Renewalling Public Real Estate Asset in Sustainable Perspective: Guidelines from International Best Practices

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Abstract. Contemporary models of urban transformation emphasize regeneration as a strategic response to mitigate and reverse the negative impacts of urbanization. The acknowledgment of evaluation methodologies and frameworks for sustainable development in a global setting highlights the necessity to analyze the urban sustainability until the building-scale of analysis. Although sustain-ability is more measurable at broader dimensions, it is challenging to apply the same evaluation methodology to more constrained geographical areas with more detail. This complex framework makes measurement particularly difficult for those interested in studying urban sustainability from different perspectives. This paper aims to identify key indicators used to assess the sustainability at various urban scales, focusing on key categories such as economic-financial, environmental and socio-cultural analyses. Using a dual approach, a bottom-up perspective - which derives indicators from a real tangible case (the redevelopment of a public housing neighborhood in Le Lignon)- is integrated by a top-down one, which identifies commonly used indicators in key sustainability categories through a review of the literature. A comparative analysis of the results obtained from both approaches allows a set of key sustainability indicators to be formulated.

Keywords: sustainable development · system indicators · urban regeneration · assessment methodology

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1 Introduction

Conurbations play a central role in sustainable development, with their increasing urbanization leading to environmental, social and economic consequences. In particular, cities significantly affect the global environment through CO2 emissions, resource consumption, and other issues including pollution, waste production, and urban heat islands [1]. Rapid sprawl also intensifies economic and social inequalities, leading to limited access to resources for low-income residents and increased social exclusion. Cities may be catalysts for constructive development, despite the difficulties presented by the fast urbanization of the world [2].

In order to mitigate and reverse the detrimental effects of urbanization on the ecosystem, regeneration is emphasized in modern models of urban transformation. As a result, it plays a crucial part in modelling sustainable development strategies [3].

These issues are widely included in international policies and agendas [4–7], highlighting the critical importance of the sustainability analysis within regeneration strategies.

The complex nature of urban sustainability requires an assessment holistic approach, by taking into account the interconnectedness of the economic, social and environmental dimensions of urban development [8]. In this context, indicator-based assessment systems are widely used by scientific communities, governments and policy makers [9]. Indeed, indicators are increasingly recognized as indispensable tools for measuring the effectiveness of sustainable development policies, initiatives and actions due to their ability to articulate and simplify complex aspects of sustainability [10–12].

The wide variety of available indicators, quantitative or qualitative, addressing a range of issues at different spatial scales, presents a challenge in identifying those best suited to capture the complexity of the specific context, scale of analysis and objectives of urban sustainability assessment [13, 14].

Therefore, defining each urban regeneration intervention involves a complex decision-making process that must take into account a wide range of factors at various scales with interrelationships between the components, stakeholders, and procedures to be taken into consideration in a diachronic dimension of time that is iterative and interactive [15]. In order to achieve this, the identification of potential solutions depends on the application of evaluation frameworks that integrate participatory techniques, multi-criteria decision-making analyses, and strategic planning tools. The objectives, which serve as the foundation for evaluating alternative intervention scenarios, must also be defined and communicated to stakeholders in relation to indicators that have been carefully chosen to take into account the effects that, e.g., adopting Nature-Based Solutions (NBS) can have on the ecosystem [16]. Composite Indicators (CI) are often required to measure the level of urban environmental and economic sustain-ability in order to express both qualitatively and quantitatively the socio-economic and environmental impact (trade-off) that the single initiative generates in the settlement context taken into consideration in the transition between the ex-ante and ex-post phases of the urban transformation process [17].

One of the challenges associated with the appropriate selection of indicators to be used to evaluate urban development and regeneration policies is the interconnectedness of issues related to sustainability [18]. In fact, many sustainability issues related

to environmental, social, and economic aspects are interrelated and affect each other, which makes it difficult to isolate and measure individual indicators by complicating the selection of appropriate indicators and the context in which they are applied [19].

