A LADDER OF URBAN RESILIENCE: TOWARDS A PARADIGM OF EVOLUTIONARY RESILIENCE TO SUPPORT COMMUNITIES FACING CHRONIC CRISES (1152)

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Abstract. This paper explores the concept of urban resilience in the context of complex socio-technical ecosystems within cities. Its objective is to move beyond the functional schematization of capacities along successive implementation phases. Instead, it proposes an integrated framework for a comprehensive approach to urban resilience that considers the interaction between i) appropriate qualities based on the specific problem characteristics, ii) processes across different system domains forming a city, and iii) the involvement of agents in decision-making and action implementation. Through an analysis of the challenges posed by chronic crises and structural disorders, the article underscores the need for a paradigm shift in governance to support communities grappling with the impossibility of contradictory adaptation choices. This is essential to ascend the ladder of city resilience through adaptive strategies, inclusive decision-making, and the co-generation of innovation, including the application of information and communication technology for this purpose.

Keywords: Urban Resilience, Evolutionary Resilience, Participatory Design, System Thinking, Complex Socio-Technical Eco-System

1. Introduction

Resilience is a concept that is increasingly being used in the urban context because it aligns with the complex socio-technical ecosystem inherent to cities. Through continuous and lively debates, with various theoretical interpretations and controversial outcomes, the concept of urban resilience has expanded beyond its initial engineering reference. It now encompasses the ability of an urban area to not only withstand and respond to disruptions such as natural disasters, economic crises, or social upheavals but also to proactively establish preventive mechanisms capable of anticipating and mitigating the negative impacts of potential stressors. Additionally, it emphasizes the improvement mechanism through reflection on lessons learned from unexpected events, enabling the activation of upgrading processes, which ensures the continuous development of the system.

However, while this systemic view encompasses the impact of internal and external

factors, it only represents part of the story, particularly the one that can be addressed using traditional management approaches. It simplifies societies as coherent self-correcting systems capable of using feedback to adjust their activities towards clear desired outcomes. Although this approach may seem reasonable for providing a comprehensive framework for understanding resilience in urban contexts and supporting the identification of operational tools to strengthen cities against potential disruptions, it often fails to account for timely or accurate feedback. This is due to the inherent difficulty of correctly predicting outcomes in complex decision environments, leading to the potential collapse of all or part of the system. Moreover, this closed-system interpretation neglects the intrinsic uncertainty of socio-environmental contexts due to their openness, as well as the multiplicity of roles, interests, and relationships among the agents that constitute them. Consequently, it is incapable of addressing the frequent paradoxical situations of choices that permeate such contexts.

Despite these considerations, the huge number of papers on resilience available in literature suggests that it is no longer a mystery. Assuming that there are means and resources available to develop economic, technological, organizational, political, and infrastructural capacities to address risks, the principle of a "one-size-fits-all" approach seems to prevail. Consequently, extensive research activities are focused on how to better characterize, implement, and achieve resilience through a pragmatic, linear or circular, but unambiguous process. Additionally, there is a quest to identify measurable indices and indicators that can be integrated into this framework. As a result, the emphasis has shifted from how to attain resilience to determining how much resilience is both relevant and acceptable. Therefore, considerable effort is dedicated to establishing methods for measuring a city's resilience capacity, as opposed to its vulnerability. An example can be seen in the normative targets 1.5.X of the Sustainable Development Goal (SDG) No. 11: "Make cities and human settlements inclusive, safe, resilient, and sustainable." These targets aim to address global challenges at the urban human scale and measure progress towards achieving them. Notably, they seek to enhance resilience by reducing community exposure and vulnerability to extreme climate events, as well as other economic, social, and environmental shocks and disasters (UN 2015).

Reports of emergencies affecting cities worldwide demonstrate that, in most cases, the conventional understanding of resilience is nothing more than a utopian ideal to be achieved or, at best, a broad objective that can only be pursued through an uncertain and variable path. The realization of resilience is highly dependent on cultures and the availability of intangible resources at the local scale. It is crucial to recognize that resilience should not be solely associated with the vulnerability of physical infrastructure. It appears that resilience has evolved into an independent concept, albeit one that is

related to, and interconnected with, vulnerability (Graveline, Marie-Hélène et al, 2022). In broader socio-ecological systems, the capacity to demonstrate resilience often emerges as a result of experiencing and learning from crises. Thus, the ability to learn from disasters and adapt accordingly contributes to the actual state of being resilient. This understanding is a valuable lesson that social science has adopted, as it recognizes the courage and resilience of individuals and communities through their willingness to be vulnerable (Brown C. Brené, 2012).

