts are strong [10–13].

The paper aims at testing an evaluative methodology, established in the literature, for choosing the best-fit alternative of development for a complex urban context, stressing advantages and limitations in using Analytic Network Process (ANP) method to rank indicators, that have been treated as the criteria through which the comparison of the alternatives has been carried out.

The proposed methodology has been tested on the area of interest which covers the eastern part of the Gulf of Naples and falls within the VI District of the City, including the neighbourhood of "San Giovanni a Teduccio".

The overall outcome of the paper highlighted that, through procedural rationality and control systems based on place-based indicators, the multi-level strategies can be tested and calibrated in terms of long-term sustainability and resilience.

In summary, the first part of the paper (Sect. 2) shows the purpose of research and methodological approach; the second one (Sect. 3) identifies the case study for which the methodology has been elaborated; the third one (Sect. 4) analyses the results obtained with the evaluation model tools, and the last part (Sect. 5) concerns with discussion and conclusions about the issues afforded.

2 Purpose of Research and Methodological Approach

The purpose of research aims at evaluating scenarios of urban transformation through sustainability indicators and MCDA methods in order to support Decision-Makers in choosing a suitable set of actions and guidelines to activate urban and territorial regeneration processes.

The Organization for Economic Co-operation and Development (OECD) has provided, over the years, guidelines for the activation of Local Agenda 21 processes promoted by the United Nations conference in Rio de Janeiro in 1992. In particular, the methodology proposed by OECD for pursuing sustainable development strategies concerns with the use of analytical tools that are able to facilitate understanding and evaluation of complex issues. These tools relate to indicators, which can be defined, in their broadest sense, as those parameters that are useful to describe the multi-dimensional phenomenon in quantitative or qualitative terms [14, 15].

According to Persada et al. 2018, evaluation indicators can be processed considering [16]:

- Main goals of the evaluation framework;
- Results of stakeholders assessment and public opinion;
- Different targets of sustainable development;
- Different data sources.

In line with these issues, the multi-dimensional approach applied in this research aims at transposing the SDGs targets into place-based indicators in order to conceive Sustainability Indicators to implement for complex landscapes interpretation and evaluation.

As shown in Fig. 1, the methodological workflow has been structured into the following 4 steps:

1. Theoretical background. The first step is concerned with the drivers of research and theory-driven models which are focused on operationalization of sustainability definitions;
2. Decision-Making Problem Structuring. In this phase, the main goal and issues to be afforded are defined, and the evaluation tools are selected;

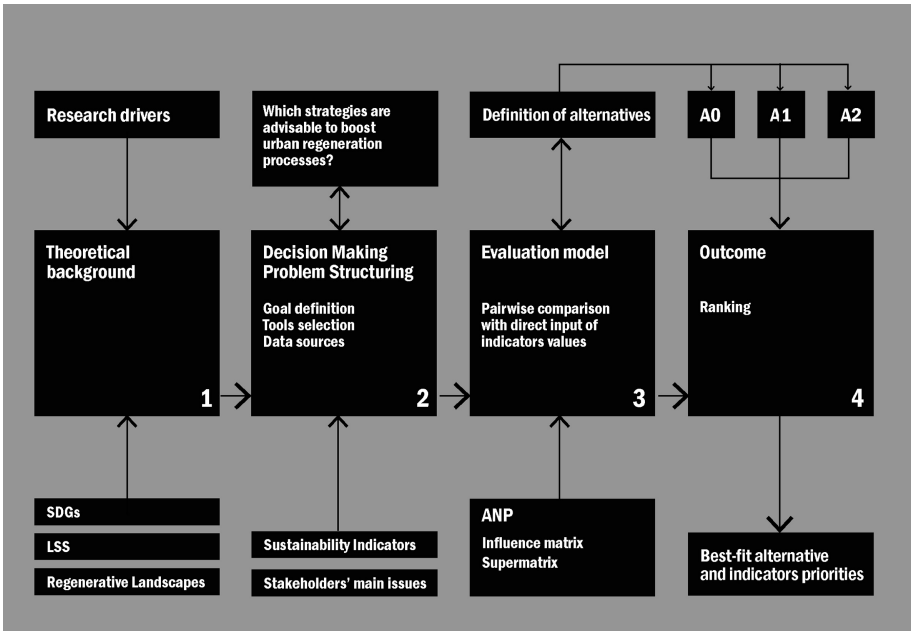

Fig. 1. The methodological workflow

3. Evaluation model. The problem structuring at the previous task leads to the choice of MCDA method and modelling of the decision-making process;
4. Outcome. The last step involves ranking the alternatives, acquiring the priorities and assessing the best-fit scenario.