A key issue that can influence the selection of indicators for sustainability assessments of urban regeneration interventions is related to the scale of analysis [20]. There are tools and indicator frameworks at different geographic scales, operating at the building, neighborhood, city, region, up to the national and supranational scale, each providing results specific to the scale considered [21, 22]. The effectiveness of indicators is closely related to the context in which they are used. For example, at the level of individual buildings, the assessment focuses mainly on aspects related to individual structures [23]. Extending the analysis to the neighborhood level, a number of interrelated issues emerge regarding the organization of different elements, such as neighborhoods, commercial areas and green spaces [24, 25]. At the city or metropolitan level, indicators tend to address general issues that affect the entire urban area, taking into account, for example, city infrastructure, regional economic trends, and environmental issues that are broader than individual neighborhoods [12]. National or international urban sustainability indicators, on the other hand, take a broader perspective, addressing general issues and trends that extend beyond individual cities [2].

The data availability is another important challenge in defining urban sustainability indicators. In fact, assessment is highly dependent on the quantity and quality of available data, with availability varying at different spatial scales. For example, data tend to be more complete at larger spatial scales, while it is more difficult to collect data at smaller scales [26]. This problem can hinder the comprehensive assessment of sustainability at different spatial scales. The data availability may also vary between different urban areas, with some having well-documented information and others lacking detailed datasets. Such spatial disparities can lead to biased assessments, favoring areas with more available data and excluding many countries from assessment and comparison [6].

In addition, there may be biases due to temporal limitations: some datasets may have limitations in terms of temporal coverage, i.e. they only include data for a specific period or a few years, hindering the ability to analyze long-term trends and understand the sustainable performance of urban areas over longer periods [27].

While there is a greater degree of measurability of sustainability at larger scales, the resulting measures may provide too general insights that fail to capture the complexities of more localized scales [26]. Replicating the same approach used in large-scale sustainability assessments becomes complicated when applied to geographically limited scales, which are characterized by unique issues and needs that require addressing [27]. The great number of existing indicators, frequently applied across various scales, coupled with the challenges related to their adaptability according to the specific purpose of the assessment, make a complex framework that causes difficulty for those subjects interested in studying urban sustainability [18].

Consequently, the guiding research questions are:

Q1: What are the main indicators used for assessing the sustainability level at different urban scales?

Q2: Was the sustainability assessment carried out through the adoption of upscaling methods?

To address the research questions, this paper aims to provide a comprehensive overview of key sustainability indicators applied at different urban scales, with reference to the main categories of economic-financial, environmental and socio-cultural analysis. To this end, a dual approach is adopted, integrating *bottom-up* and *top-down* strategies.

The rehabilitation of a social housing community in Le Lignon (Vernier, Switzerland) serves as the basis for putting the bottom-up method into practice. An expert group consisting of planners, estimators, architects, and modern architecture historians chose this community as a model for best practices in residential development neighbourhoods constructed between the 1970s and the 1990s. This approach makes it possible to derive indicators from a real case that reveal the sustainability of the intervention by assessing the variations between the *ex-ante* and *ex-post* intervention status.

Conversely, the *top-down* strategy begins with a literature review to identify commonly used indicators in the main categories of sustainability. The most widely used important performance indicators for sustainable accounting are chosen by examining the current contributions to the literature on sustainability in relation to metrics related to sustainability aspects that may be applied to the design visions.

The simultaneous use of both methodologies – top-down and bottom-up – is meant to capture the characteristics of the given situation and permit a comparison study with frequently used indicators in existing literature.

Following it provided showing to the work-flow based on the aforementioned methodologies used along the route of case-specific formulation of sustainable indicators.

