DESIGNING RESILIENCE

Strategies for the sustainable development and understanding of urban complexity

a cura di
F. Mosca
G. Oneto

GENOVA UNIVERSITY PRESS

ADDDOCS
DOCUMENTS
3

Collana / Collection
ADDDOCS Documents - Quaderni di Dottorato

Dottorato in Architettura e Design
Dipartimento Architettura e Design
UniGe – Università degli Studi di Genova

DESIGNING RESILIENCE

Strategies for the sustainable development and understanding of urban complexity

a cura di
F. Mosca
G. Oneto

GENOVA UNIVERSITY PRESS

GENOVA UNIVERSITY PRESS
è il marchio editoriale dell'Università di Genova
Università di Genova

I contributi qui pubblicati sono stati selezionati dal Comitato Scientifico del Convegno

e-ISBN (pdf) 978-88-3618-337-1

Pubblicato a ottobre 2025

Realizzazione Editoriale
GENOVA UNIVERSITY PRESS
Via Balbi 5, 16126 Genova
Tel. 010 20951558
e-mail: gup@unige.it
https://gup.unige.it

INDICE

CHAPTER 1. DESIGNING RESILIENCE

Francesca Mosca[1], Gabriele Oneto[2]

1. Exploring the concept of resilience

With the meaning of 'the ability to withstand impacts without breaking' the word resilience has gained surprising popularity in recent decades.

Like many scientific terms, resilience has a Latin origin: the verb *resilire* is formed by adding the prefix re- to the verb *salire*, meaning 'to jump, to spring forth,' with the immediate sense of 'to jump back, to return quickly, to rebound' but also the transferred sense of 'to retreat, to contract' (Oxford Latin Dictionary, Fascicle VII, edited by P.G.W. Glare, Oxford University Press 1980, translated).

From a scientific perspective, the concept of resilience has been embraced by various disciplines and fields of study, ranging from engineering and materials science to psychology and ecology. A positive connotation has been attributed to the meaning of resilience, specifically regarding the ability of a system (city,

environment, individual, element) to adapt to changing conditions due to external stresses. For a shocked system, resilience represents the capacity for adaptation and transformation in response to stress while maintaining its essential functions and identities (Steven *et al.* 2014).
In physics and engineering, for example, resilience indicates the ability of a material to resist an impact, absorbing the energy that can be released to varying degrees after deformation. This aspect is also related to other characteristics of materials, such as adaptive, or flexible, highlighting the continuous flow of energy which characterizes all the natural processes on earth (Xue *et al.* 2018).

The concept of resilience has gained increasing attention in recent years to address the challenges and uncertainties that cities are facing in the 21st century. A first comprehensive definition of resilience for urban habitats has been provided by the United Nations Office for Disaster Risk Reduction (UNDRR):

> *The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.* (UNDRR, 2007).

More recently, the European Union has defined resilience as the ability not only to withstand and cope with challenges but also to undergo transitions, in a sustainable, fair, and democratic manner (EU, 2020 Strategic Foresight Report).
The necessity of having a common definition of the concept is also related to the fact that the current environmental degradation is having a great impact on worldwide urban systems, from not only the environmental perspective but also the economic and social ones. The increasing frequency of external stresses and extreme events have posed the need for adaptation strategies: in this framework, the temporal variable is crucial.

Indeed, the concept of resilience and that of time are closely interdependent and correlated. The increase in frequency and duration of external events that cause stress on the analysed system implies the need for this system to be resilient in relation to these variables, thus requiring an adequate response time to the temporal interval with which the external agent acts. Also, the resilience of a system also relies on its ability to return to a state of equilibrium after the disturbing event, and on the time-frame, it takes to achieve this new status (Meerow *et al.* 2016). Furthermore, the concept of resilience is meaningful only when referred to a specific objective, depending on the reference field. The research question should always be 'resilient with regard to what?', depending on the most critical aspects and external stresses which can alter the system balance, the main objectives should be identified. The definition of an objective is needed to verify the effective response of the analysed system, i.e., its resilience. This aspect is crucial to allow the application of the concept of resilience in real-world case studies, independently from the field of research or intervention.

