Thinking Sustainability + Resilience _
Built Environment in Transition

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ABSTRACT **The dynamics of societies and their living environments bring many expected and unexpected changes that need to be considered in order to achieve sustainable development. These changes, their prediction, and the mitigation of their negative impact, are related to the concept of resilience. Starting from the assumption that sustainability and resilience represent two different but complementary approaches, this work aims to clarify their notions and interrelations and to discuss their concurrent, systemic use in the processes of planning, designing and managing the built environment. The work initially studies the context of the built environment affected by sustainability and resilience frameworks, and reveals that there exist different scales to which these two approaches should be applied. Several interconnected disciplines are taken into consideration to present the notions of sustainability and resilience, their application in the context of the built environment and their significance for future development. Based on a comprehensive literature review, some possibilities for transitioning towards sustainability + resilience, i.e. towards improving the ability to respond to disruptions and hazards, and to enhance human and environmental welfare, are discussed.**

KEYWORDS sustainability, resilience, built environment, urban transitions, transdisciplinarity

1 Introduction

Social development directly relates to the development of the *built environment*. In just the last few decades, unprecedented urbanisation has resulted in the transformation of the planet to become predominantly urban (Meerow, Newell, & Stults, 2016). The growth of the urban population raises new resource needs and activates new changes in the environment (Boyle et al., 2010). A growing urban society brings an increase in population density, cultural diversity, and service demands. Increasingly complex human urban systems directly affect infrastructure systems, and vice versa. Infrastructure systems further influence the design and management of physical, social, and natural components of the built (living) environment, their mutual relations, and the mechanisms for future development.

*Sustainabilit*y is a widely applied term in numerous disciplinary fields. Although originating from the context of global development (WCED, 1987), sustainability became indispensable to communities, governments, agencies, and businesses (Pickett, McGrath, Cadenasso, & Felson, 2014). The relations between environmental, social, and economic pillars of sustainability can be expressed in many different ways (Doppelt, 2008), and power, social, and political interconnections, as well as the perception of inner workings of material and biological systems (Pincetl, 2012), are at their core. The details of such workings are essential for the successful implementation of sustainability plans. To that end, even though sustainability aims to provide prosperous social and economic development, it is first understood as a set of ecological principles regarding resource efficiency and conservation, green infrastructure, transport issues, waste treatment, etc. (Munier, 2011).

The term *resilience* is equally widespread in various fields. Accordingly, (too) many different interpretations of resilience (Vale, 2014) have emerged. In the context of the built environment, resilience is pivotal to proper the interpretation and management of complexity, dynamics, and adaptation at different scales. As a principle in building design, resilience traditionally belongs to construction knowledge that dealt with oversizing the components and spaces, reparability, and redundancy. Traditional dimensioning rules were replaced with the modern engineering concept of resilience aimed at simultaneously reducing material utilisation, and optimising structural safety. Nonetheless, Hassler and Kohler (2014a) note that these two notions are not the same and even can be contradictory; while the first provides a specifically tailored solution to a particular brief and a set of functions, the second notion is provided for unknown uses and adaption. The development of the concept of resilience, according to the authors, requires a move from the approach of maintaining stability to one that expressly acknowledges a dynamic adaptive system with multiple equilibria (Hassler & Kohler, 2014a).

This work has emerged from the need to correlate sustainability and resilience within the research boundaries of the built environment and to examine the possibilities for an integrated application of the two approaches. Following Chapters 1 and 2 of this book, the research starts with the assumption that sustainability and resilience (in the context of the built environment) are two different, yet complementary, approaches. The work provides general explanations, correlations, and comparisons between resilience and sustainability, discusses the context of the built environment and describes components of it that are affected by sustainability and resilience. The study then connects the two approaches and the components of the built environment through a comprehensive review of the state-of-the-art literature and knowledge, and finally considers some strategies and measures for successful transition towards a more sustainable and resilient built environment.

2 Sustainability vs. Resilience

In literature, resilience and sustainability are defined in different ways – some more metaphorical (normative), others more specific and empirical (descriptive) (Chapters 1 and 2 of this book). Some researchers explore them separately, trying to make a clear delineation, while others consider them in combination. For example, resilience theory can be understood as a component, a subset of the broader concept of sustainability science (Folke, 2016), or as an equivalent to sustainability (Holling & Walker, 2003). However, resilience can also be interpreted as a new and a more advanced paradigm (Cascio, 2009).