2 Materials and Method

2.1 Two-Way Researching Method: Bottom-Up & Top-Down

A methodology including the systematic and parallel application of two way researching method: bottom-up & top-down is presented in order to pursue the work's purpose. Generally these approaches differ in their analytical orientation.

i). The bottom-up analysis focuses on particular elements or situations to get a full grasp of a topic. The bottom-up approach examines the fundamental and qualitative parameters/factors of the study issue from a "micro" perspective to identify those that give a better description of the phenomenon, particularly from a future perspective. It permits the progressive identification and rearrangement of a system's components, allowing knowledge of each part's function as well as the right manner to utilize and integrate it into the larger system. In the present study, it is used to examine pilot cases that are thought to be representative of a wider global environment, as was expected by the argumentations in the next Subsect. 2.2.

ii). The top-down approach starts from a broad perspective of the object of analysis and gradually delves into specific details and aspects [28, 29] After defining an overall picture of the problem under inquiry and identifying its components from a "macro" viewpoint using the top-down method, an attempt is carried out to manage and comprehend how the many pieces are related to the whole.

In the present research the combined use of *i*) and *ii*) allows for the use of the indications generated by the two approaches in a non-unidirectional manner; however, by comparing and combining them, significant common components can be identified and integrated on the basis of the discovered functionalities, as well as possible innovative paths of experimentation. Using both *bottom-up* and *top-down* to define the overall reference set for selecting indicators to be used in specific urban sustainability assessments provides a more comprehensive and balanced assessment-view [30].

The synoptic framework underlying the proposed integrated analytic technique is shown in Fig. 1.

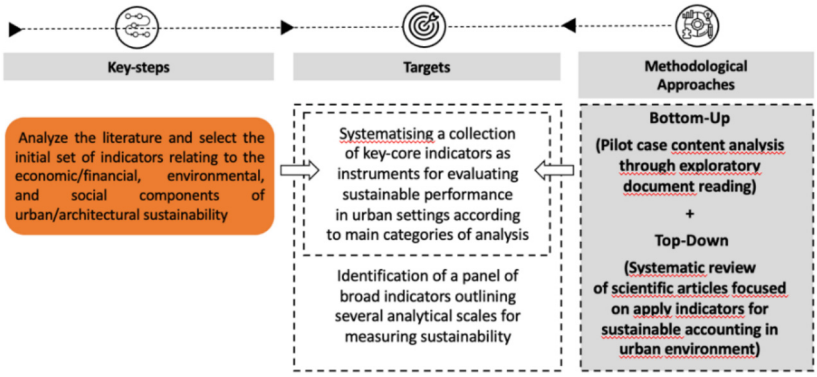

Fig. 1. Key-steps, Target and Methodological approach

The two approaches *i*) and *ii*) have been concurrently utilized in this study to establish a panel of general indicators that may be used at various analytical scales to assess the sustainability [31]. The articulation of the individual steps of two methodologies have been illustrated and shown in Fig. 2 at the conclusion of Subsect. 2.3.

2.2 *Le Lignon* Pilot Case

The modernist housing complex Le Lignon, located in the city of Vernier in the canton of Geneva, Switzerland, and designed by Georges Addor, Dominique Julliard, Louis Payot, and Jacques Bolliger, is used as a pilot case to demonstrate good practice redevelopment. Built between 1964 and 1971, with a reinforced concrete structure built using the "tunnel form" technology and 125,000 square metres of curtain wall panelling in wood, aluminium, and glass, this complex is one of the most monumental neighbourhoods in the world and the first in Switzerland. With 2,700 flats (used for a heterogeneous mix of housing forms, from subsidised rent to condominium ownership), plenty of green spaces, and public and private services, it was originally designed to quickly address the housing needs of about 10,000 people. It covers an area of 70 acres (28 ha), reflecting the architectural directions and logic of industrialised social housing typical of 1960s architecture. Its impressive architecture, which consists of two towers with 26 and 30 stories each, as well as a linear building with a Y-shaped design that extends 1,065 m,

ensures double orientation, maximum sunlight for each apartment, and the integration of green spaces and a variety of community amenities (like shops, schools, a medical centre, and a rooftop swimming pool).

