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The regenerative approach to model an integrated urban-building evaluation method☆

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Abstract

In this paper we focus on crucial issues concerning the effectiveness of evaluation of sustainability in the built environment. The paper argues that we need to rethink the evaluation of urban-building sustainability from an integrative perspective. It advances a theoretical and methodological model based on the regenerative approach, which opens up a new way to deal with the sustainability of the built environment. An enlarged definition of urban metabolism is used to carry out the integrated evaluation.

Central in it is the concept of *reliability*, which expresses the ability of products and processes in the built environment to be adaptive, resilient and regenerative. We use *reliability* in a transversal manner through the process of making the built environment sustainable, referring it both to buildings and the regenerative process triggered by sustainable actions addressed to buildings. Holistic indicators allow assessing it quantitatively or qualitatively.

Through *reliability* we bring regenerative thinking from a theoretical to an operational level. When referred to buildings, *reliability* allows considering sustainable performances not usually assessed in current evaluations. When referred to processes, it helps to understand directions of change in relation to sustainability of the built environment. Our method can be easily associated to current evaluation systems exceeding their boundaries.

Keywords: Regenerative sustainability; *Reliability*; Urban metabolism; Integrated evaluation; Holistic indicators

1. Introduction

During last centuries, the increase in knowledge and the associated technological advancements have determined an evolution of human societies superimposed on nature, with the results of jeopardizing natural systems. Becoming aware of natural resource depletion and environmental pollution is at the basis of the need to draw attention to a sustainable development, as defined in the Bruntland Report (WCED, 1987). This is considered a starting point of a major concern for the natural environment, which has

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to be interrelated with social and economic development, inter and intra generationally. Then, in recent years, the sustainability paradigm has been the leading guide for development at any scale of thought and action, pervading policies as well as practices of intervention in any field of application (Hecht et al., 2012).

The built environment is the most significant field of action for several reasons, both quantitative and qualitative: it uses natural resources and impacts the natural environment in a very relevant manner; it constitutes the socio-cultural identity of a place; it expresses the economic capacity of a society. Therefore the built environment has increasingly become the test bed of policies and practices of sustainability, the terrain for experimenting sustainable paths of governance and design so that buildings and cities have been focused subjects of interest and experimentation (Lewis et al., 2013) and sustainable buildings and cities the output of such commitment.

Now, after more than 25 years of investments in sustainability, the question is whether sustainable development is indeed sustainable (Blowers et al., 2012). The answer is arguable: it could be almost positive, if we refer to sustainability as the paradigm originating from the sustainable development definition above cited; it could be rather negative if we refer to sustainability as the ability to re-establish cooperation between the natural and the human worlds for a mutual beneficial development. The central difference resides in the approach used, which at the end defines a substantially different goal: in the first case, the sustainable development approach is aimed at reducing the natural resource depletion and the environmental impacts; in the second case, the approach is regenerative, i.e. aimed at reversing the present and persistent trend of consumption for regenerating the natural environment, indispensable for the human life (Cole, 2012a).

2. The regenerative approach to evaluate sustainability

Both approaches are concerned with a healthy development of natural and human systems, but the sustainability traced by the sustainable development approach, even improved by adding a fourth or more dimensions to the first original three of environment, society and economy, proves to be a discrete process, made by step-by-step improvements, with a distant temporal horizon but still limited. It calls for a development more sustainable than before, but still insufficient for assuring the enduring life of natural and human systems. By reducing the effects of consumption, we can delay the deadline of life on the planet, but not preserve it (Singer, 2010). This approach is still in line with the belief that man is able to manage and control both natural and human systems, superimposing the last on the first.

On the contrary, the sustainability traced by the regenerative approach appears as the result of a continuous process based on a co-evolutionary partnership between ecological and socio-cultural systems (Cole et al., 2013). The evolutionary character of such sustainability assumes it is a never-ending developmental process, able to re-determine itself during time. Moreover, the evolution in partnership reflects an ability to interrelate systems, responding to the need of a systemic view that seems the only way to really assure the enduring life of natural and human systems reversing the present trend. Sustainability reinterpreted by the regenerative approach can reactivate a human development aligned with the effort of nature (du Plessis, 2012).

The sustainability paradigm traced by the sustainable development approach is then disputable; in fact, many scholars are discussing its limits and pitfalls (Ahmad et al., 2012; Ahn et al., 2013; Kissinger and Rees, 2010), particularly in the light of the regenerative approach (Cole, 2012b). Nevertheless, it has permeated the way of thinking and acting of almost all the actors involved in development processes of any type, increasing the consciousness of each of them in contributing to sustainability. In the built environment, the learning, technological and economic investments in sustainability have been increasingly relevant during years, stimulating the public and the private sector, building industries and companies, building managers and agencies, designers, politicians, and citizens.

A clear demonstration of such investment is the effort engaged in the evaluation of sustainable buildings, neighborhoods, or cities. Evaluation methods translated into assessment systems have become the common tool of communication among actors in the building and urban development process for dealing with sustainability (Kajikawa et al., 2011). Then, at present, evaluation is considered as the guideline of a development process, and the assessment criteria have become the benchmark to measure the rate of sustainability of buildings, neighborhoods, or cities. As for the sustainability paradigm, also evaluation methods and assessment systems based on the sustainable development approach show limits and pitfalls, which however are not in the aim of this paper (see, for instance, Giama and Papadopoulos, 2012; Kumar Singh et al., 2012; Magee et al., 2013; Komeily and Srinivasan, 2015). Rather, we recognize their usefulness in stimulating sustainability processes and therefore we propose to evolve theory and practice of sustainability evaluation toward the regenerative approach.

We focus on two aspects of the regenerative approach that sustainability evaluation and assessment methods should include: the systemic view and the continuity of the developmental process, in order to pursue the required co-evolutionary partnership between ecological and socio-cultural systems, as cited above. The conceptual framework we propose for sustainability evaluation of the built environment integrates different spatial scales and considers reciprocal influences between constituent parts of the built environment. According to Cole et al. (2013), in fact, co-evolution is inapplicable to a single building, rather the

systemic relationships between the whole built environment and socio-cultural and ecological systems lead to co-evolution.