SUSTAINABILITY APPROACH	RESILIENCE APPROACH
Dominantly accepted and developed in social sciences	Dominantly accepted and developed in ecology
Goal: economic efficiency, human well-being and social justice, environmental sustainability	Goal: ecological, economic, and social sustainability
Stability, predictability	Change, uncertainty, unpredictability
Optimised efficiency of functions leading to sustainability	Maintained system dynamics, existence of function and processes in order to withstand the unexpected
Focus on 'vulnerability' of current flawed state of a system	Focus on 'resilience' – adaptive capacity of a system to cope with unknown futures
Seek for optimal stable state	Multiple stable states are possible – system is in constant non-equilibrium (adaptive cycle, panarchy)
Future options systematically examined and forecasted	Developed absorptive, adaptive and transformative capacity of a system to cope with unpredictable future
Result is predetermined – desirable future based on collective decisions, socially constructed values and/or previously acquired knowledge	Result is not predetermined – flexibility is ensured through the adaptive management of a system based on feedbacks and acquired knowledge in management process – "learning by doing"
Emphasis put on 'outcomes/products'	Emphasis put on 'process'

TABLE 2.1 Sustainability vs. resilience

Resilience and sustainability have a lot in common, and so they are sometimes used interchangeably. Despite the similar goals, there exist some clear distinctions between the two approaches. Key delineations relate to general standpoints, focuses, ways of envisioning or managing the future, understanding of the system behaviour, and the types of outcomes resulting from these differences. Thus, the fundamental difference between sustainability and resilience lies in the general, normative field (Table 2.1).

A specified (descriptive) definition of resilience does not necessarily conflict with sustainability; moreover, they could be seen as complementary approaches. When understood as a desirable system property/state, resilience represents a crucial prerequisite for achieving sustainability and sustainable development (Folke, Carpenter, Elmqvist, Gunderson, Holling, & Walker, 2002). However, unlike sustainability, which is always given a positive perspective, resilience can also be undesirable (Carpenter, Walker, Anderies, & Abel, 2001). In other words, a system can be resilient both in a desirable and in an undesirable state. Being resilient is not necessarily a good thing (Holling & Walker, 2003). To sum up, resilience can be understood as both a metaphorical/ general and specific/operational concept; as a way of thinking – an approach to managing the changes on the one side, and a feature/state of the system that is being assessed, addressed, or achieved on the other side. Although its normative dimension is often contested in the context of sustainability, the resilience approach is normative "at least as much as sustainable development is" (Pisano, 2012).

3 Affected Context of the Built Environment

To provide clarity regarding the notion of resilience, its relation to sustainability, and the links between the two concepts at different scales, it is necessary to give a description of the affected (encompassed) context of the built environment. Basically, built environment includes hard and soft infrastructures, and the community (Anderies, 2014; Hassler & Kohler, 2014a). Hard infrastructure comprises buildings, building networks, physical support systems etc., and soft infrastructure comprises values, knowledge, governance, rules, and institutions. Built environment also includes the 'unbuilt' segment, i.e. the natural environment. The components of the built environment, either public or private but nonetheless tightly interconnected, should be observed as parts of the whole, and not as isolated or independent segments. To that end, Anderies (2014) specifically points at the need for collaboration between social and ecological worlds, as a means of providing ecosystem services inside the network of connections. Considering that the complexity of a system is determined by its composition and dynamics, built environment can be studied at different scales that refer to an ecosystem type – buildings, building stocks, neighbourhoods, cities, and regions. As the scale of the built environment grows, it must be viewed as being embedded in a broader natural system (Anderies, 2014).

Resilience thinking is very significant within the context of the built environment. The resilient built environment should be characterised by persistence and transformation within a self-organising system, with a strong focus on managing principles for natural systems that can, sometimes irrevocably, "move from one stable regime to another" (Anderies, 2014). Instead of linear flows, systems are constantly changing in nonlinear ways (Meerow et al., 2016). For Hassler and Kohler (2014a), "the concepts of time have a considerable role in the description and in the dynamic of the built environment. In the case of disasters, the time constant is small and sudden. There is a possibility for immediate feedback and understanding the mechanism in detail. There are numerous analogies between the dynamic of very different systems and it is possible to learn from disasters, to reduce vulnerability and design anticipation strategies. However, for slow-moving risks that affect part of the built environment with high time constants (decades, centuries), the possibilities for prediction and anticipation are reduced." An efficient response needs to involve both resilience heuristics and anticipation measures (Hassler & Kohler, 2014a). Anderies (2014) has framed the overall system of interest and identified "practical design features known to promote robustness/resilience, independent of time scale or level of organization", including: redundancy, modularity, and diversity in components or connections.

Redundancy enables the continued functioning of a system in the case of subsystems' failure. It is typically used in biological systems and engineered infrastructure. Since redundancy requires considerable performance and investment costs, its inclusion in wide-ranging built environment systems is questionable.

Different functional modules within a system are provided by modularity. To a certain extent, modules can develop independently. The failure of one module does not endanger other modules if they are loosely linked by design. Designing the sufficient links between the modules affects learning from the activities that occur within other modules. This characteristic refers to the polycentricity.

Diversity provides the capacity to create novelties within a modular system of the built environment, so that the individual modules could be tested without interfering with other modules. The problems in creating the diversity of modules, such as neighbourhoods, public spaces, work areas, etc., relate to extremely high costs and benefits that could be difficult to define.