2. The urban system: an intricate playground

Resilience plays a crucial role in shaping the future for humans, especially as we tackle multifaceted challenges such as climate change, growth, and resource limitation. As the tendency for human to choose their habitats is an urban one, it is only logical that resilience is studied in cities. Cities are a human phenomenon whose continuous expansion is signalled in numerous reports, with alarming rates (Mahtta *et al.* 2022). This does not only mean that more humans will live in urban environments, but also that the consequences of an increased urbanized lifestyle will affect both the wellbeing of human and the quality of urban settlements. Local and international policies strive toward controlling this expansion, although they are still lacking a cohesive inter-scalar approach. Dealing with urban problems is often a matter of local knowledge and site-specific insights, as regional guidelines can prove ineffective in describing local peculiarities. This scale-behaviour is typical of systems where

uncertainty and heterogeneity elevate normal actions to a more difficult level of interpretation, while still providing room for flexibility. Cities have been called adaptive complex systems, as in entities regulated by non-linearity and circular causality and yet robust (Bettencourt 2021). As cities are human products, their primary objective should be to effectively host human life. Before, delving into how to explain 'effectively', we should discuss change.

Generally speaking, urban systems are lazy, in the sense that if not interacted with they will choose the most convenient short-term path to problem solving. These systems are often shaken by stresses, internal or external forces that causes a metabolic reaction. Coping to these stresses is a matter of identifying the type of effect, as naturally different phenomena make for entirely different scenarios. One thing is to suddenly restructure human life in the occurrence of a global pandemic, another is to slowly adapt to the inexorable sea level rise with the added complication, technical aspects aside, of human perception of risk and willingness to act (Kolte *et al.* 2023). This willingness is instrumental in enacting a certain type of policy and design, as for resilience-based solutions, and while politicians and committees are dealing with this delicate aspect, architects and designers can spearhead this paradigmatic shift with their proposal (Fig. 1).

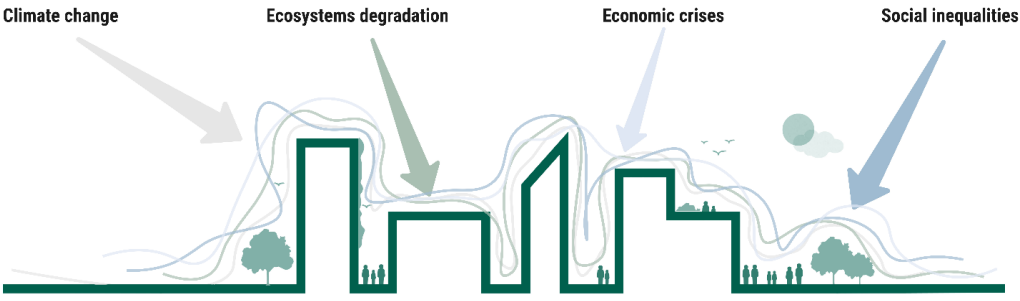

Fig. 1: the urban environment and the most impactful external stresses.

Remaining on the simple premise of protecting human life, we can start exploring the measures to define urban resilience. Understanding the level of 'bendiness', as in flexibility to change, of urban system is therefore a matter of thermodynamic inquiry. On one hand there is the problem of boundary, of input-output of resources, executed by identifying and parametrization how the edge conditions can be pushed and how far without rips. As with open systems, i.e., a system permeable to exchange of resources and energy, a border analysis can quickly assess the status of the system by posing it in relation to the surroundings. Another, more sensible, matter is to inquire the internal status of an urban system. Disregarding outside interventions, internal stresses pose enough complexity that a number of indexes have been developed to try and summarize this extraordinary heterogeneity. For example, the City Resilience Index (The Rockefeller Foundation and Arup 2016) considers factors like infrastructure, governance, social cohesion, and environmental sustainability. In both cases, the effectiveness of the 'bounce back' effect is expressed in how human can expect to go back to the previous living standards.