A Conservation Plan de site, an urban-scale protection measure intended to preserve the architectural unity of the buildings, the planning design, and the landscape quality of exterior spaces, was adopted by the Canton of Geneva in 2009, formally establishing the complex's value as a cultural asset. Between 2008 and 2011, the Canton of Geneva faced issues related to energy consumption. To address these issues, an Applied Research Project led by Professor Franz Graf and Giulia Marino of the Laboratoire des Techniques et de la Sauvegarde de l'Architecture Moderne (TSAM) at the Ecole Polytechnique Fédérale de Lausanne, along with a working group comprised of representatives of building owners, identified and developed appropriate solutions that collectively and holistically address the goals of respecting original material identity (Heritage), reducing energy consumption (Energy), considering the investment potential of the individual owners of the properties (Economy). The multi-criteria approach used in project research has sparked significant interest in Europe and North America, as described in several scholarly publications [32, 33], as well as it has received several awards and recognitions, among which: "European Heritage Awards/Europa Nostra Awards" (2013) [34] and good practice of the CoE21 Strategy' from the European Cultural Heritage Strategy for the 21st Century, Council of Europe" (2018) [35].

The library of model solutions compatible with the adopted guiding criteria, which was created by the study, validated by the participating public administrations, and added to the Plan de Site, has developed into an operational and flexible guiding and control tool that combines comprehensive implementation prescriptions and the thermal performance of the component parts to be used for the various levels of intervention that will be implemented gradually in accordance with the needs, preferences, and financial means of the occupants. This is a true instruction manual for the preventive maintenance and upkeep of buildings and common spaces, on which are based the intervention solutions to be implemented in the complex's many restoration shops, which are currently undergoing a multi-phase makeover. Despite covering 28 hectares, only 8 percent of the district's total area is built up. This arrangement facilitates the development of large green spaces, preserving the forest heritage along the Rhone and the Nant des Grebattes. The result is a rich biodiversity that has a lasting and visible impact on the social life of the neighborhood. In recognition of its importance, Le Lignon was also included in the Federal Inventory of Swiss Settlements to be Protected in 2021, under the auspices of the Swiss Conference and the Federal Law on Nature and Landscape Protection.

According to what has been pointed out, the redevelopment of the Le Lignon social housing neighborhood was chosen as a best practice example by a panel of experts and used as a pilot case to develop the bottom up approach for identifying and measuring sustainability on a micro scale.

2.3 Implementing the Two-Way Research Methods

As stated, the analytical procedure for analysing source databases, extracting and interpreting data from them, and creating a panel of indicators for gauging urban sustainability is divided into two parallel processes: i) top-down and ii) bottom-up.

The steps taken to construct the bottom-up method were as follows:

- starting with a careful examination of the document specific to the pilot case, which contains comprehensive details about the pre- and post-redevelopment circumstances. Making use of this paper facilitates comprehension of both the location's distinctive features and the overall redevelopment activities. It makes it easier to identify the key variables that are necessary to define a set of sustainability indicators that span several dimensions. Therefore, it is feasible to explore the various facets of sustainability, including the technical, typological, social, and environmental facets that are documented in the analysis document; the variables are specified by their kind (categorical/ordinal, numeric/continuous), unit of measurement, and usable source for computation. Each variable is also assigned to the appropriate sustainability category (economic, financial, environmental, social, or cultural).

With the top-down approach a systematic review of national and international literature is proposed to identify the key indicators used to assess sustainability in urban environments, in order to compare them with those identified in the bottom-up process. The systematic literature review requires the delineation of the key issues to be studied in relation to urban sustainability [36–38]. This involves carefully defining the research questions in line with the objectives of the study.