Starting from this essential premise, our methodological proposal is aimed at structuring an integrated urban-building evaluation of sustainability, built on the socio-ecological system (SES) perspective on the built environment (Moffatt and Kohler, 2008).

3. An alternative model of the built environment and its implications on sustainability evaluation

If the evaluation of the sustainability is difficult because of the ambiguity of the meaning of sustainability, the definition of sustainable built environment is not less problematic. There is no agreement or consensus on what composes the built environment. It can mean different things to different people. However, usually, and not only in the evaluation field, the built environment has been seen as a physical container for development processes and, as such, receptor of its impacts and/or benefits. In the sustainability evaluation field this absence of consensus has had several implications such as the proliferation of assessment systems and indicators to describe and evaluate sustainable performances of buildings and places (du Plessis, 2012).

The aggressiveness and intensity of urbanization processes occurring at the planetary level (Brenner and Schmid, 2013), the magnitude and harshness of social and environmental transformations together with the impacts they generate on human and natural systems have forced scholars in different fields to carefully reconsider the content and meaning of the built environment. On one hand, it has become really difficult to discern natural environments from human artifacts: the hybridization of nature is so capillary that it is no longer possible to separate nature from the human interventions (Zurlini et al., 2008; Chakrabarty, 2009; Alberti, 2015).

On the other hand, we are witnessing the return to nature in the post-industrial metropolis in different forms (Gandy, 2006). In opposition to the aridity of urban landscapes associated with technological modernism "the understanding and utilization of urban eco-systems has become more sophisticated to embrace a more holistic conception of the interaction between bio-physical processes and urban society" (Gandy, 2006, p. 69). The urgent need to make urban environments resilient to adapt to different kinds of environmental change and resource scarcity has more tightly linked the health of built environments to the health of ecosystem services.

Considering these directions of change, several studies underline the need to abandon the physical vision of the built environment as developed inside an anthropocentric, culture-dependent perspective, which traces a neat separation between natural and human systems (Moffatt and Kohler, 2008). They propose to reframe the concept of built environment using the SES theory. This last introduces the idea that, in fact, socio-ecological systems are connected into a coevolving whole by relationships generated by flows of matter and energy as well as decisions/intentions and emotions. These kinds of relationship are not necessarily based on proximity, although they are characterized by temporal and spatial cross-scales interactions.

As socio-ecological system, the built environment is nothing but an artifact localized in an overlapping zone between culture and nature and it is constituted of bidirectional relationships and processes connecting the built and the 'unbuilt' parts of the environment (Hassler and Kohler, 2014). A key variable to grasp such interactions is the urban metabolism (Wolman, 1965) as reconceived in its enlarged definitions (Garcia et al., 2008; Kennedy et al., 2011). Assuming flows of matter and energy as relationships connecting social and ecological systems is the rational underlying the dominant bio-physical interpretation of urban metabolism (Gandy, 2004; Rapoport, 2011).

However, in response to criticisms, urban metabolism currently includes environmental quality and lifestyles (Kennedy et al., 2007). Other perspectives on urban metabolism have instead focused on political, physical and social processes with the aim to overcome the dualism nature-society by showing their co-constitution (Rapoport, 2011). Urban settlements are re-conceptualized as socionature (Heynen et al., 2006): by following the flows of nature we can understand not only balance and cycles of matter and energy but also political and social processes which produced a specific socio-ecological system and the causes of social injustices and environmental decay.

Following the metaphor of urban metabolism any project aimed at transforming the built environment is simultaneously an environmental project which "entails a complex set of ecological and epidemiological effects ranging from new types of metabolic interactions with the human body to the destruction and creation of distinctive types of ecological assemblages" (Henry, 2014, p. 255). Thus, the production of a more just and healthy built environment implies expanding urban metabolism to incorporate socio-economic and policy analysis: "without a corresponding analysis of the social systemic drivers of the flows, little headway will be made toward greater urban sustainability, much less global climate change mitigation" (Pincetl et al., 2012, p. 201).

Enlarged concepts of built environment as SES and urban metabolism are keys to a regenerative development which, as defined by Mang and Reed (2013, p. 479), is "a system of technologies and strategies for generating the patterned whole-system understanding of a place, and developing the strategic systemic thinking capacities and the self-organizing and self-evolving stakeholder engagement/commitment required to ensure regenerative design processes achieve maximum systemic leverage and support". An SES perspective on the built environment helps to reinterpret it as a place, as material and relational artifact having a story constituted by collisions, connections and absence of them. In particular urban metabolism can become "a framework for seeing interrelationships rather

than things and for seeing patterns of change rather than static 'snapshots'. It addresses phenomena in terms of wholeness rather than in terms of parts" (Mang and Reed, 2013, p. 479) (Fig. 1).

There are several practical implications of our approach on the sustainability evaluation practices at both the urban and building levels. In the first place, it overcomes the idea of a scale as a close container and redefines it as an open matrix of cooperative and conflicting relationships. In this way, our approach avoids closing sustainability in the borders of a specific scale. On the contrary, the scale of evaluation will be an output of the evaluation process itself. This allows overcoming the systemic reductionism characterizing the evaluation approaches and the consequent object-centered perspective.

Although existing evaluation approaches and systems use very complex systems of indicators to describe an individual object, at the urban scale their reciprocal interactions are systematically ignored as if we know everything about them and their sustainability except for their technological implementation and contextualization. The scale-centered approach corrodes the idea of a city as a co-evolutionary and complex space of life. On the one hand, focusing on building and neighborhood sustainability it reduces urban sustainability to the construction of micro-icons such as eco-efficient buildings and eco-districts condensing any kind of eco-technological innovation. On the other hand, the scale-centered also strengthens the uneven thickening and stretching of an 'urban fabric' into a sustainable substitute of ecological dynamics (Brenner and Schmid, 2015). Therefore, from our point of view, the idea of urban sustainability as a sum of individual objects sustainability underlying existing evaluation approaches is a paradox. Since metabolism pertains agents and relationships (actions and decisions), our focus in the evaluation is both on agents and interactions (Kaika and Swyngedouw, 2014).