4 Disciplinary Perspectives

From the ecological science perspective, Pickett et al. (2014) have researched how a general resilience concept could be applied to increase the resilience of the built environment. In this study, resilience is presented as a key conceptual and modeling framework for operationalising (facilitating or inhibiting) sustainability, with sustainability described as a normative, socially derived goal, combining ecological integrity, social equity, and economic viability. "A contemporary theory of ecological resilience starts with the basic idea that internal and external drivers of system structure and activity are a changing template to which successful systems must adjust." (Picket et al., 2014) Resilience, as the ability of a system to conform to all forms of disruptions and shocks without disturbing its fundamental structure and processes, emerges from synergy between the connectedness within that system and the accumulated wealth. As such, resilience is focused on the relationship between change agents and system capacities. The interpretation given can be summarised as a flexible, *adaptive cycle,* which traces system dynamics in three-dimensional space, determined by resilience, connectedness, and capital or wealth (Pickett et al., 2014) (see Chapter 2 of this book).

As a system becomes more connected, it is more prone to shocks, granted that modularisation does not prevent the generation of negative effects (Pickett et al., 2014). High but equally connected systems and high but fixed wealth are connected to poor ability to acclimate to disturbance, i.e. low resilience. The adaptive cycle occurs in different, but connected, patches that constitute shifting urban mosaics (Hassler & Kohler, 2014a).

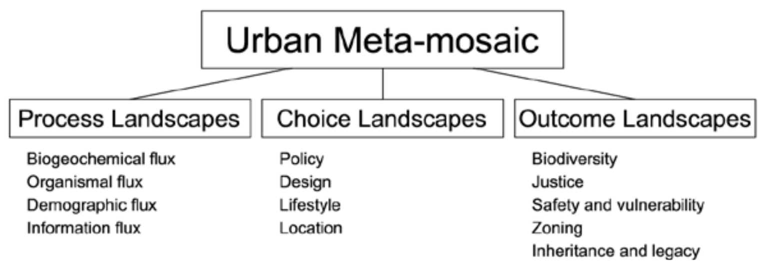

FIG. 4.1 Metacity: Hierarchical diagram *(McGrath & Pickett, 2011)*

Interacting mosaics determine a 'metacity', an open-ended, porous, and dynamic model appropriate for the understanding of urban transformation at multiple scales and across the globe (Fig. 4.1). A large-scale urban meta-mosaic consists of distinct patches with peculiar structure, established interactions with distant and neighbouring patches, and divergent porous boundaries. The patches can evolve over time, following the dynamic types incorporated in the adaptive cycle. A metacity is composed of a spatially and temporally shifting mosaic of patches. Key tools used to combine ecological thinking on resilience and social deliberations involve: the new idea of metacity, landscape/path ecology, the design and assessment of ecological models, and the use of designs as experiments.

While ecological resilience underlines the capacity of the site to adapt to external changes and disturbances in controlling interactions, 'engineering resilience' underlines the capability of returning to a state that existed prior to disturbance (Pickett et al., 2014). On the other hand, 'resilience engineering' is, according to Hollnagel (2011), the capacity of the system to sustain the required operations under expected, as well as the unexpected, conditions by adjusting its operating, before, during, or after the occurrence of disturbances, shocks, or changes. So, resilience is not so much a characteristic or a quality as it is a feature of behaviour or performance of a system. A built system is considered resilient if it possesses the ability to monitor, anticipate, respond, and learn. Regarding the level of a built system en masse, it is possible to use resilience engineering to propose appropriate steps for improvement, depending on the characteristics of a particular field of activity (Hollnagel, 2014). Ascertaining the significance and the right proportion of the main abilities is necessary for any organisation or domain. The prerequisite for establishing a resilient system is that none of the abilities are excluded. All abilities must be able to address what happens within and without the system boundary (Hollnagel, 2014). Survival is enabled thanks to the anticipation of what may happen outside the system boundary, now and in the future. Therefore, it is more significant to understand the operation and purpose of the system than the structure or components, and to focus on its ability to withstand threats and use favourable circumstances. For built environment that is referred to as a socio-technical system, built in order to provide a particular service or functionality, resilience is not just a problem of sustainability and disaster risk management. It is a matter of sustaining the necessary operations under expected, as well as unexpected, conditions, which are also opportunities rather than only threats. A built system that is incapable of recognising and learning from opportunities will eventually prove to be no better than a system that cannot respond to disruptions and threats (Hassler & Kohler, 2014a).