In particular, the following was done:

- identifying the databases to be used in the literature search and, therefore, the selection of keywords that can identify research articles aligned with the objectives of the study, such as "urban sustainability assessment", "urban sustainability indicators" and "sustainability indicators". The establishment of exclusion criteria that are applied to the acquired articles ensures that only those directly relevant to the objectives of the study are retained. This selection process results in a set of scientific studies relevant to the work. Articles without a complete set of indicators and those that are not relevant to the top-down urban scaling approach are excluded;
- selecting articles gather a range of information data. Specifically, since the indicators are the main object of analysis, the proposed methodology involves collecting the following data: the year of publication of the article, the title of the article, the main objective, the categories of sustainability considered and variables/indicators used, and, for each indicator, the type of methodology (e.g., quantitative or qualitative), the mode of measurement, the unit of measurement, the spatial scale, and the sustainability services/disadvantages associated with each indicator.

Figure 2 illustrates the many phases and outputs of the top-down and bottom-up approaches used to provide answers to the evaluation questions posed in the introduction. The results obtained from the comparison and union of the outputs obtained from the combined use of the two methods are described in Sect. 3.

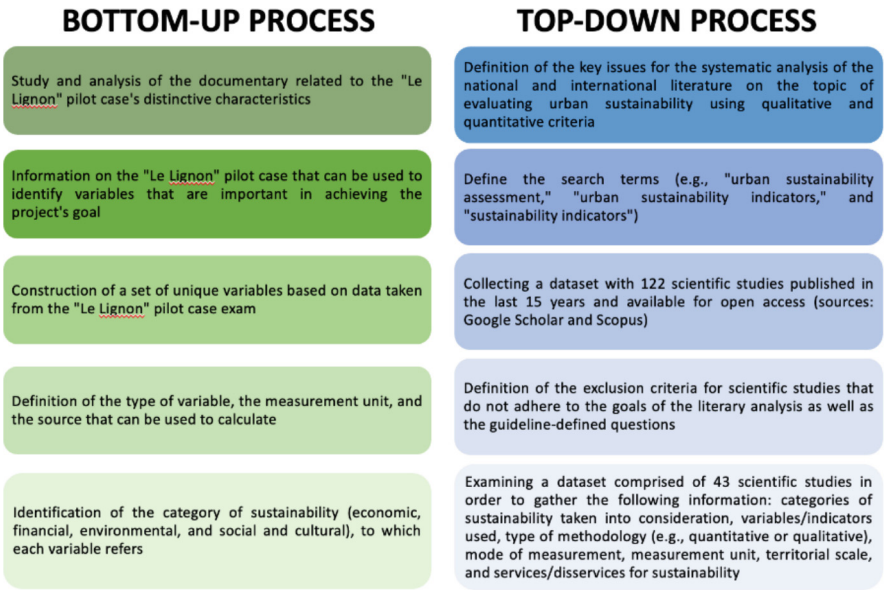

Fig. 2. Steps in both top-down and bottom-up processes

3 Results

The integration of the results obtained from the application of the two approaches mentioned above facilitated the formulation of a set of essential sustainability indicators. In fact, the *bottom-up* approach applied to the *Le Lignon* pilot case allows the identification of initial indicators that allow to capture the specificities that should be taken into account while redeveloping social housing areas constructed between the 1970s and the 1990s. The *top-down* approach, on the other hand, allows to identify, from the literature analysis, sustainability indicators of a more general nature. An initial comparison of the results obtained from the application of the two approaches allows them to be validated and allows the systematic organization of a collection of key indicators as tools for assessing the sustainable performance of urban areas at different scales and according to the main categories of analysis: environmental resilience, socio-cultural adequacy and economic and financial sustainability.

An extract of the total number of indicators identified is shown in the Fig. 3. For each of them, the unit of measurement is indicated, as well as the type of variable, specifying whether it is numeric/continuous, categorical/nominal, or whether it is a variable to be calculated. In addition, the sources of the indicators are made explicit, specifying whether they are official sources (e.g. statistical institute, territorial real estate market agency, etc.) or from a survey.

