

Achieving sustainability through a cyclical process of evaluation and adjustment: a support system for urban design

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Abstract This paper investigates the possibility of making visible what is usually invisible in the urban design conceptualization phase. An evaluation system, constituting a basic guide for the assessment of sustainability for urban design projects, acting both on the existing and the new fabric, is presented here. The proposed system translates the complex social and physical systems into measurable units of information, thus making them visible to decision makers.

In particular, this work explores the concept of evaluation as a support tool for urban design; for instance, the results of the application of some indicator methods can be useful for representing themes that are crucial for assessing the sustainability of urban design projects. The study starts with the construction of a system of urban sustainability indicators by exploring the concept of assessment as a tool to support the communication of sustainability of urban design.

Currently, numerous environmental certification and evaluation systems at the urban or district scale are available. These tools, starting from a set of criteria and indicators inspired by the model of a compact and efficient city, aim at guiding the urban design process. These indicator systems try to respond to challenges emerging from the complexity of the city. The focused use of sustainability indicators at the scale of neighborhood design (master-planning) allows the conceptualization of the design process in an action space of n dimensions, where n is the number of indicators chosen for this purpose. The indicators are selected according to the objectives, which can be identified by policy needs, by stakeholders or by the people to ensure the improvement of the quality of life.

Urban transformations are played within complex environmental dynamics, so it is impossible to define a priori the space of action. Hence, it becomes necessary to consider the design as a process of continuous adjustment derived from the available design alternatives: in fact, the design process reveals itself to be a navigation between small portions of that area in respect of which it is possible to evaluate different design alternatives. For instance, it is possible to outline a generic situation with two criteria (c1 and c2) and four alternatives (a1, a2, a3, a4). In the research of the space of action, it is possible to have two directions for its modification: (1) modification of the set of criteria, (2) modification of the set of alternatives.

Hence, this paper proposes an approach to design as a cyclical process of evaluation and as an adjustment of different project solutions, such as an exploration of the space of actions. In particular, this paper presents at first a system of urban sustainability based on indicators, which are derived from existing evaluation systems. Then, the system is applied for evaluating three different design proposals for the retrofitting of a social housing district from the 30ies located at the periphery of a European city. These alternatives allow to identify the portion of space of action in respect of which the process of evaluation and subsequent design can start.

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Evaluation in urban design

Evaluation can assume different meanings and roles within decision-making processes, especially if it is related to urban design. E. R. Alexander (2006) underlines that evaluation is intrinsic to all decision-making, and a more focused approach can be expressed by evaluation in urban design.

Cities and territories have to deal with strategic challenges in sustainable development. In this perspective the integrated approaches to decision support for planning and urban design can help to generate more efficient and effective results than sectoral approaches and, at the same time, they are able to work in an inter-sectoral and multidimensional decision space. "Integration in evaluative approaches means to consider the dynamic interaction among different contextual dimensions, able to combine the *existing relationships* and explore the potentiality to build *new relationships*" (Cerreta, 2010). The peculiarities and specificities of context suggest that the most appropriate integrated approach will depend on the *nature* of the decision-making situation to handle (Leknes 2001).

The evolution of evaluation methods reflects the relation established each time with the planning process and also the way these methods interact with the diversity and multiplicity of knowledge and values.

However, a direct match between planning-evaluation methods, planning models and form of rationality is not so obvious, although the diffusion of new paradigms and the identification of new rationalities activated the development of new approaches and methods towards complex multi-methods evaluation systems. This type of analysis can be explained by Vilfredo Pareto's principle of optimal economic approach, based on the assumption that one has to take into account a plurality of interests, many of which are in conflict. The concept of Pareto optimality recognizes, in fact, the multiplicity of interests and the conflicts of each social subject. This principle was adopted by the world of production under the pressure derived from the need to improve the quality and possibly reducing costs (Concilio, 1999).

The multi-criteria analysis arises from the recognition of the centrality of the conflict and the need to find solutions to it, by extending the framework. Pareto's principle states that there is no single solution to this conflict, but a set of efficient solutions. This means that you have to compare various alternatives, to develop trade-off between objectives/conflictual criteria.

Such a process where the conflict is a structural element characterizes all the design processing, at any scale. In fact, the design project is the result of the research of the best compromise between the various needs: functionality, visual/perceptual quality, costs of construction, maintenance and management. The process is completed when the solution is closer to that ideal, that "up" all the different goals and follows them to a satisfactory level.

Numerous types of multi-criteria analysis are available, but we can identify some characteristics in common: i) the need to identify the objectives and criteria; ii) to assign weights to criteria; iii) to construct an evaluation matrix; iv) to conduct a sensitivity analysis of the results.