Our approach also helps to grasp the multidimensional and conflicting 'nature' of sustainability. As it focuses on urban and natural agents' qualities and their relationships, it does not require disaggregating sustainability in social, economic and environmental factors (Monno and Conte, 2015). When the socio-ecological relationships are under scrutiny, it is difficult to escape from the uncomfortable confrontation with the contradictions inherent to our way of building cities and producing the built environment. Urban is integral to nature, and our decisions and actions will change ecological dynamics (Zurlini et al., 2008). Furthermore, it is clear that the usual impact oriented evaluation can only represent one of the many forms of interactions. There are destructive but/and also regenerative interactions. If working on impacts can be useful to escape ethical troubles through compensating and mitigating ecological losses, when regenerative is under scrutiny there is no escape since any compensation or mitigation cannot produce a win–win solution. There cannot be compensations for a loss of a piece of forest or an animal species. Sustainability, when seen from a regenerative point of view, requires a different approach: one which is co-creative rather than less destructive.

The regenerative horizon together with these two implications of our approach have important repercussions on citizens' involvement in the evaluation process. As well known the choice of a scale also determines actors, resources and problems to be considered in the evaluation (Lebel, 2006). Instead in our approach, their inclusions and exclusions will depend on the 'extent' of the built environment metabolism. In our vision on the built environment, none of these components of evaluation can be predefined. This implies a more democratic approach to the evaluation

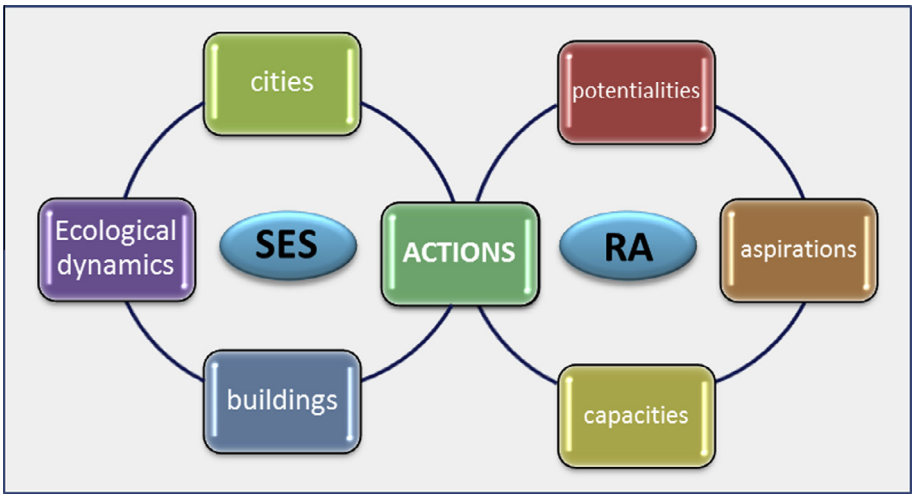

Figure 1. Conceptual framework of our integrated approach (in the figure, SES and RA indicate respectively the socio-ecological system and the regenerative approach).

as actors, resources and problems will emerge along the evaluation. At the same time, the ethic of co-creativity underlying the regenerative approach offers a less ambiguous evaluative framework than that provided by sustainability. However, "seeing interrelationships rather than things and seeing patterns of change rather than static 'snapshots'" (Mang and Reed, 2013, p. 479) through a co-creative rather than a less destructive attitude can help to manage conflict. Co-creativity implies searching complementarities without eliminating dissonance. It can create a sense of living together on this planet thus spurring a more sincere and less interested interpretation of the problems at hand and a shared recognition of what is going to be gained and lost through action.

4. From the approach to the assessment

Our integrated urban-building evaluation approach draws on an SES perspective on the built environment and in particular it adopts an enlarged definition of urban metabolism as connector among scales of evaluation. Hence, it dismisses a conceptualization of built environment as a collection of man-made objects which impact in a more or less complex ways on local or wider ecological dynamics. In our approach, the built environment is a spatial context "in-between" whose extension and shape depend on the specific social and ecological relationships which shape its metabolisms. This is a set of material and immaterial relationships and flows connecting agents which interact and shape the built environment. In this sense, instead of talking about the built environment we rather prefer to talk about *urban matrix* whose texture is defined by its own urban metabolism. This last, in turn, defines the matrix spatial boundaries.

Within the *urban matrix* the *urban* alludes both to the urbanized space and to the urbanization of nature. The *matrix* is more than a neighborhood in which a building is situated: it is a multi-scalar space defined by the metabolic interactions among agents/nodes composing the neighborhood and the sustaining ecological dynamics. The texture and borders of *urban matrix* are defined by its metabolism, meaning that the assemblage of socio-ecological material and immaterial flows and relationships connecting the agents. Within the *urban matrix*, a building is an agent/node contributing to and shaping the *urban matrix* metabolism. Therefore, it is through metabolism that the built environment and a building interact.

If buildings and the built environment are not socio-technological islands but agents interconnected by a distinctive set of relationships and dynamics through urban metabolism, then variations of *urban matrix* metabolism can express their reciprocal interactions. Furthermore, transformations or alterations of the existing relationships constituting at a certain time the *urban matrix* metabolism can help to understand the direction of transformations, and if those transformations are contributing to the mind and cultural shift required by the regenerative approach.

As far as the interaction between the building and the matrix is concerned, our approach aims at focusing on the regenerative qualities of metabolic interactions rather than assessing environmental, social and economic impacts or the ability of an action to reach agreed sustainable targets. In fact, thinking about the evaluation of building sustainability through an enlarged definition of urban metabolism can offer the possibility to reconnect building sustainability to the regenerative potential of the built environment. To be regenerative an action has to contribute to a metabolism characterized by processes of activation–regeneration and alignment of socio-ecological relationships instead of being simply less destructive. It has to accompany a project of transformation of the environment from an understanding of regenerative potential of a place toward the activation of regenerative capacities.

