From concepts to action: urban metabolism and resilience thinking

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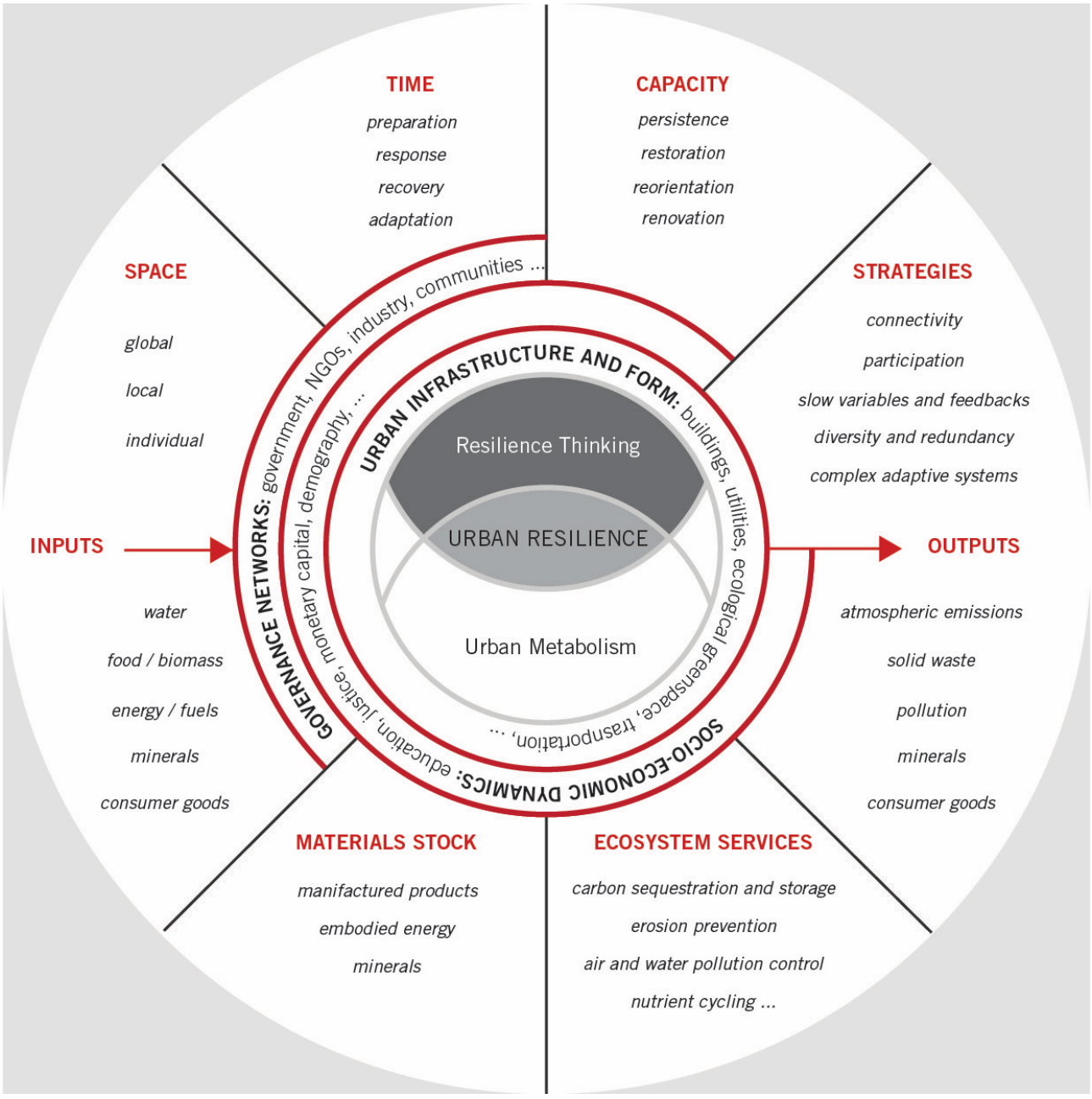
Graphical Abstract



Cities are complex adaptive systems, constantly facing multifaceted challenges such as rapid population growth, resource depletion, extreme weather events, and social inequalities. In this context, urban resilience has rapidly gained momentum as a topic for sustainability policy and research into design strategies to address context-specific problems (Fastenrath, Coenen and Davidson 2019).