The multi-criteria analysis allows to combine and to make different types of information (qualitative and quantitative) comparable and to evaluating them. We often need to use a trade-off process because one alternative solution rarely dominates the other. There are many evaluation systems in planning based on indicators. These want to be simple systems to evaluate sustainability and play an important role in the definition of policies, hence becoming transparent tools of measurement for the avoidance of doubt and misunderstanding: in fact they facilitate communication awareness and public participation. Peter Bosselmann (2008) defines indicators as educational tools for the community to define, observe, compare, interpret, measure, model and transform the alternatives analyzed.

For a proper use of these assessment tools it is necessary to be aware of their limitations. In fact, we can consider the working space of indicators and the space of approximation, and it is necessary to consider the results obtained with critical surveillance. These systems of indicators

provide a useful way for comparing alternative solutions, but they do not provide absolute standards.

Various systems of urban sustainability indicators relate to fundamental aspects of sustainable development of cities and have been influenced by cultural and social characteristics of the places where they originate. This paper considers some of the existing indicator systems, which are more pertinent for the proposed work¹.

Methodology: the construction of the matrix and the definition of the guidelines

The aim of the paper is the construction of an innovative indicator system for assessing urban sustainability. Starting from existing evaluation systems it proposes a set of indicators of sustainability in urban design, which aims to evaluate and drive transformation projects. The indicators were chosen according to the three dimensions of sustainability (environmental, economic, social).

The five relevant criteria proposed by Spiekermann and Wegener $(2003)^2$ were chosen to define the indicators. For the composition of this set of indicators we took as main reference the one proposed by the '*Plan Especial de Indicatores de Sostenibilidad Ambiental de la Actividad Urbanistica de Sevilla*' (2007) because of its efficient structure. The indicator system we propose is divided into six categories as follows:

- Urban morphology. The principal objective of the urban morphology design to achieve the urban sustainability are create a polycentric and compact city, ensure an adequate density to create a functional mix, design the road hierarchy in order to facilitate the spread of walking and cycling mobility integrated with public transport³.
- Urban metabolism, aiming at a reduction of energy demand and raw materials and thus moving towards in a circular dimension development, which enables the reuse of resources, both pursuing strategies of retrofitting of the existing building stock and as well exploring new urban morphologies, that take into account soil sealing issues and passive architecture strategies (shape and orientation indicators)⁴.
- Urban comfort. In order to achieve the well-being of people we have to take into account those psycho-physiological aspects that refer to the perception of the urban environmental quality of indoor and outdoor spaces⁵.
- *Ecological system*. The proper use of vegetation in planning can improve the urban and natural habitats (ensure the well-being of human beings and biodiversity), control and mitigate the quality of microclimate (through the process of evapo-transpiration and shadowing).
- Accessibility. The design of the built environment and the street network highly affect mobility and access to urban services and facilities. A proper design an encourage connectivity, proximity and sustainable mobility.

¹ i) Plan Especial de Indicatores de Sostenibilidad Ambiental de la Actividad Urbanistica de Sevilla (2007); ii) LEED 2009 for neighborhood development (2009); iii) HQE2R (2002); iv) PROPOLIS (Spiekermann & Wegener, 2003); v) European Foundation (Mega & Pedersen, 1998); vi) Indicators for Chinese cities (Columbia University, Tsinghua University, and McKinsey & Company, 2010); vii) Executive branch of the government of Mexico (Hernandez-Moreno & De Hojos-Martinez, 2010); viii) Other systems of indicators (Porta & Renne, 2005; Morello & Ratti, 2007).

² Relevance, representativeness, policy sensitiveness, predictability, feasibility.

³ The urban morphology design defines the places where people live and the connection between people and places. These aspects influence the economic and sustainable growth of a city area, the architectural design of landscapes. It can generate opportunities for socialization, interaction and mutual learning for the inhabitants of the area, using local resources in order to minimize also the use of energy (Urban Task Force, 1999; Jenks, Burton & Williams, 2000).

⁴ Mindali et al., 2004; Newman & Jennings, 2008; Berghauser Pont & Haupt, 2010.

⁵ See for instance: Littlefair et al., 2000; Girdharan & Lau, 2004; Ramos & Steemers, 2005.

- *Complexity*. It is here intended as environmental diversity and mixed uses and typologies, thus ensuring urban vitality through social mix and integration, civic engagement.