Operatively, we describe the *urban matrix* metabolism through flows, environmental qualities, structure and lifestyles (Conte and Monno, 2012). From our point of view, the choice of these categories of analysis helps to integrate economic, social and environmental dimensions/impacts of a project/action addressed to building since the beginning of the evaluation, thus avoiding a difficult search for their later integration. These categories are not chosen to be integrated and in fact their integration could be really problematic; but they are used to understand their reciprocal alignments and activation, their intersections, disconnections, and then how these can exploit the regenerative potential of a place. The multiple building-*urban matrix* sustainable and unsustainable reciprocal interdependences will emerge from the comparison of categories of analysis describing the *urban matrix* and the building.

To be more specific we consider the structure of the built environment as a result of a nested network of artifacts and ecosystem dynamics. The environmental quality describes the current status and trend of structure of the *urban matrix*. Lifestyles embed culture, aspirations and practices of change of a place. In our evaluation model flows concern the usual balance of matter and energy as well as decisions and practices of transformation of places. Such a structure of analysis is complex, however it is necessary if we want to write down the story of a place as a base to recognize and move from the regenerative potential to the regenerative capacities.

Recognizing the regenerative potential of the *urban matrix* is crucial in our analysis to understand collisions or reciprocal reinforcement between on the one hand the *urban matrix* metabolism and on the other hand the aims and aspirations of a project. In order to explore the regenerative potential of the *urban matrix* we use the concept of resilience intended not only as the ability of a system of retaining function and structure after a stress, but also as its capacity to self-reorganize, learn and eventually change itself. However, assessing resilience is not an easy task since we are not still able to appreciate the adaptive capacities and measure thresholds of regime shifts of complex socio-ecological systems. Vulnerability is usually used as

the specular property of resilience. Thus we appreciate the regenerative potential of the *urban matrix* through comparing its metabolism to its vulnerability and considering its variations as an indicator of the direction of change.

Following du Plessis (2012, p. 7) who maintain that "The regenerative paradigm provides an alternative that is explicitly designed to engage with a living world through its emphasis on a co-creative partnership with nature based on strategies of adaptation, resilience and regeneration", agents and actions in the built environment can express the ability to exploit local nature/human potentialities for self-improving the living world, turning regenerative potentials of a place into capacities.

5. Reliability: a conceptual and practical tool to evaluate regenerative sustainability

To evaluate regenerative sustainability is then necessary to take into account such comprehensive ability of agents and actions in the built environment to be sustainable based on strategies of adaptation, resilience and regeneration.

We use the concept of *reliability* to represent, evaluate and assess this ability, i.e. regenerative sustainability. Thereby, *reliability* can be conceptually referred both to agents and actions of sustainability and practically become a tool to measure sustainability of the built environment developmental processes, quantitatively as well as qualitatively. Therefore, we use *reliability* in a transversal manner through the process of making our built environment sustainable in a regenerative manner (Fig. 2).

The fundamental reasons for choosing the concept of *reliability* in our evaluation model are related to the use we all make of such concept in daily life; particularly, we are accustomed to consider reliable a product in its functioning or a person in his/her social relationship (Audi, 2009). Among many others, reliability is then a quality that gives us confidence in a product or person helping our decision-making, for example when buying an object or starting a friendship. In this case, the parameters of evaluation that we use are often qualitatively, and they can largely vary from person to person, situation to situation. Nevertheless, reliability is also an engineering variable associated to the characteristic of physical systems –structures, installations, buildings and constructions or parts of them, production processes– to assure the expected performance over time (Zio, 2009). In this case, the evaluation is based on a physical quantity.

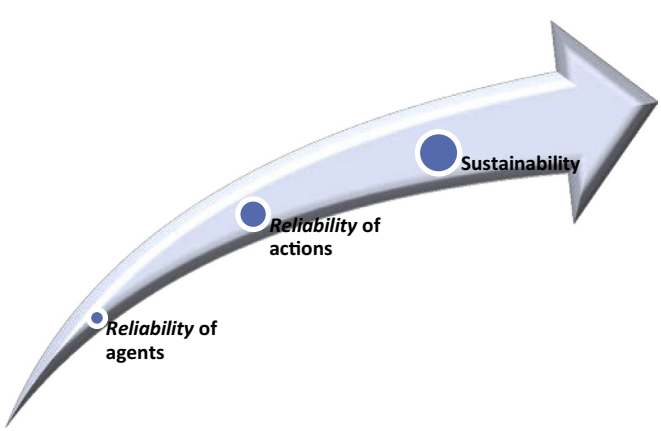

Figure 2. Transversality in using the concept of *reliability* through the process of making the built environment sustainable.

Therefore *reliability* is referable to objects as well as people, which in the built environment can be interpreted, in a more comprehensive way, as human and non-human agents; it is applicable also to processes, hence in the case of the built environment *reliability* can be linked to actions characterizing the sustainable development process; it is associable to quantitative but also qualitative measurements, this allowing to respect the need for an interpretative flexibility of sustainable development (van Opstal and Hugé, 2013). In our evaluation model, *reliability* becomes the assessable characteristic of regenerative sustainability, and it can be considered in relation to the constituent parts of the built environment, i.e. agents, which can be both natural and artifacts as buildings and infrastructures, and also in relation to development processes implemented for pursuing sustainability, i.e. regenerative actions.

Our interpretation of r*eliability* shows its potential when sustainability is considered in the light of the regenerative approach. According to Mang and Reed (2012, p. 26), "Regeneration depends on a developmental process that improves the value of the whole, works to take systems to the next level, evokes a set of higher order aims and develops the capacities to pursue them". Moreover, du Plessis (2012, p. 15) argues that "... to be sustainable, it is necessary to move towards a developmental model that aligns human development efforts with the creative efforts of nature".

Regenerative actions generate a high-order level of sustainability; *reliability* in our evaluation model can be associated to actions in order to show their regenerative contents. To simplify the concept on the operational level, we can represent the dynamic of creating a *Regenerative Action* for the built environment reinterpreting the dynamic of creating a regenerative concept as depicted by Mang and Reed (2012; Fig. 6, p. 34). In Fig. 3, we can associate: the *Alignment* required between human and natural development efforts to the *Place Potential* in the left vertex of the triangle; the *Activation* necessary for triggering the co-creative partnership between nature and the living world to the *Project Aims & Aspirations* in the right vertex of the triangle; and the *Regenerative Action* able to improve the value of the whole to the *Regenerative Concept* (*Systemic Role*) to the upper vertex of the triangle.