3. Resilience, resistance, and sustainability

During the last decades, due to the increasing complexity of city development and external stresses which threaten human settlements and the related processes, researchers have explored different strategies to fight against these external factors.
Historically, the initial response strategies to these environmental alterations focused on defining sustainable development, to address the underlying causes of environmental imbalances (United Nations, 2015). For example, one of the key objectives of sustainable development was to reduce consumption, and consequently, the extraction of fossil fuels, which are responsible for the increase in global temperatures causing climate change (Achakulwisut *et al.* 2023). In parallel, considering the need to respond to extreme events, in addition to addressing the causes, various strategies have been defined to make urban systems resilient to various criticalities, such as floods, storms, and over-

flow (Bulkeley & Tuts, 2013). Only in the last few decades, due to the steady increase in the frequency and intensity of extreme events, the concept of resilience has been considered one of the most promising approaches to ensure the survival of urban systems, by making them adaptive and transformable towards changes (Glaeser, 2022).
The consequentiality of the development and study of these three concepts (sustainability, resistance, and resilience) is worthy of note and further analysis (Fig. 2).

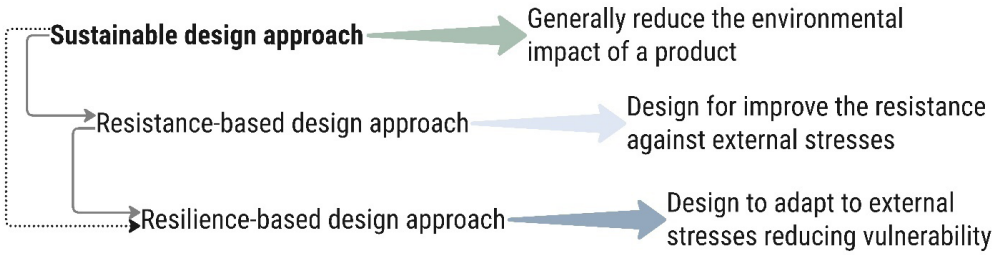

Fig. 2: The differences between the three approaches: sustainable, resistant, and resilient.

After the initial scientific demonstrations of the effects of anthropogenic activity on the environment, with the Brundtland Report and subsequent collective meetings, the most obvious and optimistic response to the problem was to address the causes directly. However, international scientific reports such as those from the Intergovernmental Panel for Climate Change (IPCC) demonstrate that even if global states were able to reduce resource consumption as stipulated by international goals, there would still be a transition period to allow the Earth's ecosystem to process the accumulated emissions in the atmosphere and reverse the process of global warming (IPCC, 2021). In parallel, the already-triggered process of climate change still causes extreme events that threaten the health of ecosystems and humans, prompting the need for protection. Therefore, after the concept of sustainable development, strategies for resisting extreme events began to be proposed (Nel *et al.*, 2014). Similar directives come from the Sustainable Development Goals (SDG, United Nations 2023), partic-

ularly SDG 11 (Sustainable Cities and Communities): emphasizing making cities inclusive, safe, sustainable, and resilient, as a goal for urban planning. Simply speaking, the objective is again to slow down external stresses with an intention of 'blocking' negative interferences. This friction perfectly describes the traditional resistance-based methodology, the equivalent of an inflexible wall to the bendiness of resilience. The need for sustainability comes after the realisation that resistance-based solutions are not always the right course of action. Save the most extreme events, grey solutions and traditional engineering are often misused, causing complications and damage on the same assets that were sworn to protect. Often, resistance-based solutions are found to be overpriced and are difficult to adjust to human well-being, while also creating difficult scenarios in the occasional conversion or urban transformation process (Ouyang *et al.* 2019).