For each indicator a detailed sheet was provided indicating the strategic objective, its meaning and description, the method of implementation, the calculation method, including the required data and the methodological process to get it. In particular, indicators are chosen according to the objectives identified by policy needs and then used to enable the conceptualization of an approach to design intended as a cyclical process of evaluation and adjustment of design solutions. It is possible to analyze the results of different alternatives through a weighted summation, elaborated by the program *Definite*, which assesses the relevant criteria for the improvement of the analyzed proposals. Therefore, from the results of the analysis of different alternatives it is possible to deduce some guidelines that help improving the various options within the space of action, as deducted from each evaluation criterion. Indeed, an alternative might be dominant for some criteria and dominated by others. A process of trade-off is activated thus allowing to understand how a worse behavior of a specific option can be offset by a better performance of the same option over another criterion.

Finally, it is possible to deduce operational strategies for action to improve one and/or other alternative designs. After having taken into account all the design alternatives, the derived guidelines can be used to deliver a better alternative then the originals. Again, the aim is not to look for the optimal solution, but for a satisfactory solution, according to a trade-off process.

Hence, to replicate this evaluation procedure it is possible to follow five simple steps, as follows: i) Select the alternatives that have to be evaluated, based on the policy objectives of stakeholders and citizens; ii) Follow the instructions for the calculation of each indicator; iii) Produce a multi-criteria evaluation; iv) Deduce some guidelines for finding one or more alternatives from a comparison of the results obtained on each criterion; v) Apply the guidelines by modifying one alternative or some alternatives to create a new urban regeneration project and trying to build a solution that meets all the criteria considered.

The application of the procedure to a case study

Three different design proposals (Fig. 1a, 1b, 1c) for the sustainable retrofitting of a social housing district from the 30ies located at the periphery of a European city were used to test the proposed system. An overall redevelopment of the district itself is required, in order to promote a settlement characterized by typological, functional and social diversity. Moreover, the site requires a green link to the existing green areas, plus the introduction of new functions. Starting from the same functional program (same density), the proposed schemes assume two different directions: on one hand, the choice to preserve part of the existing housing and, on the other hand, the opportunity to completely demolish the existing fabric and replace it with different building typologies, open spaces and distribution of retail spaces and services within the district.

The evaluation matrix indicates thresholds for almost all indicators, but for some indexes further consideration is required: in fact, in those cases, the threshold directly depends on the context. This paper considers the thresholds in relation to the analyzed case-study area. For instance, for the 'population density' (Urban Morphology category) index it was necessary to carry out a local investigation in order to assess the proper threshold. The same analysis was provided for the 'land covered area ratio' and for the 'average height of buildings'. For the Urban Comfort category indicators it was not possible make an evaluation to be applied everywhere, but it was fundamental to consider site specific climate data.

Therefore. after considering these limitations based on the context analyzed, we could start the evaluation of the three alternatives. After the calculation of each indicator for every case study it was possible to make a weighted summation through the software program *Definite*[®]. The first step was aiming at giving the same weight to every indicator: in that case we could deduce that the first case study dominates the other alternatives, and that every category contributes in different ways to the results (Fig. 2a). In fact, if we analyze each category separately, we can see that the other case studies are not dominated in every category by the first design alternative. For example, the third case study dominates the Urban Comfort category and the second one dominates the Complexity category. These results help us to understand which are the aspects to improve on the first case study. After, the sensitivity analysis follows. We give each time a higher weight for each category (50%), and we observe that the first case study dominates every category (Fig. 2b).

Hence, in this case the domination of case study 1 suggests only one exploration of the space of action. This exploration refers only to one solution, i.e. the first case study. The design adjustments are oriented to improve each category where the chosen solution does not dominate. This alternative design can be restored with reference to those characteristics of the decisional space with respect to which it is locally dominated by other available alternatives. The analysis of the results, carried out considering each category independently, helps to derive some suggestions for identifying guidelines for the reformulation of the identified alternative.

Afterward, from the results we can deduce those categories in respect of which the case study 1 can be improved thus proposing a new design scheme. The categories to be improved in case study 1 are three, namely: Urban Metabolism, Urban Comfort (both dominated by the case study 3) and Complexity (dominated by the case study 2) as shown in table 1.