The methodology has been elaborated and tested on the case study which will be presented and described in the next section (Sect. 3).

3 Case Study

The area of interest is located in the eastern part of the Gulf of Naples and falls within the VI District of the City, including the neighbourhood of San Giovanni a Teduccio. Figure 2 frames the focus area, which extends over the coast of the Tyrrhenian Sea between the residential district and the Port System Authority zone.

Nowadays it is constituted by numerous residential properties and abandoned industrial buildings. The inhabitants are 11,159 and population density is approximately 6,841.9/Kmq. The unemployment rate is 36.5%, while the young unemployment rate is 69.4%. The place is concerned with the changing pattern of land uses, taking into account the strong decrease in demand for industrial activities.

The administrative boundaries are regulated by policy systems both of the Metropolitan City of Naples and the Port System Authority of the Central Tyrrhenian Sea (AdSP), which are the main stakeholders in force.

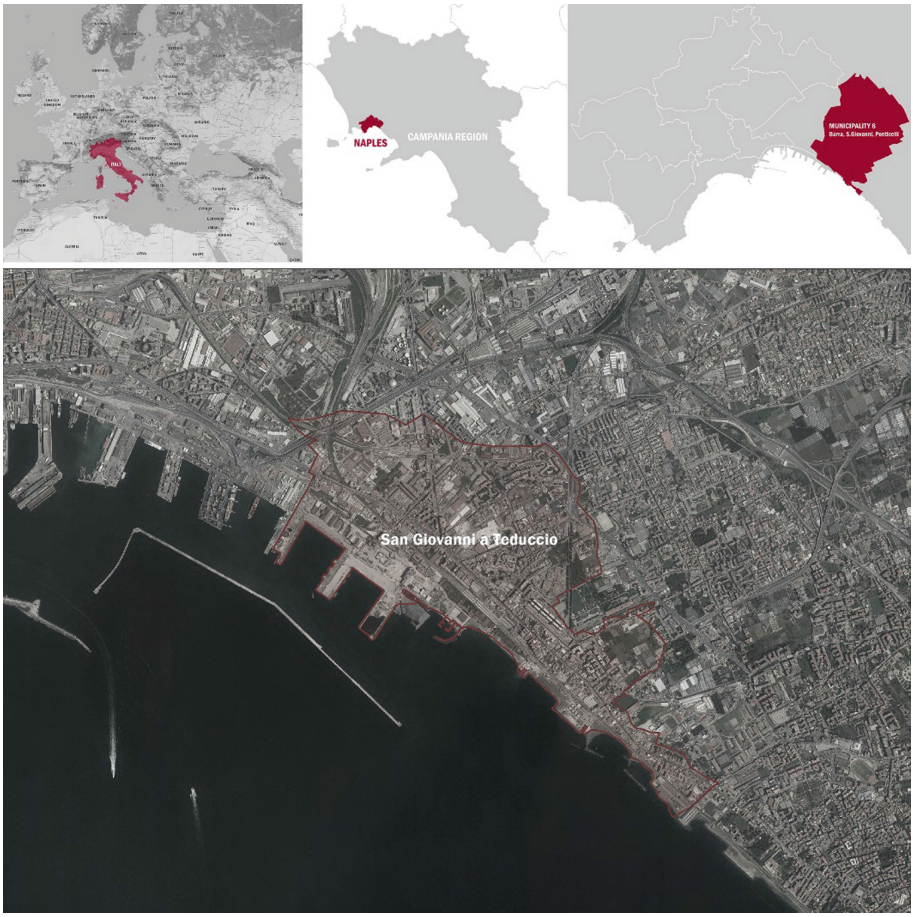

Fig. 2. The focus area in San Giovanni a Teduccio neighbourhood, within the VI District of Naples, Italy

The coastal area of San Giovanni a Teduccio is currently marked by a large number of abandoned industrial buildings and brownfields, strengthening the previous caesura between port and city.