Hassler and Kohler (2014a, 2014b) have analysed the context of the sustainable, lasting management of the built environment that consists of an array of capitals (such as physical, natural, social, economic, and cultural), and brought resilience into context with other long-lasting concepts of stability, continuity and equilibrium, durability and duration, vulnerability and robustness, as well as slow and fast-moving risks. By reviewing vulnerability and continuity, the authors have revealed that the notion of resilience evolves according to the differences in scale, from an engineering definition at the level of a building to an ecosystem definition, devoting special attention to the neighbourhood, city, and regional levels. Different scales have different time constants; regarding capitals, it is possible to connect time scale categories with different dimensions (Hassler & Kohler, 2014b). "As a design principle, resilience increases according to the expectations for time scale (longevity) and can be used as a central timing and memory concept". (Hassler & Kohler, 2014b) Considering that anticipation could only refer to shorter intervals and related dimensions and scales, it presents a strategy which permits a quick reaction and a fast learning process fundamental to risk management. Reducing vulnerability and increasing resilience depends upon progressive increase of control in practical and conceptual ways, such as scenarios, future options, time horizons, etc.

In view of the interpretation derived by Hassler and Kohler (2014b), resilience becomes a superior guiding principle that utilises lessons from lasting surviving systems and incorporates limited ability to predict the future. Namely, the built environment is in danger of both fast-moving and slow-moving risks whose profiles are different and thus require distinct, separate approaches. "Although a system may have some adaptive capacities, this does not guarantee the quality of the subsequent situation." (Hassler & Kohler, 2014b) Here, natural and cultural capitals are central aspects of resilience because they cannot be replaced or reproduced. In this sense, resilience would allow a rising value of the human-made capital and positive feedback loops for natural and cultural capitals. Resilience can be put into use when referring to some forms of clearly defined social or ecological systems, but for built environment and other more intricate systems, no simple modes or metrics are available. An anticipation-based strategy is attainable for more or less known threats, by increasing the adaptive capacity and reducing the vulnerability. Due to unknown threats, their combination, or reactions of the built environment to human-made and natural disruptions, tackling uncertainty can only rely on heuristics obtained during the observation of successful outcomes (Hassler & Kohler, 2014b). Resilience does not have much to do with the precise definition of social or ecological systems in this sense, but is more a rule of design for such intricate systems. Instead of a descriptive concept, resilience becomes a standardising one (Brand & Jax, 2007).

For Moffatt (2014), resilience and sustainability are processes that depend highly upon the framing and interpretation of the notions of time. At their very core is an innovative outlook on how humankind perceives and values the future. Resilience and sustainability are attempts to redefine the time concept, because in the modern age time concepts generally favour present over future, which is called time preference. Both approaches share low time preference, i.e. slow change. If built environment fails to recover losses and endure a reasonable time period, then it is neither resilient nor sustainable (Moffat, 2014). The notion of sustainability recalls a static perspective aiming at an immutable and stable future (Hassler & Kohler, 2014a). Sustainability, even though it is often viewed and characterised in utopian terms, is actually based on a single slow-moving disaster scenario where humanity exhausts all critical physical resources or miscalculates the ecological carrying capacity (Moffatt, 2014). On the other hand, resilience presents a more dynamic outlook on the future; risks, surprises, and uncertainty are viewed as the norm, and the increasing size, intricacy, and co-dependencies of the built environment create an increasing frequency, severity, and diversity of disaster scenarios (Hassler & Kohler, 2014a). The inherent capacity of built environments and their socio-economic systems to adapt and recover from change and loss, proactive policies, and foresight may, in fact, dictate the quality of life in such a dynamic future (Cole, 2012).

The incorporation of resilience within urban plans, requires that time frames, as well as the expert teams, must be determined. With the passage of time, the likelihood of various disaster types and uncertainty rise. The teams of experts indicate transdisciplinarity, having regarded that, for achieving sustainability goals, the disturbances and shocks of every sector have to be considered. For the goals regarding biodiversity, air quality, water quality, preservation, and increment of green spaces, etc., potential threats refer to climate change, earthquakes, tsunamis, floods, etc. Liveability, health, security, and choice within the social goals could be threatened by sabotage, crime, civil unrest, war, computer viruses, etc. Achieving economic goals such as community development, assets, work opportunities, and prosperity is also threatened by urban development, loss of critical revenue, global financial system, or the disruption to trade. Nonetheless, the identification of all potential threats is not possible, considering that the further research brings the uncovering of more threats (Moffatt, 2014).

Bosher (2014) has determined 'built-in resilience' through the reduction of disaster risks, and defined it as an ability of the built environment to continue to conform to current and developing threats, a quality considered in social, physical, institutional, and economic terms. Bosher (2014) noted that, for disaster risk reduction, the required information needs to be contextually specific. Local knowledge is crucial to correctly ascertain risk levels and options to further reduce risks. If levels of risk are considered important, the risk could be reduced, eliminated, transferred, or controlled in various ways. The classification of typical risk reduction options implies:

- inherent safety (refers to the elimination of the possibility of occurrence of threats/hazards);
- prevention (refers to the reduction of the expectance of possible threats/hazards);
- detection (refers to securing measures for early warning of imminent disasters);
- control (refers to the limitation of the hazards' magnitude);
- mitigation and adaption (refers to retrospective or proactive protection from the damage effects of hazards); and
- emergency response (refers to organisation of evacuation and access for emergency services) (Bosher, 2014).