Resilience is a polysemic concept with interpretative flexibility depending on the context in which it is used, the purpose it serves, and the disciplinary lens through which it is observed. However, its multiple interpretations have something in common: the concept of resilience has been used to express the ability of a system to respond effectively to unpredictable crises and abrupt change.

With its origins in systems ecology, resilience refers to the capacity of ecosystems to resist and recover after a perturbation. The "social-ecological" resilience included a social dimension to the original concept and an important focus on the relationship between communities and natural resources while exploring ecosystem dynamics (Perrotti, Hyde and Otero Peña, 2020). Deeper knowledge of the complexity and interconnectedness of social-ecological systems has highlighted the importance of focusing not only on responses to acute shocks but also to slow variables or chronic stresses operating at multiple scales and across varied timeframes.

In social-ecological system analysis, the temporality of a system's response to a shock extends over four phases, ranging from (pre-shock) preparation and immediate response to recovery and adaptation (Sanchez and Zamora, 2016). A different level of capacity is associated to each of the three post-shock phases: *restoration*, the capacity to provide an immediate response, measuring the speed at which a system can provide that response; *reorientation*, the capacity of the system to reorient itself after the shock; and *renovation*, the ability to adapt to a new configuration and learn from what has happened, while resuming the system development over time. Moreover, factors used to investigate a system's assets and vulnerabilities can be classified according to space (local/global), time (slow/fast) and their nature (human/economic/cultural/environmental/social). These factors can be quantified by indicators measurable over time and contextualized through sociology (knowledge of history, culture, identity). Research into factors, indicators, and thresholds can highlight multiple entanglements between resilience and urban metabolism in order to develop more efficient strategies for urban sustainability policy and planning.

Urban metabolism (UM) describes how cities use and consume key resources through quantification of resource inputs and outputs and the associated waste and emission flows (Perrotti and Iuorio, 2019). Since its outset in the work of American engineer Abel Wolman in the 1960s, the UM field offers valuable insights into the relations cities establish with their environment. Recent years have seen a wide range of practical applications of "UM thinking" in urban planning and design (Perrotti, 2019).

UM and urban resilience are both system-based concepts, which can be translated into strategies to achieve integrated urban sustainability solutions and, under certain circumstances, enhance stakeholders' and communities' engagement. The UM approach is based on mass-balance methods, such as material and energy flow analysis, or life cycle assessments, and hence relies on measurable data. On the contrary, resilience is a more malleable concept whose strategies

need to be oriented towards goals (such as environmental and social sustainability). Based on their complementarity, "resilience thinking" (Magoni, 2017) can improve the management and governance of urban resource flows and cycles providing an ever-growing reservoir of techniques and tactics to see and operate in the city through different eyes. At the same time, UM research can be used to enhance the most widely used resilience strategies, including connectivity, redundancy, diversity, social cohesion, participation, and information.

Finally, UM strategies and resilience thinking can complement each other toward the common goal of improving urban planning throughout design, implementation and management phases. UM could provide a deeper knowledge and awareness of the material and energy functioning of cities in terms of management and governance of natural resources (Perrotti, 2015). Resilience thinking is more focused on bottom-up initiatives involving stakeholders and, as such, can respond to the growing demand for community involvement in resource management policy while broadening the basis of resource governance systems. Resilience thinking can help build the trust and relationships needed to improve the legitimacy of knowledge and authority in decision-making processes (Stockholm Resilience Centre, 2015). Future research should focus on new cross-fertilizations between UM strategies and resilience practices as a way forward to (re-)negotiating a shared agenda for the community resilience to be.

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