This paper is developed within the context of the reCITY research project, which seeks to establish a socio-technical ecosystem capable of fostering community-oriented resilience. Resilience is not solely viewed as preparedness for response, which refers to the ability to withstand and absorb impacts, or as recovery capacity, which relates to the efficiency and speed of recovering from stressors. Instead, it emphasizes the importance of learning and creativity as integral components of resilience. These elements enable the harnessing of adversity to drive system innovation. In line with this perspective, the paper proposes a paradigm shift from the implementation of mainstream resilience approaches that are primarily focused on specific types of disasters. Instead, it advocates for the reinforcement of resilience without having undergone a earlier shock through the development of transversal and systemic capacities that support the sustainable co-development of territories. The goal is to create a supportive, dematerialized, and flexible backbone for communities. This foundation enables communities to perceive themselves as a unified system capable of reorganizing and adapting to various types of emergencies. In doing so, it aligns more closely the concept of resilience with them.

In the reCity project, this objective has been pursued through the development and dissemination of ICT platforms for communities and administrations. These platforms have a dual purpose: firstly, they enable the creation and operation of horizontal smart communities, fostering truly cooperation and support. Secondly, they facilitate a constant two-way communication between urban governance and citizens, creating an integrated and intelligent service ecosystem in a vertical dimension. As a whole, this framework would provide the city with a nerve system, enabling it to adapt and respond to emerging dynamics and various needs, including environmental and socio-economic emergencies. The dual-level connectivity would establish a flexible network structure capable of integrating different types of resources, tangible and intangible and to support the sustainable development of territories through the identification and sharing of effective local resilience practices. Additionally, this framework supports the long-term development of territories, enabling a more efficient and coherent system preparedness to unforeseen events, allowing for a swifter and coordinated action and a proactive response to potential crises.

More specifically, this contribution reflects on the implications of applying this approach

to the city of Taranto, Italy, drawing on the lessons learnt from local community involvement. Taranto is a significant Mediterranean port city characterized by a declining industrial economy and decades of pervasive social and environmental problems, which have led to high pollution levels and detrimental impacts. This case serves as an emblematic example of chronic stress and long-term structural disorder resulting from unresolved issues and inconclusive decision-making. Taranto represents an atypical disaster situation that is not limited to a specific time frame and is difficult to confine spatially. It is a condition characterized by continuous structural challenges and multiple emergency implications with transversal and multi-scalar effects. This context highlights the importance of resilience, not only in terms of having efficient mechanisms in place to respond to and recover from natural or man-made disruptions, but also in recognizing and supporting bottom-up changes. Taranto's situation demonstrates the need to go beyond traditional approaches and focus on developing means to identify emerging innovative practices and support their growth. It emphasizes the importance of fostering resilience by nurturing and leveraging bottom-up initiatives and empowering communities to drive positive change.

This contribution critically examines the current state of research on urban resilience, drawing on evidence from an emblematic case study. It proposes an integrated framework that reorganizes the multiple components encompassed by the concept of resilience, considering categorical dimensions and the subsequent community processes and actions. This approach provides a more comprehensive and intentional structure for addressing the specific types of problems and emergency situations that cities need to manage, while promoting their evolution.

The paper is structured as follows: after introducing the problem and objectives of the study, the next section provides background on resilience definitions and formalizations. This is followed by a methodological chapter that explores the characteristics of socio ecological resilience in a qualitative ladder pattern and following both system and problem domain, with a process-based description of each step. The discussion section elaborates further on the main innovative potentials of such approaches when applied to tackle critical conditions and the degree of ICT application for this purpose. It also offers reflections on the implications and limitations of the proposed approach for decision-making at different scales. Final remarks draw out overall conclusions.

By following this organizational structure, the paper aims to provide a comprehensive analysis of urban resilience, considering the specific insights from the case study and offering a blueprint into how resilience can be effectively fostered to support communities facing chronic crises.