Versatility and adaptability are sustainable qualities rarely found in grey solutions, although are a common norm for resilient strategies. These resilient frameworks integrate strategies and practices that lead to liveable, self-sustaining communities over the long term, meeting both the needs of the current and next generations (Liu *et al.* 2023). Versatility speaks of the polyfunctionality of resilient solutions, attracting different stakeholders into wanting something different for their habitats. Contrary to traditional design solutions, a versatile resilient composition changes its usage and role depending on the time of the year and the degree of external stresses. The Netherlands, for example, have deeply invested in researching floodable landscape architectures that can accommodate the routines flooding events while providing a liveable space during normal days (Oukes *et al.* 2020).

While scientific projection might correctly estimate external stresses on urban environments, one of the actual biggest benefits of adaptability is the capability of change to the different spatial needs of human dwellers. Grey-solutions, often difficult to remove or modify, are often incapable of following the cur-

rent direction of urban development, being a product of a past epoch where urban lifestyle was different.
But the strongest reason for introducing resilience in urban strategies is of economical nature. A growing portion of literature already shows the evidence of long-term benefits in many different fields of application, from climate change (Egerer *et al.* 2021) to people well-being (World Health Organization 2022), or heritage preservation (Fabbricatti *et al.* 2020).
If the administrations are finally starting to understand the importance of resilient solutions in urban environments, the next step is to explore what do designers have to offer.

4. Resilient Design Strategies

Given the importance of introducing new planning and design strategies to manage the increasing complexity of cities and the external stresses that can influence their development, in recent decades, various lines of research and action have been defined with attention to different aspects of sustainability: starting from environmental sustainability to social and economic ones.

In order to face environmental degradation, biodiversity loss and the reduction of ecosystem services provision, the European Commission has started promoting research projects and activities to promote innovative and low-impact solutions. Among them, the concept of Nature-based solutions (NBS) has been recognized at the International level as one of the most promising: defined as solutions which can integrate natural elements in the urban environment or which are inspired by nature, this category of solutions have the main goal to fight the urbanization process through the regeneration of natural processes within cities, by introducing vegetation and other living species, to support local biodiversity, reduce environmental risks, improving climate change adaptation and ecosystem services provision (Bernd Eisenberg *et al.*, 2019). In parallel with the development of these kinds of greening strategies, which can be implemented starting from the building scale (with vertical and roof greening), up to the urban scale, particular attention has been given

also to the biophilic design theories. The term *biophilia* refers to the natural and innate connection between human beings and their natural surroundings, which plays a key role in improving psychological well-being, reducing physical stress and diseases, but also increasing social cohesion and reducing crime risks. Starting from this theory, a biophilic design theory has been developed by Timothy Beatley (2011), considering the positive effect of vegetation and more in general of nature on humans, and how it can be systematically implemented in the urban environment to provide positive effects both on the environmental aspects and on the social ones.
It is however worth mentioning that the complexity described in the above section poses the necessity to develop strategies for holist approaches to sustainability (Reubens, 2016). For example, only during the last years also economic sustainability been deeply studied not only in relation to cost reduction, typically included in the circular design approaches (which aims at reducing waste production by reusing and recycling components of a specific product or process), but also in relation to the reduction of costs brought from the mitigation of environmental risks. This field of study is widely known as the 'natural capital accounting' approach, which aims at quantifying the monetary value of nature in the urban environment in relation to its capacity to reduce risks related to environmental hazards, as well as improve the provision of ecosystem services (Azqueta & Sotelsek, 2007). In fact, one of the key aspects of this theory is that the environmental degradation which characterizes our cities is increasing costs related to actions needed to react to extreme events which can have negative impacts on local infrastructures, the built environment, and human beings (Gasper *et al.*, 2011).

In this context, the need to structurally introduce the concept of resilience, encompassing environmental, social, and economic dimensions, into land planning and management practices is even more evident.