In such dynamic of creating a *Regenerative Action* for the built environment, if the processes of *Alignment* and *Activation* and their related actions have a high *reliability*, then the regenerative sustainability content of the whole process will be high. Thus, *reliability* in our evaluation

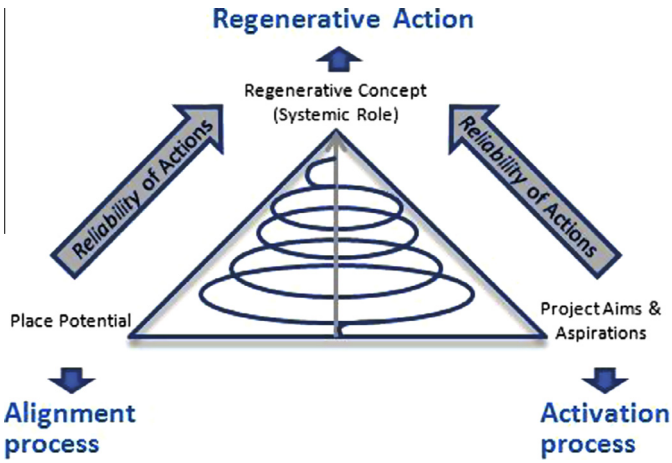

Figure 3. Dynamic of creating a regenerative concept reinterpreted on an operational level defining a regenerative action. adapted from Mang and Reed, 2012; Fig. 6, p. 34.

model can be associated to actions determined by the processes at the low vertexes of the triangle and represents at first the sustainability of those actions and then the sustainability content of the whole developmental process able to be regenerative for the built environment.

However, moving toward the regenerative approach is fairly recent and perhaps the timing for its affirmation will be long, since it requires a cultural shift; in the same way, innovative processes based on the regenerative approach need to be experimented, and related actions implemented and evaluated in order to demonstrate their regenerative character, and then their sustainability. Such necessary change of mind (Mang and Reed, 2012) should be considered a priority for reversing the present trend of an unsustainable development, but meanwhile regenerative processes and actions propagate and succeed, the built environment continues to evolve mainly following the sustainability path traced by the sustainable development approach.

Nevertheless, we agree with Mang and Reed (2012) that different sustainability approaches and practices are not alternative or even competing, rather they are interrelated and interdependent, and work on differentiated levels within a hierarchy where regeneration is at the upper level. Therefore, improving the sustainability meaning and content of agents in the built environment may be a useful effort to engage in accompanying the transition of sustainability practices positioned at the lower levels toward the upper level of a regenerative sustainability. *Reliability* contributes to this; in fact, we use *reliability* in a transversal manner in our evaluation model, so in addition to actions, *reliability* can be also associated to the ability of an artifact, such as a building in the built environment, to express adaptation, resilience and regeneration, i.e. those characteristics depending on strategies to be used in the co-creative human-natural partnership emphasized by the regenerative paradigm.

5.1. Assessing reliability

The transition from the conceptual to the operational level of assessing *reliability* requires the identification and characterization of indicators, which allow measuring it. In our evaluation model, we have chosen holistic indicators in order to express the required character of interrelatedness and interdependency between different qualities that *reliability* has to possess and show at both levels of its application (Fig. 4).

5.1.1. Agents

Starting from the lower level of application, *reliability* is associated to an agent in the built environment, human or non-human, that is a constituent part of it. Currently in our evaluation model, we have considered the building artifact as an agent and associated *reliability* to its ability to be sustainable in a regenerative way; then, indicators have to measure the characteristics of adaptation, resilience and regeneration performed by buildings (Fig. 5). At this level, a quantitative assessment can be managed based on engineering rules and 'conventional' reliability theory.

Posed that the *reliability* of a building can be referred to its ability to perform the expected quality of functioning under any condition of use over time, the indicators of adaptation, resilience and regeneration can be, at a specific time of the building operational life or after a renovation/refurbishment or even after an exceptional event, respectively: I_{adp}, the level of residual functioning; I_{res}, the remaining capacity to meet the needs of users despite degradation/obsolescence or damage suffered; I_{reg}, the quantity of parts to be substituted or integrated because of degradation/ obsolescence or damage suffered. Finally *reliability* can be determined by means of a composition of these indicators.

Examples can help in making more explicit the indicators used for determining such reliability of building agents in the built environment. For instance, we can consider the case of extending the life cycle of the building or the case of reacting to an extreme event as flooding. In the first case, it is appropriate to plan and intervene with renovation/refurbishment aimed at giving the building the capacity to meet the new requirements of users as well as conform to

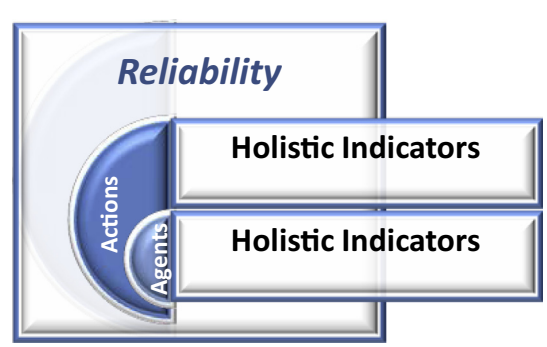

Figure 4. Holistic indicators are needed to represent a nested *reliability*.

Figure 5. *Reliability* of agents in the built environment.

new regulations and context modifications. In the second case, it becomes urgent to restore the functionality of the building for its normal use. In both these situations, buildings can show different abilities to react to the ordinary or extraordinary events; such abilities are expressed through its *reliability* and the related indicators of adaptation, resilience and regeneration. Then, in case of renovation/refurbishment: indicator I_{adp} detects how much the building continues to match new requirements of users or regulations; indicator I_{res} detects how much the building has not been deteriorated by its use and aging; indicator I_{reg} detects how much is necessary to intervene in the building with substitution or integration of parts and components to regenerate the required performances. And, in case of flooding: indicator I_{adp} detects how much the building continues to perform its global functioning; indicator I_{res} detects how much the building has not been damaged by the event; and indicator I_{reg} detects how much is necessary to intervene in the building to restore the entirety of functioning.