The environmental resilience category within the framework outlined includes key indicators for assessing the impact of urban development on the environment. Specifically, these indicators provide an assessment of the overall environmental quality of

N.	Variables	Is it indispensable data to acquire?	Unit of measure	Type of variable	SUSTAINABILITY CATEGORY: Enviromental	Economic-financial	Socio-cultural	Source	Source in Italy	Possible combination of variables
1	Number of dwellings for non self-sufficient people	x	n.	Numeric/continuos			x	from relief		Housig typology by users type
2	Cost of construction	x	€	Numeric/continuos				from relief		
3	Cost of renovation project	x	€	Numeric/continuos				from relief		
4	Minimum temperature (Year based)	x	°C	Numeric/continuos	x			from climatic analysis		
5	Maximum temperature (Year based)	x	°C	Numeric/continuos	x			from climatic analysis		
6	number of parking lot	x	n.	Numeric/continuos		x	x	from relief		in relation with 13
7	number of garage		n.	Numeric/continuos		x	x	from relief		in relation with 13
8	Building typology		type	Categorical/nominal		x	x			
9	number of commercial space typology	x	n.	Numeric/continuos		x		from relief		in relation with 13
10	Employment status of residents		n	Numeric/continuos		x	x	Statistics Institute	ISTAT	in relation with 13
11	is the project a masterpiece?	x	Yes or no	Categorical/ordinal		x	x			
12	Does the Upcycling involves the residents?	x	Yes or no	Categorical/ordinal		x	x			
13	Are the architects specialist in Upcycling?		Yes or no	Categorical/ordinal		x	x			
14	is the project fittable for The UpCycling?	x	Yes or no	Categorical/ordinal		x	x			
15	is the type of construction usual in the area?	x	Yes or no	Categorical/ordinal	x	x	x			
16	Are the clients Private or Public?	x	Yes or no	Categorical/ordinal		x				
17	Gross internal floor area	x	m^2	Numeric/continuos	x			from relief		
18	extension of the green area	x	m^2	Numeric/continuos	x			from relief		10/9
19	extension of the built area	x	m^2	Numeric/continuos	x			from relief		10/9
20	Density of the building/the area	x	ab/ha	to be calculated	x					13/11
21	Number of inhabitants		n.	Numeric/continuos	x	x	x	from relief		13 - 16 age pyramid
22	number of family members		m^2	Numeric/continuos			x	from relief		
23	sqm for inhabitant	x	m^2	to be calculated	x	x	x			
24	Age of inhabitant	x	n.	Numeric/continuos		x	x	Statistics Institute		
25	number of houses		n.	Numeric/continuos		x	x	from relief		in relation with 13
26	number of commercial space		n.	Numeric/continuos		x	x	from relief		in relation with 13
27	Construction technologies for natural risk minimazing	x	n.	Numeric/continuos	x	x		from relief		
28	Sources of renewable energy system	x	n.	Numeric/continuos	x	x		from relief		
29	minum sqm for residential	x	m^2	Numeric/continuos		x		from relief		in relation with 13
30	Systems of water recycle	x	n.	Numeric/continuos	x	x		from relief		
31	number of residential typology		n.	Numeric/continuos		x		from relief		in relation with 13
32	average sqm for residential		m^2	to be calculated		x				
33	maximum sqm for residential		m^2	Numeric/continuos		x		from relief		in relation with 13
34	average sqm for commercial		m^2	to be calculated		x				
35	minum sqm for commercial		m^2	Numeric/continuos		x		from relief		in relation with 13
36	maximum sqm for commercial		m^2	Numeric/continuos		x		from relief		in relation with 13
37	Average temperature (Year based)		°C	Numeric/continuos	x			from climatic analysis		
38	relative humidity	x	%	Numeric/continuos	x			from climatic analysis		
39	wind condition	x	m2/s	Numeric/continuos	x			from climatic analysis		
40	Rain precipitation (average)		mm	Numeric/continuos	x			from climatic analysis		
41	Minimum Rain precipitation		mm	Numeric/continuos	x			from climatic analysis		
42	Maximum Rain precipitation		mm	Numeric/continuos	x			from climatic analysis		
43	local radiation average value			Numeric/continuos	x			from climatic analysis		
44	exposure of the apartments	x		dummy variable	x			from relief		