The selection of focus area has been determined according to the coverage of information, data and issues highlighted by the working team of Master's Degree Course Level II in "Sustainable planning and design of port areas", coordinated by prof. Maria Cerreta, during their thesis elaboration for the academic year 2016–2017.

4 Decision-Making Problem Structuring with ANP

The general question underlying the structure of the decision-making problem is the following:

– Which alternative urban regeneration processes of the East Naples harbour is preferable to activate for the neighbourhood of "San Giovanni a Teduccio"?

Starting from the main issue, the decision-making problem has been structured according to ANP method and with the support of "Super Decisions" software v.3 [17]. ANP is a Multiple Criteria Decision Aid (MCDA) method that allows outclassing the rigidity of the Analytic Hierarchy Process (AHP), taking into account inner and outer dependencies among sets of criteria [18, 19].

By defining the sets or clusters - i.e. goal, criteria and alternatives - which contain subsets or nodes - i.e. the inner elements characterizing criteria - the global priorities of alternatives can be obtained with the pairwise comparison technique.

In the case study, five domains - corresponding to: Economic Growth and Development (EGD), Traffic Accessibility (TA), Urban Metabolism (UM), Society and Culture (SC), and Urban Landscape Quality (ULQ) - have been conceived as clusters of the network; while sixteen sustainability indicators, distributed into each five clusters, represent the nodes of network, as shown in Fig. 3.

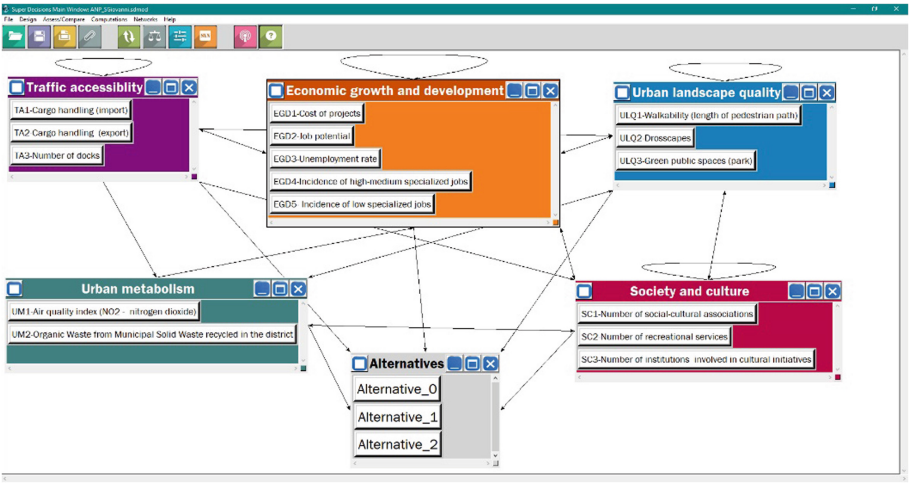

Fig. 3. The graphical network (screenshot from Super Decisions software v.3)

When the problem has been formulated and clusters and nodes defined, it has been possible to complete the influence matrix.

The influence matrix, represented in Fig. 4, shows the dependencies among the elements of the network recording them with a cross. Specifically, the cross inside the coloured clusters highlights the inner relationships among the nodes. In an example,