5.1.2. Actions

On the upper level of application and still considering building agents in the built environment, it is only through connecting buildings to a differentiated range of scales that we can assess their contribution toward sustainability; in fact, "there is no such thing as a sustainable building – only buildings that enable people to live and work in sustainable ways" (Gibberd 2001 quoted by Cole, 2013, p. 471). The goal of the assessment is the understanding of the ability of an action addressed to a building to turn the regenerative potential of *urban matrix* into regenerative capacities, thus triggering alignment and activation processes. To face this challenge in our evaluation model, sustainable buildings and the *urban matrix* are interconnected through the concept of *reliability* of the action.

At this level of application the variation of *urban matrix* vulnerability measures the *reliability* of an action. A positive change of the *urban matrix* vulnerability will indicate a poor *reliability* of an action, in opposition a negative change will show a valuable reliable performance of a building within the *urban matrix*. The variation of vulnerability can be the incidence respectively on: environmental quality (I_{eq}), flows (I_{fl}), structure (I_{st}) and lifestyle (I_{ls}); where the incidence corresponds to the ability of actions inspired by the alignment and activation processes to determine a modification in the metabolism of the *urban matrix*, which can range from negative through neutral to positive values depending on whether such ability worsens or improves the vulnerability of the *urban matrix* over time.

In our model, *reliability* of an action synthetizes the quality of a complex system of socio-ecological interactions connecting agents (buildings) and the *urban matrix*. For this reason, *reliability* includes not only impacts (I_i) of a building on the *urban matrix*, but also the change of aims and aspirations of a community (I_{ch}) and regenerative capacities activated by the action (I_c) (Fig. 6). These indicators are the result of a comparison rather than a mere composition between the categories of analysis describing the *urban matrix* and a sustainable building. In each category of analysis, indicators allow understanding different responsiveness and speed of transformation which generate a step forward the regenerative development. So to measure the direction and quality of the co-evolution process in the *urban matrix*, the regenerative capacities can be identified through the design choices, which translate into practice sustainability aims and aspirations of a specific project (Fig. 7).

Starting from these premises, actors involved in the evaluation process will bring and generate their own knowledge and indicators according to the idea of *reliability* which is specific to the *urban matrix*. Hence, *reliability* becomes a tool for exploring conflicts and producing co-creative solutions.

6. Discussion

The evaluation model we propose shows interesting potentialities on the basis of what we consider its strengths. First of all, our evaluation overcomes the current usual focus on single objects or parts of the built environment, since the model integrates both the building and the urban scales and evaluates reciprocal influences and mutual benefits of sustainable development processes in the built environment. In this light, our evaluation model respects the need to deal with sustainability drawing on a regenerative perspective in order to consider its complexity and uncertainties, and its evolving character over time (Godfrey, 2010; Quental et al., 2011). Moreover, our evaluation model is intended for accompanying and not substituting current sustainable buildings or sites/neighborhoods/communities or cities evaluation systems, thus adding value to their operative potential when applied at a scale of a detailed performance assessment.

Figure 6. *Reliability* of actions in the *urban matrix*.

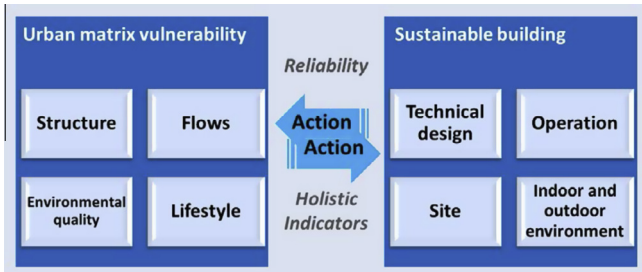

Figure 7. Integrated assessment framework.

However, also our evaluation model allows assessing performances; in fact, through *reliability* and its associated indicators both agents in the built environment –buildings– and actions addressed to them –the variations of *urban matrix* vulnerability– can be assessed in relation to their performances, planned and designed on the basis of a regenerative approach. Since operationally our model allows assessing performances, it offers the prospect of an easy and immediate application, because its operation is similar to the most common evaluation systems of sustainability, to which we have increasingly accustomed in recent years. On this line, it is very likely that our model can act as a communication tool between actors involved in sustainable development processes in the built environment, as it has happened to other sustainability evaluation systems.

Moreover, applicability of our assessment to different levels of sustainability implementation, from agents to actions, favors a flexible interpretation of sustainability considering its complexity, uncertainties, and evolving character over time as well as different attributions of meaning and sense determined by varied and differentiated situations of socio-cultural and ecological context. The possibility to measure *reliability* quantitatively or qualitatively, supports such need for a more fluid interpretative frame (Guy, 2011) on the operational level. As stated above, this happens because we use *reliability* in a transversal manner through the process of making the sustainable built environment. Our evaluation model includes the ability to go beyond step-by-step advancements in sustainability, promoting instead a continuous process of improving the built environment toward the upper level of regenerative sustainability.

To *reliability* that is a crucial concept in our evaluation model, we can associate the potential to stimulate a fluid transition (Eames et al., 2013) from lower to upper levels of sustainability paradigms and approaches. Being applied in a transversal manner, *reliability* can help in overcoming fragmentation and dispersal of actions implemented in sustainable development processes, which we identify as a reason for their inconsistency and consequently for their ineffectiveness in producing a regenerative sustainability of the built environment. At the same time, *reliability* in our model and its assessment by means of holistic indicators simplifies the evaluation of sustainability. Assessing *reliability* from early stage of planning and design supports decision-making activities related to development processes, increasing the chances of making effective implementations of sustainability in the built environment. *Reliability* as defined in our model maintains its validity also when assessed during operation; therefore, such flexibility of *reliability* assessment ex-ante or ex-post can activate a virtuous cycle of a continuous re-definition of what makes more reliable an agent or action in an evolving built environment, fostering regenerative actions.