The classification is made according to the preference, so the first to be addressed should be 'inherent safety', indicating that the threats and hazards should be eliminated. This can be possible for some hazards, such as certain floods and fires, but not for some others, unless the built assets are relocated to areas not disposed to disasters. Although some risk reduction options may be suitable for one kind of hazard, they may not be appropriate for other types. Therefore, the assessment of multi-threats/hazards needs to be undertaken, and any threat reduction recourse should be proportionately examined alongside any other threats that have been identified. This indicates that the decision-making processes need to involve a complex range of stakeholders. However, up to now, the research has shown that there is a large gap between the actual implementation and regulatory intentions. To bridge the theory and operationalisation, Bosher (2014) defines built-in resilience as a process, a quality, and an ultimate goal. The quality presents the capability to intuitively and proactively cope with an array of dynamic changes. In that way, a resilient built environment is in consensus with sustainable development.

Nicol and Knoepfel (2014) have studied housing stocks as parts of the built environment that is affected by resilience and sustainable development. To these authors, resilience and sustainable development are substantial generic postulates that cannot be applied directly;

instead, implementation could be possible through the institutional framework. Namely, a sustainability study involves a very systematic implementation of the framework of institutional regimes. In every stock, each service and good could be assessed in terms of sustainable use and the effect on the use of other services and goods. Regulations controlling every use should be analysed to assess whether incoherence in, or between, regulations could be producing unsustainable uses. Nicol and Knoepfel (2014) conclude that a more comprehensive understanding of the regulation of services and goods related to resilience is necessary, as is further research into determining the best kind of institutional conditions to ensure the maximal resilience of housing stocks.

5 Transitioning Towards Sustainable and Resilient Built Environment

Instructions for operationalising how built environments could progress to a more resilient future are presented as feasible facets for devising and sustaining the strategies of urban transition, including geospatial information and communication technologies (G-ICT), new design using collaborative responses, climate planning, limiting urban sprawl, short-circuit economic approaches (Collier et al., 2013) and green infrastructure planning.

G-ICT and spatial data infrastructures are supporting tools for sustainable development and urban resilience. Developed geospatial databases of cities improve the process of planning and facilitate e-planning (Wang, Song, Hamilton, & Curwell, 2007), and directly assist in providing crucial answers to the problems of sustainability and resilience, like resources depletion, climate change impact, and urban sprawl (Collier et al., 2013). Integrated planning relates to the utilisation of data represented in different scales and with boundaries obtained through analytical, institutional, and administrative processes, as well as the data defined ecologically, and a lot of textual, numerical, and graphical information from planning documents. G-ITCs are aimed at overcoming problems regarding integration of the data from various sources and securing their functional interoperability and formatting, by administering all facets of the planning process and allowing the application of various methods including visualisation, communication, and analysis.

A policy on transition towards sustainability and resilience should be communicated clearly, founded on deliberative processes, and informed by important interconnection between the stakeholders, thus ensuring their full participation. Given conditions ultimately imply a transdisciplinary approach (Collier et al., 2013), and a balance between scientific and non-scientific – local knowledge (Collier & Scott, 2009). Collaboration aims to stimulate the processes conceived and driven by citizens, promoted by a sizeable number of stakeholders and relied on existing social capital networks with continuing collaboration from management practice, novel design groups, and academic research

(Hostetler, Allen, & Meurk, 2011). Regarding the occurrence of threats or hazards (Kosanović, Hildebrand, Stević & Fikfak, 2015), continuity in planning and managing would help to overcome the lack of interest of stakeholders.

Collier at al. (2013) have explained that the challenges regarding climate city planning operationalisation need to be taken into consideration because the effects of natural hazards on global economies and cities will likely grow in the future for two complementary reasons. The first is that severity and frequency of climate related events are expected to rise. The other is that the economic impact might increase due to growing population and activity in vulnerable areas. Adaptation measures reduce transfer risks or potential damage and decrease the probability of disasters.

Planning for a climate resilient built environment is faced with further challenges regarding heat and energy management. Strategic energy planning aspires to lower the demand for end-use and to increase renewable energy shares, which further strengthens "urban energy resilience through lower long-term costs of running urban energy systems" (Collier et al., 2013). There is a need for implementing new infrastructure-related measures (e.g. water- or energy-related) through land use management and urban planning. As these measures imply changes in current land use, their success is very limited in urban areas. Where requirements for green areas, different building strategies, food protection, or water storage are in collision, the priorities in land use must be established. To support the adaptation planning, the assessment of urban functions and improved techniques for linked land use modelling are necessary.