Following these concrete needs, innovative design approaches which try to go beyond the traditional design solutions as well as the approaches listed above, have been developed. Currently, in architecture and urban planning, two main categories have been identified: regenerative design approach, and adaptive design. The former aims at supporting the co-existence between humans and the natural environment, by considering the built environment and the natural one as a one single system which co-evolve for a joint well-being of all the inhabitants (Cole, 2012). This design approach poses the basis for a holistic design approach considering not only human needs but also environmental ones, as well as the needs of different living organisms which play a key role in ecosystems regulation and development. The latter, instead, aims at promoting the adaptation capacity of the designed object in relation to external forces. Today is mainly studied in relation to climate change, and this is the reason why it's commonly known as climate-adaptive design approach. Differently from the regenerative design approach, which can be potentially worldwide applied, this field of study is more site-specific, and it depends on the critical aspects of a precise area/design. To propose a practical example, depending on the geographical location of interest, adaptive design strategies can vary significantly. For instance, if designing a building in an area prone to frequent flooding, its adaptive capacity would need to address this phenomenon (Roös, 2021). Conversely, if planning a park in an area susceptible to heatwaves, the design strategies would focus on adapting to such extreme conditions. The presented approaches are strictly interconnected and go beyond the traditional meaning of 'sustainable design' with reference to minimize the environmental impact of the design and set the ground for more holistic and comprehensive design strategies. Among the most recent design theories, the responsive design approach emerges, stemming from the need for adaptation and regenerative design. It places a central focus on the capacity of a project (a product, a building, or even an urban area) to dynamically respond to external and internal inputs, aiming to

ensure the achievement of necessary performance levels (Mehager, 2015) (Fig. 3).

Although these approaches aim to overcome the limitations of previously studied and developed design strategies, some limitations remain. In particular, given the complexity of the subject and the level and quantity of data now available to designers, the definition of a true holistic approach to resilient design still seems to be distant. Simply reducing the negative effects in cities is not easy, nor intuitive. As we move from the most extreme events to more mundane ones, more and more factors fuzzy the designer vision, making it difficult to identify a clear line of action. While global stresses are for politician an occasion for a top-down design, designers can leverage the privilege to interact directly with the urban fabric for a bottom-up approach. And from the latter, usually new stakeholders and initiatives shine in urban systems. Cities are a collection of human initiatives built in accord to our need and provide the perfect canvas for a new season of interventions.

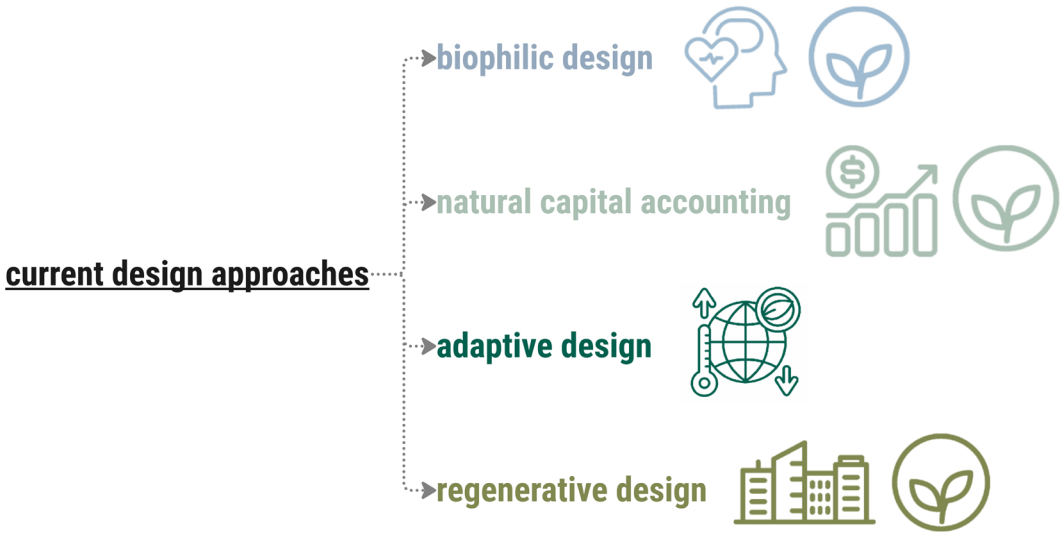

Fig. 3: Current sustainable design approaches.