Certainly, our evaluation model has also weaknesses, on which we are engaged for its further development. For example, the concept of *reliability* at the agent level shall be tested through its application to different human and non-human agents of the built environment, so to improve the robustness of our model. In fact, at the moment we consider only the buildings as agents in the built environment to evaluate and assess, but obviously not only buildings are the constituent parts of the built environment (Sarkis et al., 2012). Other human artifacts, as urban services and infrastructures, as well as natural systems shall be considered. Enlarging the model will work as a testbed for proving our *reliability* concept and its flexibility in application. By including more agents in the built environment the evaluation method shall become more complicated and the *reliability* assessment procedure more laborious and demanding, but also more powerful in the process of decision making.

Open questions also exist concerning *reliability* associated to the regenerative action. In our model a regenerative action originates from alignment and activation processes (see Fig. 2); this means that it can be produced by multiple and various processes, exploiting the ability of a place to establish a co-creative and co-evolutionary partnership between nature and human systems. Consequently, our model shall be validated through the assessment of *reliability* applied to specific case studies involving local actors and specifying holistic indicators case by case.

7. Conclusions

Improving theory and practice of sustainability in the built environment is an evident need, which is shown by the insufficient results achieved despite investments fielded in more than two decades for developing sustainable buildings and cities. Lately, regenerative theory offers a perspective that seems to work in this direction, since it draws renewed attention to consider coexistence between natural and human systems in the light of evolutionary processes, which can model cooperatively and dynamically sustainable development of all life forms on the planet. However, as always happens, it takes time to systemize the theory and experiment its applications; therefore, attempts and efforts carried out at any level to advance regenerative theory (Robinson and Cole, 2015) and practice (Pedersen Zari, 2015), can support the debate within the scientific community as well as inform and stimulate all the actors involved in sustainable development processes, promoting

the diffusion of a new way of thinking about and acting for sustainability in the built environment.

In order to contribute to such debate and knowledge improvements, in this paper we present the result of a research work that we started to address the several shortcomings currently showed by policies and practices of sustainability in the built environment (Conte and Monno, 2012). Crucial for our evaluation model is an alternative conceptualization of the built environment which draws on socio-ecological and relational interpretation of the built environment. We discuss the regenerative approach as an ethical horizon for an integrated urban-building evaluation. Then we translate our SES model on the built environment into an operational method. The *urban matrix* metabolism that we define based on the SES theory, and *reliability* that we use as a tool to evaluate the regenerative sustainability of buildings and sustainable actions addressed to them, are our conceptual and operational contributions to advance the evaluation of developmental processes in the built environment. For us the sustainability evaluation is a terrain for experimenting conceptual, methodological and operational advancements in regenerative sustainability. In fact, *reliability* is a crucial concept in our evaluation model to stimulate a fluid transition from lower to upper levels of sustainability paradigms and approaches. For these reasons, our method can be easily associated to current evaluation systems exceeding their boundaries.

References

Ahmad, W., Soskolne, C.L., Ahmed, T., 2012. Strategic thinking on sustainability: challenges and sectoral roles. Environ. Dev. Sustainability 14, 67–83.

Ahn, Y.H., Pearce, A.R., Wang, Y., Wang, G., 2013. Drivers and barriers of sustainable design and construction: the perception of green building experience. Int. J. Sustainable Build. Technol. Urban Dev. 4, 35–45.

Alberti, M., 2015. Eco-evolutionary dynamics in an urbanizing planet. Trends Ecol. Evol. 30, 114–126.

Audi, R., 2009. Reliability as a virtue. Philos. Stud. 142, 43–54.

Blowers, A., Boersem, J., Martin, A., 2012. Is sustainable development sustainable? J. Integr. Environ. Sci. 9, 1–8.

Brenner, N., Schmid, C., 2013. Planetary urbanization. In: Brenner, N. (Ed.), Implosions/Explosions. Towards a Study of Planetary Urbanization. Berlin: Jovis, Berlin, pp. 160–163.

Brenner, N., Schmid, C., 2015. Towards a new epistemology of the urban? Cities 19, 151–182.

Chakrabarty, D., 2009. The climate of history: four theses. Crit. Inquiry 35, 197–222. Available online: http://www.law.uvic.ca/demcon/2013%20readings/Chakrabarty%20-%20Climate%20of%20 History.pdf (accessed on 12 December 2015).

Cole, R.J., 2012a. Regenerative design and development: current theory and practice. Build. Res. Inf. 40, 1–6.

Cole, R.J., 2012b. Transitioning from green to regenerative design. Build. Res. Inf. 40, 39–53.

Cole, R.J., 2013. Rating systems for sustainability. In: Loftness, V., Haase, D. (Eds.), Sustainable Built Environments. Springer, New York Dordrecht Heidelberg London, pp. 464–477.

Cole, R.J., Oliver, A., Robinson, J., 2013. Regenerative design, socio-ecological systems and co-evolution. Build. Res. Inf. 41, 37–47.

Conte, E., Monno, V., 2012. Beyond the building centric approach: a vision for an integrated evaluation of sustainable buildings. Environ. Impact Assess. Rev. 34, 31–40.

du Plessis, C., 2012. Towards a regenerative paradigm for the built environment. Build. Res. Inf. 40, 7–22.

Eames, M., Dixon, T., May, T., Hunt, M., 2013. City futures: exploring urban retrofit and sustainable transitions. Build. Res. Inf. 41, 504–516.

Gandy, M., 2004. Rethinking urban metabolism: water. Space Mod. City 8, 363–379.

Gandy, M., 2006. Urban nature and the ecological imaginary. In: Heynen, N.C., Kaika, M., Swyngedouw, E. (Eds.), In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism. Routledge, Abingdon, pp. 62–72.

Garcia, G., Abajo, B., Olazabal, M., Herranz, K., Proy, R., García, I., et al., 2008. A step forward in the evaluation of urban metabolism: definition of urban typologies. In: Havránek, M., Špot, M., Škopková, H. (Eds.), ConAccount 2008 Book of Proceedings, Urban Metabolism: Measuring the Ecological City, Prague, Czech Republic, 11–12 September 2008, pp. 4–20.

Giama, E., Papadopoulos, A.M., 2012. Sustainable building management: overview of certification schemes and standards. Adv. Build. Energy Res. 6, 242–258.