Resilience and sustainability of the built environment should be analysed through spatial patterns derived from diverse policies and strategies for land use, in order to limit urban sprawl. This is important because urban density is a requisite factor of sprawl, and its increment could have a negative impact on urban development. According to Ostrom (2010), contemporary urban spatial patterns can be classified as 'dispersed city', 'compact city', and 'polycentric development'. Particular problems with city sprawl are related to the differences regarding economic and social opportunities and the varying environmental quality in certain parts of a city. The compact city model, as an alternative to sprawl issues and the dispersed city, is a mixture of land uses, growth within the city boundaries, and innovative and intensive use of urban space (Collier et al., 2013). On the other hand, the experience has pointed to some problems regarding overdevelopment and congestion without clear social benefits. In contrast, the idea of polycentricity promotes medium-sized cities, cooperation between urban areas, and endogenous potential, to concurrently fulfil the functionality and physically connect the regions. The central goal here should be to combine spatial and social cohesion with economic growth.

Besides previously mentioned spatial patterns, 'shrinking cities' are becoming a frequent problem of present times. Referring to Florentin

(2010), Vujičić & Đukić (2015) have pointed out that the shrinking city significantly deviates from the traditional concept of the compact city as an entirely new pattern of distribution of population and the economy. Lütke-Daldrup (2001) has depicted the spatial manifestation of this phenomenon as a 'perforated city', where spatial holes of abandoned land – so-called brownfields – dramatically degrade urban fabric. Considering the complexity of the problem, implementation of the resilience framework is central to the achievement of sustainability of these cities.

Recognising that social and economic legislation are slow to arise, or that they might have conflicting effects, reveals the challenges related to deficient management of transformations. These challenges irrevocably dissipate the land and seriously limit the opportunities to be granted to future generations, as well as to their welfare and socio-economic development. Hence, it is necessary to determine municipal accounting tools for land use and the availability of under-used and non-urban areas (Collier et al., 2013). Innovation opportunities and emerging economic tools would play a key role in resilience planning and would also create an opportunity to embed resilience in communities.

Urban greening is a potent measure for enhancing the sustainability and resilience of the built environment. The sufficient existence of greenery in urban areas gives numerous ecological benefits, such as: mitigation of the urban heat island (Goode, 2006); reduction of flood occurrence by runoff water retention; and improvement of water quality by purification (Vijayaraghavan, 2016); improvement of air quality and reduction of greenhouse-gas emissions (Rowe, 2011); noise reduction (Yang et al., 2012); support to biodiversity (Nurmi, Votsis, Perrels, & Lehvävirta, 2013), etc. By improving the existing green infrastructure, a number of additional social and economic benefits could be achieved. In already densely built urban spaces, the only way to achieve the benefits of greening is most often through the interventions on building envelope. With regard to the building stock, ecological performance would be improved with system application in any case, but for achieving social and economic benefits, some physical characteristics of the stock also need to be taken into consideration (Stamenković, Miletić, Kosanović, Vučković, & Glišović, 2017). To perform ecosystem functions, acting on the private property with greenery systems' interventions is required; in that way, the municipal ecological network (De Lotto, Esopi, & Strula, 2017) is being established. Green infrastructure can be optimised by mixing private and public initiatives and new technologies into a methodical strategy aimed at creating healthier, more sustainable, and resilient urban environments.

6 Discussion and Conclusions

In the last few decades, sustainability and resilience have become crucial concepts dedicated to responding to numerous looming challenges posed by environmental change and urbanisation. The approaches to sustainability and resilience are related to each other, but are neither identical nor interchangeable, due to the differences found in their foci, the way of envisioning or managing of future, the understanding of system behaviour, the dynamics and types of outcomes, i.e. the general standpoints, etc. To that end, Hassler and Kohler (2014a) have provided a central description of the conditional relationship between the two approaches, where sustainability has been identified as a group of protection goals addressing different types of capitals that need to be maintained for future generations, and resilience as a tool aimed at providing a mindset and a series of methods used to overcome difficulties regarding adaptation to current and future unknown changes. By handling these changes and managing the uncertainty, resilience becomes an instrument for operationalising sustainability over time.

The particular relationship between sustainability and resilience depends on the context to which these two concepts are applied, as well as on the disciplinary perspective taken (e.g. Pickett et al., 2014; Hollnagel, 2011; Moffat, 2014; Bosher, 2014). The achievement of a sustainable and resilient built environment presents a complex, long-time process due to a range of threats/hazards at different scales and the contributing involvement of all stakeholders. Collier et al. (2013) have assigned a central role to communities in fulfilling the transitioning objectives, accented the importance of transdisciplinary approaches, and proposed a set of strategic measures to achieve sustainable and resilient urban development, which have been discussed in this work.

Nonetheless, the measures for enhancing both sustainability and resilience also need to be custom-tailored, as every particular built system requires a specific kind of performance feedback. The context of the built environment, viewed through the lenses of sustainability and resilience, is multi-component. According to Anderies (2014), characteristic temporal and spatial scales, and their associated levels of organisation and scales of operation, together form the overall systems of interest, where resilience and robustness should be used in tandem to provide adequate responses to shorter-, intermediate-, and long-term design challenges. Additionally, the author has identified practical design features that were briefly debated in this paper, including: redundancy, modularity, and diversity in components or connections.