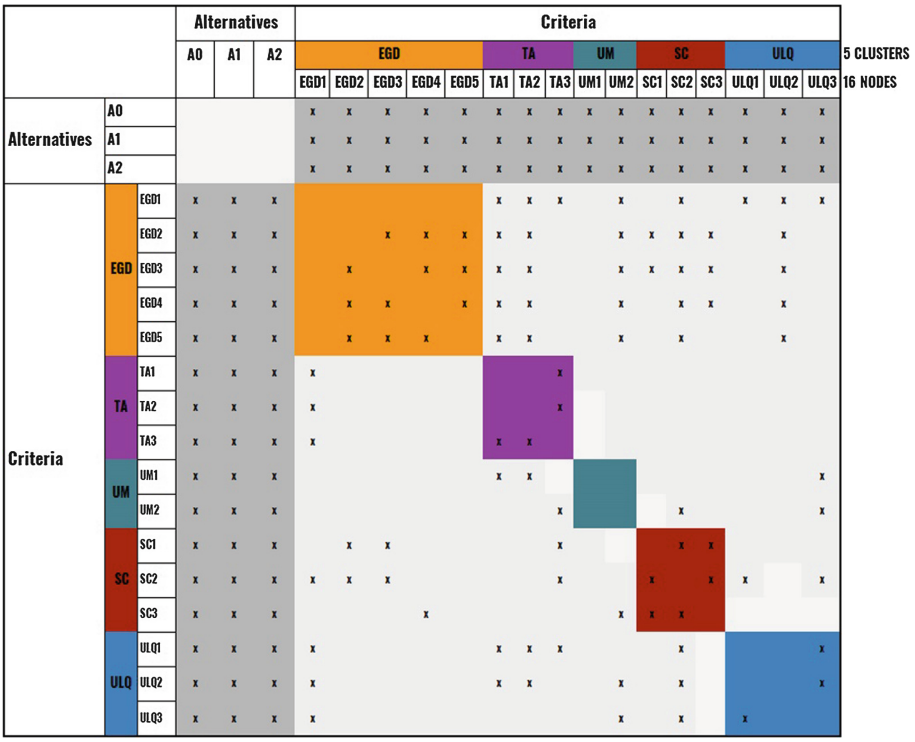

Fig. 4. The influence matrix

across signed at the intersection between EGD3 row and EGD2 column means that the increasing of EGD2 - job potential - could positively impact on EGD3 - the unemployment rate - and vice versa.

The choice of criteria (clusters) is directly determined by the alternatives, so it is possible to exclude the goal from the influence matrix [20]. Therefore, the five clusters that represent the thematic categories of indicators have been conceived taking into account the compared alternatives; then, the chosen criteria, based on the alternatives, will be comparison of with the SDGs target at the global level.

The current state of the area (A0) and two development scenarios (A1 and A2) have been assumed as the set of feasible alternatives for the urban and territorial regeneration of the focus area. Figure 5 shows the three alternatives of design for the harbour. A detailed description of the alternatives follows on.

The current layout of "San Giovanni a Teduccio" focus area, identified as A0 alternative and representing No-intervention alternative, has been conceived as the control scenario in order to analyze two scenarios of transformation.

Due to the changing pattern of land uses triggered by the strong decrease in demand for industrial activities, "San Giovanni a Teduccio" neighbourhood is currently marked by a large number of abandoned industrial buildings, brownfields and drosscapes.

Despite its location and connections guaranteed by two railway stations, the district has a peripheral character strengthened by inadequate accessibility to the coastal area and scarce presence of green urban areas. Nevertheless, along last years, new activities and functions have been implemented, improving the cultural supply and sense of place, as the first step towards urban regeneration processes.

A1 alternative provides for a tourist harbour with recreational, commercial, nautical and sport facilities, extending on 145,000 square meters. Five typologies of interventions have been defined in order to pursue the transformation of the area:

1. new layout for yachting facilities including 850 berths and one dockyard;
2. restoration of warehouses within industrial archaeology site and allocation of new functions related to commercial, manufacturing and nautical facilities;
3. construction of new "building as a bridge" to facilitate the pedestrian accessibility for the harbour;
4. design of new green areas and urban public spaces;
5. refurbishment of existing roads and implementation of the road network for vehicles accessibility to the harbour.

This alternative has been commissioned by Naples Municipality and is part of a larger process of the urban periphery regeneration.

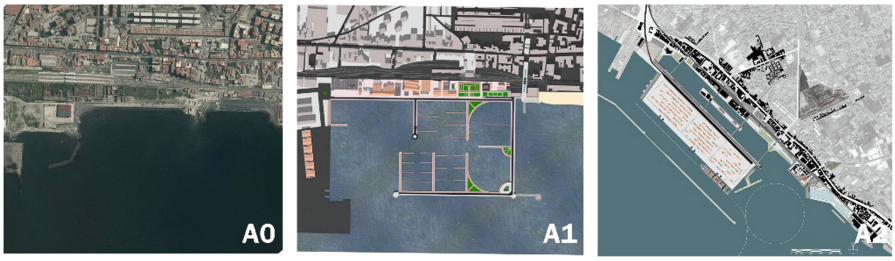

Fig. 5. The three alternatives: the current scenario (A0), the tourist harbour (A1) and the commercial terminal with urban waterfront regeneration (A2)

A2 alternative provides for multiple interventions related to three major thematic categories: the commercial port, the urban waterfront and the innovation dock.