This book aims to propose a comprehensive overview of the role of resilience in urban design and planning, by collecting different perspectives and methodologies to manage current urban complexity. In particular, the contributions will offer a multi-disciplinary view of possible design approaches to different aspects of the urban context: starting from the need for new design approaches for resilient buildings, to the potential of re-using and adapting the cultural heritage to current needs, the necessity to make cities self-sustaining and able to produce foods and other resources for citizens, or also the needs for adaptive regulation and monitoring systems for cities.

references

+ Achakulwisut, P., Erickson, P., Guivarch, C., Schaeffer, R., Brutschin, E., & Pye, S. (2023). Global fossil fuel reduction pathways under different climate mitigation strategies and ambitions, *Nature Communication*, 14(1), 5425. https://doi.org/10.1038/s41467-023-41105-z.
+ Bettencourt, L.M.A. (2021). Introduction to Urban Science: Evidence and Theory of Cities as Complex Systems, *The MIT Press: Cambridge*, ISBN 9780262366441. https://doi.org/10.7551/mitpress/13909.001.0001.
+ Bulkeley, H., & Tuts, R. (2013). Understanding urban vulnerability, adaptation and resilience in the context of climate change, *Local Environment*, 18(6), pp. 646–662. https://doi.org/10.1080/13549839.2013.788479.
+ Cole, R.J. (2012). Regenerative design and development: Current theory and practice. Building Research & Information, 40(1), 1–6. https://doi.org/10.1080/09613218.2012.617516.
+ Egerer, M., Haase, D., McPhearson, T., Frantzeskaki, N., Andersson, E., Nagendra, H., & Ossola, A. (2021). Urban change as an untapped opportunity for climate adaptation, *npj Urban Sustainability*, 1, 22. https://doi.org/10.1038/s42949-021-00024-y.
+ Fabbricatti, K., Boissenin, L., & Citoni, M. (2020). Heritage Community Resilience: towards new approaches for urban resilience and sustainability, *City Territorial Architecture*, 7, 17. https://doi.org/10.1186/s40410-020-00126-7.
+ Glaeser, E.L. (2022). Urban resilience, *Urban Studies*, 59(1), pp. 3–35. https://doi.org/10.1177/00420980211052230.
+ IPCC (2021). *Climate Change 2021 The Physical Science Basis*. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf.
+ Liu, Z., Fang, C., Liao, X., Fan, F., Sun, B., & Mu, X. (2023). Adaptation and adaptability: Deciphering urban resilience from the evolutionary perspective, *Environmental Impact Assessment Review*, 103, 107266, https://doi.org/10.1016/j.eiar.2023.107266.
+ Mahtta, R., Fragkias, M., Güneralp, B., Mahendra, A., Reba, M., Wentz, E.A., & Seto, C.S. (2022). Urban land expansion: the role of population and economic growth for 300+ cities, *npj Urban Sustainability*, 2, 5 (2022). https://doi.org/10.1038/s42949-022-00048-y.
+ Meagher, M. (2015). Designing for change: The poetic potential of responsive architecture. Frontiers of Architectural Research, 4(2), pp. 159–165. https://doi.org/10.1016/j.foar.2015.03.002.
+ Meerow, S., Newell, J.P., & Stults, M. (2016). Defining urban resilience: A review, *Landscape and Urban Planning*, 147, 2016, pp. 38-49. https://doi.org/10.1016/j.landurbplan.2015.11.011.
+ Nel, J.L., Le Maitre, D.C., Nel, D.C., Reyers, B., Archibald, S., Van Wilgen, B.W., Forsyth, G.G., Theron, A.K., O'Farrell, P.J., Mwenge Kahinda, J.M., Engelbrecht, F. A., Kapangaziwiri, E., Van Niekerk, L., & Barwell, L. (2014). Natural hazards in a changing world: A case for ecosystem-based management, *PLoS ONE*, 9(5). https://doi.org/10.1371/journal.pone.0095942.