Although resilience is often perceived as "good", it can also be analysed from a less positive perspective. Hassler and Kohler (2014a) and Andereis (2014) have provided a thorough insight into the weaknesses in the current understanding of resilience and potential obstacles in the implementation of resilience-building policies and design measures. However, the development and implementation of the concept of resilience into sustainable development need to be encouraged without question because of their paramount importance for countering the complexity, changeability, and uncertainty affecting the built environment.

References

Anderies, J. M. (2014). Embedding built environments in social–ecological systems: resilience-based design principles. *Building Research & Information*, *42*(2), 130-142. http://dx.doi.org/10.1080/09613218.2013.857455

Bosher, L. (2014). Built-in resilience through disaster risk reduction: operational issues. *Building Research & Information*, *42*(2), 240-254. http://dx.doi.org/10.1080/09613218.2014.858203

Boyle, C., Mudd, G., Mihelcic, J. R., Anastas, P., Collins, T., Culligan, P., Edwards, M., Gabe, J., Gallagher, P., Handy, S., Kao, J., Krumdieck, S., Lyles, L. D., Mason, I., Mcdowall, R., Pearce, A., Riedy, C., Russell, J., Schnoor, J. L., Trotz, M., Venables, R., Zimmerman, J. B., Fuchs, V., Miller, S., Page, S., & Reeder-Emery, K. (2010). Delivering sustainable infrastructure that supports the urban built environment. *Environmental Science and Technology*, *44*, 4836-4840. DOI: 10.1021/es903749d

Brand, F., & Jax, K. (2007). Focusing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. *Ecology and society*, *12*(1), 23. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art23/

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: resilience of what to what?*Ecosystems*, *4*(8), 765-781. DOI: 10.1007/s10021-001-0045-9

Cascio, J. (2009). The next big thing: Resilience. *Foreign Policy, 172*, 92. Retrieved from http://www.openthefuture.com/media/FP-cascio.pdf

Cole, R. J. (2012). Transitioning from green to regenerative design. *Building Research & Information*, *40*(1), 39-53. http://dx.doi.org/10.1080/09613218.2011.610608

Collier, M. J., Nedović-Budić, Z., Aerts, J., Connop, S., Foley, D., Foley, K., Newport, D., McQuaid, S., Slaev, A., & Verburg, P. (2013). Transitioning to resilience and sustainability in urban communities. *Cities*, *32*, S21-S28. http://dx.doi.org/10.1016/j.cities.2013.03.010

Collier, M. J., & Scott, M. (2009). Conflicting rationalities, knowledge and values in scarred landscapes. *Journal of Rural Studies*, *25*(3), 267-277. http://dx.doi.org/10.1016/j.jrurstud.2008.12.002

De Lotto, R., Esopi, G., & Strula, S. (2017). Sustainable policies to improve urban ecosystem resilience. *International Journal of Sustainable Development and Planning*, *12*(4), 780-788. DOI: 10.2495/SDP-V12-N4-780-788

Doppelt, B. (2008). *The power of sustainable thinking:" how to create a positive future for the climate, the planet, your organization and your life"*. London, UK: Earthscan Publishing.

Florentin, D. (2010). The "perforated city": Leipzig's model of urban shrinkage management. *Berkeley Planning Journal*, *23*(1), 83-101. Retrieved from https://hal.archives-ouvertes.fr/hal-01265930/file/eScholarship%20UC%20item%2097p1p1jx.pdf

Folke, C. (2016). Resilience (Republished). *Ecology and Society, 21*(4):44. https://doi.org/10.5751/ES-09088-210444

Folke, C., Carpenter , S., Elmqvist , T., Gunderson, L., Holling , C. S., & Walker , B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *Ambio, 31*(5), 437-440. https://doi.org/10.1579/0044-7447-31.5.437

Goode, D. (2006). *Green infrastructure report to the Royal Commission on Environmental Pollution.* London, GB: Royal Commission on Environmental Pollution.

Hassler, U., & Kohler, N. (2014a). Resilience in the built environment. *Building Research & Information, 42*(2), 119-129. DOI: 10.1080/09613218.2014.873593

Hassler, U., & Kohler, N. (2014b). The ideal of resilient systems and questions of continuity. *Building Research & Information*, *42*(2), 158-167. http://dx.doi.org/10.1080/09613218.2014.858927

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual review of ecology and systematics*, *4*(1), 1-23. Retrieved from http://pure.iiasa.ac.at/26/1/RP-73-003.pdf

Holling, C., & Walker, B. (2003). Resilience defined. *Internet Encyclopedia of Ecological Economics.* International Society of Ecological Economics. Retrieved from http://www.ecoeco.org/pdf/resilience.pdf

Hollnagel, E. (2011). RAG – The resilience analysis grid. In E. Hollnagel, J. Paries, D. D. Woods,& J. Wreathall (Eds.), *Resilience engineering in practice: a guidebook* (pp. 275-296). Farnham, UK: Ashgate Publishing Limited.