Designing a channel among the existing coastline and terminal container is intended to redefine the urban waterfront configuration. The waterway is conceived as filtering area, connecting and dividing port from the city at once. Three categories of interventions have been defined in order to pursue "San Giovanni a Teduccio" regeneration:

1. new layout for maritime trade: extension of the terminal container, equipped with new rail freight infrastructure in addition to backing areas for the commercial function among which the distripark;
2. new layout for urban waterfront: waterway marked by commercial activities and urban loisir activities;
3. innovative manufacturing hubs placed in two urban landmarks with commercial and research functions.

The "Alternative 2" has been developed within the above mentioned Master's Degree Course by the students Silvia Sivo, Gennaro Salzano, Teresa Scandale, Stefania Regalbuto, Irina Di Ruocco, Vincenzo Lobasso, Salvatore Polverino.

The main stakeholders involved in the area management processes are: Municipality of Naples, Campania Region, Port System Authority of the Central Tyrrhenian Sea (AdSP), University of Naples Federico II, the power plant "Tirreno Power", and the construction company "Porto Fiorito".

4.1 Sustainability Indicators as Tools for Evaluating the Best-Fit Scenario

In the context of the above-mentioned evaluation methodology, a place-based set of indicators, which are useful for the focus area knowledge and the decision-making problem structuring, has been defined in Table 1.

Table 1. The sustainability indicators

Domain (Cluster)	Indicator (Node)	Indicator code	Data source	Relation to SDGs
Economic **G**rowth and **D**evelopment	Costs	EGD1	Authors elaboration	9
	Job potential	EGD2	ISTAT	9
	Unemployment rate	EGD3	ISTAT	9
	Incidence of high-medium specialized jobs	EGD4	ISTAT	9
	Incidence of low specialized jobs	EGD5	ISTAT	9
Traffic **A**ccessibility	Cargo handling (import)	TA1	AdSP	9
	Cargo handling (export)	TA2	AdSP	9
	Number of docks	TA3	AdSP	9
Urban **M**etabolism	Air Quality Index (AQI)	UM1	ISPRA	12
	Organic Municipal Solid Waste recycled in the district	UM2	Authors elaboration	12
Society and **C**ulture	Number of social-cultural associations	SC1	OpenStreetMap	11
	Number of recreational services	SC2	OpenStreetMap	11
	Number of high schools involved in cultural initiatives	SC3	Authors elaboration	11
Urban **L**andscape **Q**uality	Walkability (length of pedestrian path)	ULQ1	OpenStreetMap	11
	Drosscapes	ULQ2	Authors elaboration	11
	Green public spaces	ULQ3	OpenStreetMap	11

Properly identified on the basis of theoretical guidelines proposed by SDGs, the selected indicators have been gathered and categorized into five domains (clusters) which have been determined along with the local stakeholders within the thematic focus group held at the Master's Degree course:

1. **E**conomic **G**rowth and **D**evelopment;
2. **T**raffic **A**ccessibility;
3. **U**rban **M**etabolism;
4. **S**ociety and **C**ulture;
5. **U**rban **L**andscape **Q**uality.

The sixteen selected indicators, clustered into the above five thematic classes, have been assumed as pivotal in choosing the best-fit strategy for the sustainable regeneration of "San Giovanni a Teduccio" harbour.

Each class, indeed, has been correlated to one of three SDGs selected from the seventeen goals of 2030 Agenda.

The Sustainable Development Goal 9 underlying the strategic relevance of "industries, innovation and infrastructure" in increasing productivity, improving health and education, has been considered alongside "Economic Growth and Development" and "Traffic Accessibility" cluster. The "Urban Metabolism" domain is instead put in relation to SDG 12 dealing with "responsible consumption".

Aiming to minimizing economic, environmental and social costs and maximizing economic competitiveness at once, the goal calls upon to define development plans taking into account the entire supply chain. Lastly, the clusters concerned with "Society and Culture" and "Urban Landscape Quality" are put in relation to SDG 11 "sustainable cities and communities", leveraging on increasing public transport, creating green public spaces, with the purpose of making cities safer and more sustainable.

4.2 Indicators Sources

The indicators have been built starting from databases of national and international relevance and from the scientific literature.

In particular, LEED and ITACA, which are two databases from which six indicators have been derived, are systems structured to assess sustainability.