Godfrey, P., 2010. Using systems thinking to learn to deliver sustainable built environments. Civ. Eng. Environ. Syst. 27, 219–230.

Guy, S., 2011. Designing fluid futures: hybrid transitions to sustainable architectures. Environ. Innovation Soc. Trans. 1, 140–145.

Hassler, U., Kohler, N., 2014. Resilience in the built environment. Build. Res. Inf. 42, 119–129.

Hecht, A.D., Fiksel, J., Fulton, S.C., Yosie, T.F., Hawkins, N.C., Leuenberger, H., et al., 2012. Creating the future we want. Sustainability: Sci. Practice Policy 8, 62–75. Available online: http://sspp.proquest.com/archives/vol8iss2/1203-002.hecht.html (accessed on 12 June 2015).

Henry, A., 2014. Urban space in perspective: an interview with Matthew gandy. Alternate Routes: J. Crit. Social Res. 25, 253–257.

Heynen, N., Kaika, M., Swyngedouw, E., 2006. Urban political ecology: politicizing the production of urban natures. In: Heynen, N.C., Kaika, M., Swyngedouw, E. (Eds.), In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism. Routledge, Abingdon, pp. 1–19.

Kaika, M., Swyngedouw, E., 2014. Radical urban political-ecological imaginaries planetary urbanization and politicizing nature. Eurozine, 1–6 (available online http://www.eurozine.com/pdf/2014-05-14-swyngedouw-en.pdf [accessed on 24/11/2015]).

Kajikawa, Y., Inoue, T., Goh, T.N., 2011. Analysis of building environment assessment frameworks and their implications for sustainability indicators. Sustainability Sci. 6, 233–246.

Kennedy, C., Cuddihy, J., Engel-Yan, J., 2007. The changing metabolism of cities. J. Ind. Ecol. 11, 43–59.

Kennedy, C., Pincetl, S., Bunje, P., 2011. The study of urban metabolism and its applications to urban planning and design. Environ. Pollut. 8–9, 1965–1973.

Kissinger, M., Rees, W.E., 2010. An interregional ecological approach for modelling sustainability in a globalizing world – reviewing existing approaches and emerging directions. Ecol. Model. 221, 2615–2623.

Komeily, A., Srinivasan, R.S., 2015. A need for balanced approach to neighborhood sustainability assessments: a critical review and analysis. Sustainable Cities Soc. 18, 32–43.

Kumar Singh, R., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2012. An overview of sustainability assessment methodologies. Ecol. Ind. 15, 281–299.

Lebel, L., 2006. The politics of scale in environmental assessments. In: Reid, W.V., Berkes, F., Wilbanks, T.J., Capistrano, D. (Eds.), Bridging Scales and Knowledge Systems: Concepts and Applications in Ecosystem Assessment. Island Press, Washington, D.C., USA, pp. 37–57.

Lewis, J.O., Ní Hógáin, S., Borghi, A., 2013. Building energy efficiency in European cities. Cities of Tomorrow-Action Today. URBACT II

Capitalisation 2013. Available online: http://urbact.eu/sites/default/files/import/general_library/19765_Urbact_Crosscutting_low_FINAL.pdf (accessed on 12 June 2015).

Magee, L., Scerri, A., James, P., Thom, J.A., Padgham, L., Hickmott, S., et al., 2013. Reframing social sustainability reporting: towards an engaged approach. Environ. Dev. Sustainability 15, 225–243.

Mang, P., Reed, B., 2012. Designing from place: a regenerative framework and methodology. Build. Res. Inf. 40, 23–38.

Mang, P., Reed, B., 2013. Regenerative development and design. In: Loftness, V., Haase, D. (Eds.), Sustainable Built Environments. Springer, New York Dordrecht Heidelberg London, pp. 478–501.

Moffatt, S., Kohler, N., 2008. Conceptualizing the built environment as a social-ecological system. Build. Res. Inf. 36, 248–268.

Monno, V., Conte, E., 2015. Sustainability in the built environment: integrating scales of action and evaluation. Eur. J. Sustainable Dev. 4, 51–60.

Pedersen Zari, M., 2015. Ecosystem services analysis: mimicking ecosystem services for regenerative urban design. Int. J. Sustainable Built Environ. 4, 145–157.

Pincetl, S., Bunjeb, P., Holmesc, T., 2012. An expanded urban metabolism method: toward a systems approach for assessing urban energy processes and causes. Landscape Urban Planning 107, 193–202.

Quental, N., Lourenco, J.M., Nunes da Silva, F., 2011. Sustainability: characteristics and scientific roots. Environ. Dev. Sustainability 13, 257–276.

Rapoport, E., Interdisciplinary perspective on urban metabolism. A review of the literature. UCL Environmental Institute Working Paper 2011. Available on line: <https://www.bartlett.ucl.ac.uk/dpu/urban-metabolism/project-outputs/UM_Lit_Review_final.pdf> (accessed on 12 June 2015).

Robinson, J., Cole, R.J., 2015. Theoretical underpinning of regenerative sustainability. Build. Res. Inf. 43, 133–143.

Sarkis, J., Meade, L.M., Presley, A.R., 2012. Incorporating sustainability into contractor evaluation and team formation in the built environment. J. Cleaner Prod. 31, 40–53.

Singer, M., 2010. Economics: are the planet-unfriendly features of capitalism barriers to sustainability? Sustainability 2, 127–144.

van Opstal, M., Hugé, J., 2013. Knowledge for sustainable development: a worldviews perspective. Environ. Dev. Sustainability 15, 687–709.

WCED. Our Common Future. Report of the World Commission on Environment and Development. UN Documents 1987. Available on line: http://www.un-documents.net/wced-ocf.htm (accessed on 12 June 2015).

Wolman, A., 1965. The metabolism of cities. Sci. Am. 213, 179–190.

Zio, E., 2009. Reliability engineering: old problems and new challenges. Reliab. Eng. Syst. Saf. 94, 125–141.

Zurlini, G., Petrosillo, I., Cataldi, M., 2008. Socioecological systems. In: Jørgensen, S.E., Fath, B.D. (Eds.), Systems Ecology, Encyclopedia of Ecology, vol. 4. Elsevier, Oxford, pp. 3264–3269.