+ Oukes, C., Leendertse, W., & Arts, J. (2022). Enhancing the Use of Flood Resilient Spatial Planning in Dutch Water Management. A Study of Barriers and Opportunities in Practice, *Planning Theory & Practice*, 23(2), pp. 212-232, https://doi.org/10.1080/14649357.2022.2034921.
+ Ouyang, M., Liu, C., Xu, M. (2019). Value of resilience-based solutions on critical infrastructure protection: Comparing with robustness-based solutions, Reliability Engineering & System Safety, 190, 106506. https://doi.org/10.1016/j.ress.2019.106506.
+ Roös, P.B. (2021). A Regenerative-Adaptive Pattern Language. In P.B. Roös (Ed.), Regenerative-Adaptive Design for Sustainable Development: A Pattern Language Approach, *Springer International Publishing*, pp. 145-160. https://doi.org/10.1007/978-3-030-53234-5_10.
+ Rushikesh, K., Shipra, G., Ashwani, K., & Satish, P. (2023). Challenges in practical implementation of the concept of urban resilience in cities, *International Journal of Disaster Risk Reduction*, 99, 104142. https://doi.org/10.1016/j.ijdrr.2023.104142.
+ Southwick, S.M., Bonanno, G.A., Masten, A.S., Panter-Brick, C., & Rachel Yehuda (2014). Resilience definitions, theory, and challenges: interdisciplinary perspectives, *European Journal of Psychotraumatology*, 5(1). https://doi.org/10.3402/ejpt.v5.25338.
+ The Rockefeller Foundation and Arup (2016). City Resilience Index. https://assets.rockefellerfoundation.org/app/uploads/20171206110244/170223_CRI-Brochure.pdf.
+ UNDRR (2007). Terminology on disaster risk reduction, s.v. 'Resilience'. https://www.unisdr.org/we/inform/terminology.
+ United Nations (2015). TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT. https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.
+ United Nations Department of Economic and Social Affairs (UN DESA) (2023). *Global Sustainable Development Report 2023: Times of crisis, times of change: Science for accelerating transformations to sustainable development. United Nations*, New York. https://sdgs.un.org/sites/default/files/2023-07/The-Sustainable-Development-Goals-Report-2023_0.pdf.
+ Xue, X., Wang, L. & Yang, R.J. (2018). Exploring the science of resilience: critical review and bibliometric analysis, Nat Hazards, 90, pp. 477–510. https://doi.org/10.1007/s11069-017-3040-y.

note

[1] Francesca Mosca – ORCID ID: 0000-0001-8898-8727, francesca.mosca@edu.unige.it, Dipartimento Architettura e Design – Università di Genova
[2] Gabriele Oneto – ORCID ID: 0000-0003-3621-1179, gabriele.oneto@edu.unige.it, Dipartimento Architettura e Design – Università di Genova

Francesca Mosca, architect and Post-Doc at the Department of Architecture and Design of UNIGE. Obtained the EU PhD label in Architecture cum Laude. She was visiting researcher at the Technical University of Munich, and she contributed to National and International research projects. Her research focuses on nature-based solutions for climate change adaptation to improve urban environmental conditions.

Gabriele Oneto, PhD student at the Department of Architecture and Design of UNIGE, holding a PNRR PhD research grant. He visited the Technical University of Munich (Germany) and at CIMA Foundation (Italy), contributing to International and National research projects. His research interests range from urban form and spatial analysis, landscape and urban ecology, and applied machine learning.

The European Union defines resilience as the ability to withstand and undergo transitions in a sustainable, fair and democratic way. For an urban system, resilience represents the ability to adapt and transform in response to stress while maintaining its essential functions and identities. The designer is therefore called to guide this movement, conducting innovative analyses and validating and experimenting with new ways of designing cities. Designing resilience involves adopting a holistic and systemic approach that considers the interdependencies and interactions between different urban components. Only by addressing urban habitats in their entirety can designers truly understand the changing kinetics of cities and their populations.

e-ISBN: 978-88-3618-337-1