LEED (Leadership in Energy and Environmental Design) is a certification of sustainability that was developed by U.S. Green Building Council, first just for buildings and later for cities and communities, including differentiated formulations for any kind of building and for urban areas, to provide a worldwide consistent way to measure and communicate performance [21].

ITACA protocol (UNI/PdR 13:2015) is an Italian evaluation tool that derives from the international evaluation model, raised to face the need of Regions to provide professional, public and private bodies with a certified tool for the sustainability assessment of buildings and urban areas. "ITACA Protocollo a Scala Urbana" was developed internationally by iiSBE (International Initiative for a Sustainable Built Environment) [22].

In this study, indicators EGD3, UM1 and UM2 have been carried out from LEED recommendation; while EGD2, ULQ1 and ULQ3 indicators have been derived from ITACA protocol.

The selection of sustainability indicators has been carried out starting from the identification of some macro-issues that characterize the area of interest, and then assumed as thematic categories/domains.

4.3 Outcomes

In this study, the ANP multi-criteria method has been chosen since it is capable to grasp and assess the relationships among different phenomena affecting the decision-making process' stages. ANP has been employed for decision-making problem structuring and definition of best-fit scenario addressed to the harbour development for the regeneration of "San Giovanni a Teduccio" neighbourhood.

ANP is, indeed, one of the alternative-based methods which are able to take into account inner and outer dependencies among multiple criteria, therefore the interrelations between the economic, social, environmental and cultural dimensions. The sustainable development alternatives for the focus area have been analyzed using the proposed Sustainability Indicators set.

As shown in Table 2, quantitative values have been processed in relation to 12 of 16 indicators, and subsequently placed as direct input into Super Decisions software in order to perform the pairwise comparison; the judgments for other four indicators - EGD3, EGD4, EGD5 and SC3 - have been inferred qualitatively instead.

The Inconsistency Ratio (IR), which refers to the stability of judgement attribution, has been processed and reported for each indicator in Table 2. All the judgments of pairwise comparison are consistent since the IR is always minor than 0.1 [23].

The limit super-matrix in Fig. 6 provides the priorities vector of each element of the decision network.

It is possible to observe that the most relevant issues are expressed by the values of the indicators within the cluster "Society and Culture". Specifically, the highest priority has been attributed to indicator "SC2" – referring to the number of recreational services – with 0.1 as eigenvector value. Also "SC1" – referring to the number of social-cultural associations in the same cluster – reaches 0.07 value.

High values have been obtained also for "Economic Growth and Development" cluster, where the most relevant issues concern with indicator "EGD2" – referring to the job potential and reaching 0.07 value – and "EGD3" – related to the unemployment rate – with the same value.

Conversely, the indicators within the cluster "Traffic Accessibility" and "Urban Metabolism" have low values, varying into the range 0–0.03.

From the observation of the values graph, the results show that the best-fit scenario for the focus area is A2 with 66.9% of priority, normalized by the cluster "alternatives". Meanwhile, A0 and A1 reach almost the same value, that is approximately the 16%; it means pursuing A1, or remaining at the current state (A0), is not suitable in terms of multi-dimensional sustainability.

Table 2. Indicators values and Inconsistency Ratio (IR) of the judgements

Indicator	A0	A1	A2	Measure unit	IR
EGD1	0	77,627,660	653,000,000	€	0
EGD2	14.6	15.1	21,1	%	0
EGD3	13.2	A1 is strongly more preferable than A0	A1 is very strongly more preferable than A0	%	0.062
EGD4	19.9	A1 is moderately more important than A0	A2 is strongly more preferable than A1	%	0.037
EGD5	24.9	A1 is equally as preferable as A0	A2 is very strongly more preferable than A0	%	0.01
TA1	536,917	536,917	1,200,000	TEU	0
TA2	499,631	499,631	1,116,666	TEU	0
TA3	200	828	500	n.	0
UM1	40.9	40.9	150.3	mg/Nm3	0
UM2	0	0	390	ton/year	0
SC1	8	8	10	n.	0
SC2	10	10	18	n.	0
SC3	8	A1 is equally as preferable as A0	A2 is moderately as preferable as A0	n.	0
ULQ1	2.23	1.32	5.29	km	0
ULQ2	62.03	27.05	1.91	he	0
ULQ3	3.66	4.36	9.70	he	0