Hollnagel, E. (2014). Resilience engineering and the built environment. *Building Research & Information*, *42*(2), 221-228. http://dx.doi.org/10.1080/09613218.2014.862607

Hostetler, M., Allen, W., & Meurk, C. (2011). Conserving urban biodiversity? Creating green infrastructure is only the first step. *Landscape and Urban Planning, 100*(4), 369-371. https://doi.org/10.1016/j.landurbplan.2011.01.011

Kosanović, S., Hildebrand, L., Stević, G., & Fikfak, A. (2015). Resilience of inland urban areas to disasters occurred due to extreme precipitations. *Open Urban Studies and Demography Journal*, *1*(1), 41-51. DOI: 10.2174/2352631901401010041

Lütke-Daldrup, E. (2001). Die perforierte Stadt. Eine Versuchsanordnung [The perforated city. A test arrangement]. *Stadtbauwelt*, *150*, 40-45. Retrieved from http://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/IzR/2003/Downloads/1_2Daldrup.pdf?__blob=publicationFile&v=2

McGrath, B., & Pickett, S. T. (2011). The metacity: A conceptual framework for integrating ecology and urban design. *Challenges*, *2*(4), 55-72. DOI:10.3390/challe2040055

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38-49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Moffatt, S. (2014). Resilience and competing temporalities in cities. *Building Research & Information*, *42*(2), 202-220. http://dx.doi.org/10.1080/09613218.2014.869894

Munier, N. (2011). Methodology to select a set of urban sustainability indicators to measure the state of the city, and performance assessment. *Ecological Indicators*, *11*(5), 1020-1026. https://doi.org/10.1016/j.ecolind.2011.01.006

Nicol, L. A., & Knoepfel, P. (2014). Resilient housing: a new resource-oriented approach. *Building Research & Information*, *42*(2), 229-239. http://dx.doi.org/10.1080/09613218.2014.862162

Nurmi, V., Votsis, A., Perrels, A., & Lehvävirta, S. (2013). *Cost-benefit analysis of green roofs in urban areas: case study in Helsinki.* Helsinki, FI: Finnish Meteorological Institute.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, *20*(4), 550-557. https://doi.org/10.1016/j.gloenvcha.2010.07.004

Pickett, S. T., McGrath, B., Cadenasso, M. L., & Felson, A. J. (2014). Ecological resilience and resilient cities. *Building Research & Information*, *42*(2), 143-157. http://dx.doi.org/10.1080/09613218.2014.850600

Pincetl, S. (2012). Nature, urban development and sustainability – What new elements are needed for a more comprehensive understanding? *Cities*, *29*(S2), S32-S37. https://doi.org/10.1016/j.cities.2012.06.009

Pisano, U. (2012). *ESDN Quarterly Report N°26 - Resilience and sustainable development: Theory of resilience, systems thinking and adaptive governance.* ESDN - European Sustainable Development Network. Retrieved from http://www.cjwalsh.ie/wp-content/uploads/2013/01/ESDN_Resilience-and-Sustainable-Development_September-2012.pdf

Rowe, D. B. (2011). Green roofs as a means of pollution abatement. *Environmental Pollution*, *159*(8), 2100-2110. https://doi.org/10.1016/j.envpol.2010.10.029

Stamenković, M. G., Miletić, M. J., Kosanović, S. M., Vučković G. D., & Glišović, S. M. (2017). The impact of a building shape factor on energy performance in the green roof concept implementation. *Thermal Science*, OnLine-First (00), 205. http://www.doiserbia.nb.rs/img/doi/0354-9836/2017%20OnLine-First/0354-98361700205S.pdf

Vale, L. J. (2014). The politics of resilient cities: whose resilience and whose city? *Building Research & Information*, *42*(2), 191-201. http://dx.doi.org/10.1080/09613218.2014.850602

Vijayaraghavan, K. (2016). Green roofs: A critical review on the role of components, benefits, limitations and trends. *Renewable and Sustainable Energy Reviews*, *57*, 740-752. https://doi.org/10.1016/j.rser.2015.12.119

Vujičić, T. M., & Đukić, A. (2015). Methodological framework for shrinking cities case study research: northwest region of Bosnia and Herzegovina. *Geodetski vestnik, 59*(3), 520-536. DOI: 10.15292/geodetski-vestnik.2015.03.520-536

Wang, H., Song, Y., Hamilton, A., & Curwell, S. (2007). Urban information integration for advanced e-Planning in Europe. *Government Information Quarterly*, *24*(4), 736-754. https://doi.org/10.1016/j.giq.2007.04.002

WCED - World Commission on Environment and Development. (1987). *Our common future: Report of the 1987 World Commission on Environment and Development*. Oxford, UK: Oxford University Press.

Yang, H. S., Kang, J., & Choi, M. S. (2012). Acoustic effects of green roof systems on a low-profiled structure at street level. *Building and Environment*, *50*, 44-55. https://doi.org/10.1016/j.buildenv.2011.10.004