Fig. 1 The three design schemes (a, b, c) proposed for the redevelopment of the Lorenteggio district, and the masterplan (d) resulting from the application of the method

CATEGORY: MORPHOLOGY								
Indicator	unit	Case study 1	Case study 2	Case study 3				
Building density	m ² /m ²	• 1,32	• 1,34	• 1,52				
Population density	inhabitants/ha	• 469	• 581	• 568				
Façades continuity	%	• 62,14	• 43,86	• 64,8				

Tab. 1 Abstract of results: the best (green), in-between (yellow) and worse (red) performance in relation to the indicator



Fig. 2 Description of results and summary tables. Weighted summation: (a) preferability order of project according to the results divided by category, giving equal weight to the categories; (b) sensitivity analysis (processed by Definite®)

Description of guidelines for a possible new proposal: how to use outcomes for re-designing and adjusting the initial proposal

From the guidelines (Tab. 2a) design decisions for a new proposal (Fig. 1d) can be taken. These decisions do not upset case study 1, but retain its morphological aspects. Then, following the guidelines of the category of Urban Morphology we can proceed with a series of improvements (such as lowering the height of the buildings along the north side of the district, increasing the amount of fronts with views along the roads by closing facades of the courts adjacent to the park, maintaining the population density). Then, the guidelines derived from the results of the Urban Metabolism suggest maintaining the greatest amount of the existing buildings, thus preserving an almost constant 'rate of retention' provided by the case study 1 solution. We also keep a constant 'surface to volume ratio' in respect of a clear improvement compared to other indicators. Case study 3 totally dominates the Urban Comfort indicators and serves as a useful reference. It is necessary to lower the fronts facing the street in the south part of the district and then to open the courts through the construction of a new road, that allows an improvement of the shading condition compared to the case study 1.

Moreover, we investigate the Ecological System performance. Even if dominated by the first alternative, the guidelines prescribe an increase of the number of trees and of the green surfaces to improve the public green spaces per capita. The first alternative analyzed already placed a large green area in the center of the district, so it is necessary to intervene in the area inside the courtyards, where green areas are fragmented. Then, the new project will increase parking places by reducing the access road to school in a one-way road. At the same time it opens a new road between the buildings in the south area of the district, decreasing the size of the blocks and increasing the amount of blocks per unit area. Finally, the results for the category of complexity suggest to increase the typological mix and the number of services, so it was decided to introduce a new building for students. Finally, it is possible to verify the partial results of each design decision by re-calculating the indicators (Tab. 2b).

CATEGORY: MORPHOLOGY				PROPOSAL		
Indicator	Discussion	Incipit of design change		Case study 1 values	Project values	Result
Building density [m ² /m ²]	Case study 1 dominates	-		1,32	1,29	(· ·)
Population density [people/ha]	Case study 1 dominates.	udy 1 tes.		469	430	\bigcirc
Façades continuity [%]	Case study 3 dominates.	Increase the length of fronts of the buildings adjacent to the park in the south area of the district.		62,14	66,1	$\begin{array}{c} \hline \end{array}$
(a)				(b)		

(a)

Tab. 2 (a) List of argumentation and modification/Reflection and possible design changes; (b) Analysis of the results of the proposed project in relation to the case study

Conclusions: Considerations about the proposed methodology and future work

The proposed system represents an innovative support to urban design that can translate the complex urban systems into measurable units of information, and enables to identify the possible implementation areas of design alternatives. In fact, the evaluation, verifies that the multidimensional and inter-sectorial goals of sustainability can be transformed into visible criteria that can guide design and the decision process. Therefore, we can define the action space at which we can activate the integrated evaluation and design process for the construction of a new project that "learns to be more sustainable" from design alternatives and outcomes evaluation. The final project can be evaluated again to demonstrate its improvement in the space of action as compared to the design proposal from which it derives. This work shows that the integration assessment and planning is possible and that the proposed tools can serve as a support to urban planning. These tools do not generate the best alternative but they guide the improvement of the given alternatives analyzed. In this way, the design is coherent with a dynamic decision model that considers the impacts produced on the environment by each component or dimension of the project.

An important critical element of the evaluation system is the individuation of a priority order of the criteria in the matrix. In fact, it is possible to analyze data considering the performance of the indicators (objective approach) and on the other hand it is possible to assign a weight to each indicator in the matrix. This raises the problem of making an explicit "judgment of value"; in fact the assignment of relative weights to each indicator used to establish an order between them (relative approach) introduces the choice of weights of each criterion, which can be assigned to a decision maker, or to a group of experts or to the community, in case of participated social choice.

Furthermore, it is important to guarantee the replicability for every evaluation system. Hence, we argue that the system presented in this paper can be adapted and reused according to some rules as follows. Firstly, it is necessary to select the alternatives that can be evaluated according to political goals and stakeholders' objectives. Secondly, it is possible to follow the instructions for the calculation of each indicator. Thirdly, the multi-criteria evaluation can be edited, and new guidelines from the comparison of the outcomes can be given. Finally, the guidelines are used to modify the design alternatives aiming at fulfilling as much as possible the chosen criteria.

Finally, this work suggests possible future implementations like: How can we make this system more user-friendly? How can the evaluation continue after construction (monitoring)? What is the role of public administration in the use of these evaluation systems? How can citizens be involved in the process of evaluation?

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