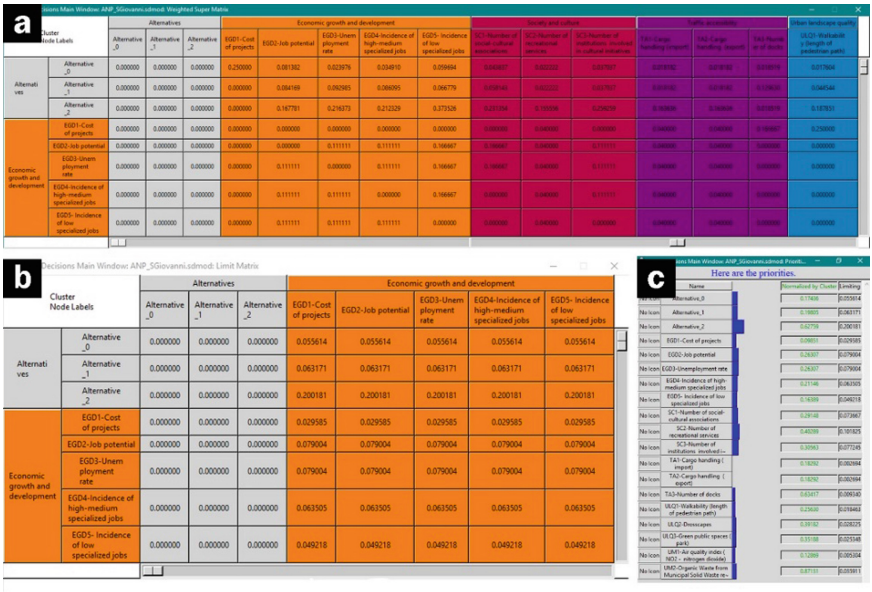

Fig. 6. Screenshot from super decisions software v.3 showing the weighted super-matrix (a), the limit super-matrix (b), and the priorities (c)

5 Discussion and Conclusion

In order to aid Decision Makers in choosing the best-fit sustainable development strategies for a complex urban context, the SDGs, as programmatic guidelines for balancing economic, social and environmental dimension of development, can be assumed.

According to place-based and use-inspired features of LSS, the cross-scale regenerative development provided the theoretical framework by which the proposed methodology has been developed [24–26]. With the purpose of operationalizing the SDGs targets, a Problem Structuring Method (PSM) [27], requiring a selection of indicators and Multi-Criteria Decision Aids (MCDA), has been proposed.

Moreover, assuming port-cities as complex systems, ANP method has been chosen since it allows to grasp the existing relationship among criteria, which have been arranged as proxies for sustainability domains [28].

The decision-making problem structuring in complex urban context requires a selection of indicators and Multi-Criteria Decision Aiding (MCDA) methods which are suitable for supporting the Decision Maker in choosing the preferable alternative among a feasible set [29].

Sustainability indicators set as part of a knowledge-based system has been set up, in order to improve the logical processes through which Decision Makers take choices regarding the urban transformation [30].

In this research, the organizational structure of data allowed the management of significant quantities of information with different features; meanwhile, the selection of suitable indicators has been a crucial point in the elaboration of the decision-making process, since that make rational and objective "ex-ante" evaluation, along with an alternative-based process [31].

The main drawbacks related to the ANP method are concerned with: more complex problem modelling; time-consuming questionnaire and surveys, when stakeholders are involved into decisional problem solving; the need of high computational power; and results which could be difficult to understand and communicate.

The advantages in using this multi-criteria method refer to: opportunity of considering interdependencies among criteria; capacity of expressing the complexity of urban systems and implementation of the dynamic evaluation process; ability to activate multidimensional interactions among quantitative and qualitative characteristics of urban transformations.

Although the direct input of data, allowed by the software, make rational and more objective the judgment attribution in the pairwise comparison phase, some limitations can be identified in this study. Firstly, particular care must be taken in processing indicators values since the errors at this stage affect the final results of the analysis. Secondly, the stakeholders engagement for preferences attribution at cluster level should be performed in order to weight the five domains highlighting trade-off and conflicts. Finally, using different MCDA methods, also considering the use of outranking methods to obtain priorities, is advisable to test the consistency of results.

This study is intended as a first step to stress the evaluation methodology in decisional arenas with local stakeholders, by implementing it with the integration of multi-group assessments and spatially explicit multi-criteria approach.

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