Fig. 3. Extract of the total number of indicators identified (N/C: Numeric/continuous, C/O: Categorical/ordinal)

urban areas in terms of sustainability of resource use and ecosystem health. For example, temperature-related indicators have been included that provide insight into the state of the atmospheric environment. Land use indicators are also included in this category, that provide information on the spatial distribution of built and green areas in relation to the total area under analysis, facilitating the assessment of the environmental impact of different land uses. The environmental resilience category also includes indicators related to building technologies, which provide information on the impact that the built environment can have on the surrounding environment.

The socio-cultural suitability category involves a set of indicators designed to assess various dimensions of urban life related to social and cultural dynamics. These indicators shed light on social dynamics, cultural diversity, and the general well-being of individuals in the urban context. Within this category, indicators are represented by a number of critical aspects such as the quality and accessibility of educational institutions, the availability of health services, and safety conditions as measured by crime rates. In addition, measures such as the amount of green space in the city and the distance to public transportation and public services provide insight into the accessibility and impact of these spaces on the well-being and connectedness of urban residents. Indicators focused on the regeneration project are also involved in the category of the socio-cultural suitability, which provide information on residents' perceptions of the project.

The economic and financial sustainability category provides a comprehensive assessment of the district's resource management and overall economic vitality. This category includes employment considerations, with indicators analyzing unemployment rates, employment opportunities, and local job creation. Indicators of residential market and rental values are also in this category, as well as average costs associated with water supply and heating and cooling services. In relation to the regeneration project, this category involves indicators that measure the investment costs of interventions, while also providing information related to building maintenance, including the cost and frequency of such maintenance.

4 Conclusions

The growing importance of urban sustainability requires a careful assessment of urban regeneration initiatives in the broader context of sustainable development. Despite the availability of numerous indicator-based tools and frameworks designed to assess these interventions, the challenge lies in adapting these indicators to different scales of analysis in a context characterized by abundance and generality. To address this complexity, this research has proposed a methodology to bridge the measurability gap at different scales.

Beginning with an in-depth examination of the redevelopment intervention of the district of the *Le Lignon* as a best practice pilot study, the methodology adopts a dual approach. First, a *bottom-up* strategy is used to identify an initial set of elementary variables that involve the unique features of the case in analysis. Simultaneously, a *top-down* approach is used to identify key sustainability indicators derived from existing literature.

A comparative analysis of the results derived from these two approaches has generated a set of indicators, that provide a framework for measuring the urban sustainability of interventions, offering a perspective specifically adapted to the case under consideration. Regarding the analyzed case study, as the initiatives are carried out in a public housing complex, the characteristics and the needs are specific, affecting both the scale of the building and the broader urban context that must address the immediate requirements of the neighborhood.

It is crucial to point out that the proposed methodology, although it has been developed starting from the characteristics of the specific case study, is replicable for different urban regeneration interventions and located in other territorial contexts, due to its ability to systematically capture the specificities that distinguish urban regeneration initiatives in different market locations.

An initial comparison of the results obtained from the simultaneous application of the two approaches makes it possible to mutually validate the information first obtained from the in-depth study of the specific case with the more general information obtained from the literature review. In order to prove the general validity of the information that emerged from this comparison, future research activities will include a validation phase. This will involve administering questionnaires to professionals, including technicians and operators in the construction and real estate sectors, as well as environmental and social experts. This step aims to strengthen the reliability and applicability of the results.

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