2. Background

The world today is predominantly urban and if rural to urban migration trend will remain unchallenged driven by inequity in resource distribution, real and perceived job opportunities and investments backing cities, it will continue to grow. Cities due to rapid urbanisation are facing increasing development challenges and problems which can increase disaster risk. Fast urban development drives the concentration of people on high density and poorly planned areas, which are prone to disaster, e.g. the soil sealing increases the risks of flash flooding and give rise to the urban heat island effect (Wamsler, Christine et al. 2019). Indeed, cities are highly vulnerable to many types of shocks and stresses, including natural hazards like storms and earthquakes, but also man-made ones like pollution, terrorist acts or accidents. Unexpected crises have the potential to bring city systems to a stop and reverse years of socio-economic development gains. Therefore, urban government thrive to find ways to address these. Moreover, cities must prove resilience at an increasing pace in order to adapt to the constantly changing demands of the citizens, but the built environment changes very slowly in comparison to the new functions that want to fill it. Therefore, it must be considered that change for resilience's sake must be met without losing historical-architectural and cultural identity (Esposito, Dario et al., 2021). Instead, each city must cultivate its past and exploit its memory and peculiarities as resources, which can boost resilience.

Urban science has benefited from the conceptual development of resilience that is following a debated path to establish and stabilise itself, and this is thanks to the contribution of different scientific fields. At the same time, however, it can offer a significant contribution to the interpretative advancement of the concept in that it is a liquid discipline with dilated and blurred margins that constitutively welcomes contributions from other fields and with constant effort strives to coherently connect them into a web of meanings and practices that are useful in sustaining the sustainability and resilience of the communities. A survey of the main definitions of urban resilience from literature sources and international organisations is given in the Annex.

From these, a word cloud was constructed to visually represent coherences in terms of semantic recurrence, see figure 1.

Figure 1. World cloud of urban resilience definitions

The qualitative analysis conducted reveals a gap in the definitions collected regarding the themes of socio-ecological resilience, with a clear bias towards the engineering perspective. Moreover, it is evident that each definition reflects the specific interests and viewpoints of its proponents. Economists emphasize the economic aspect, sociologists stress the political aspects, and so on. As a result, the term resilience is used ambiguously with different intentions (Brand Fridolin S., et al, 2007).

Furthermore, literature proposes a long list of diverse capacities that need to be developed to achieve resilience. These capacities range from resistance to recovery, absorption to response, repair to adaptation, and learning to transformation (Holling Crawford S., 1973; Walker Brian, et al., 2004; Carpenter Steve, et al., 2001). These, in turn, rely on multiple properties and qualities that the system must implement, including anticipation, robustness, redundancy, resourcefulness, rapidity, stability, change, persistence, flexibility, identity, learning, fluidity, reflexivity, contingency, connectivity, multiplicity, inclusivity, polyvocality, redundancy and diversity (Davoudi S. et al. 2012; Graveline, Marie-Hélène et al, 2022). Issues of social justice, equity, legitimacy, and participatory democracy have also been raised in the quest to prioritize whose resilience is emphasized. This highlights the wisdom that a more equal society requires a greater citizen participation and diverse range of people in civic discourse

surrounding resilience (Leach Melissa 2008).

Urban resilience primarily pertains to the resilience of human-made territories and predominantly urbanized environments (resilience in urban contexts). Therefore, at the operational level, the concept of urban resilience is primarily spatially contextualized. However, this raises questions about the advantages and disadvantages of defining the boundaries of an open system like a city and the need to clarify the dimensions considered in describing it. Initially, a normative simplification addressed the question of the spatial dimension by referring to the administrative boundaries of the relevant areas.

Traditionally, urban resilience was mainly focused on responding to unexpected risks and managing disasters. Indeed, the engineering view of resilience, which is embedded in disaster risk planning, has traditionally focused on short-term post-disaster responses. Thus, aligned with it, these capabilities are typically organized along the temporal dimension.

Consequently, urban resilience is primarily defined in relation to specific time and space frameworks, explaining which properties to activate at different times within these frameworks. This representation suggests what actions to take and when to take them in response to the location and timing of a disaster. Sometimes, the variability of the spatial dimension is also considered by referencing the type and size of the emergency, as well as the affected community and context.

The well-known framework of "prevent, prepare, respond, and recover" follows a linear approach that places emphasis on the temporal order of interventions. However, this rigid and linear categorization of phases starkly contrasts with resilience thinking, which views cities as interconnected open systems with extensive feedback processes. The framework fails to demonstrate the relative variability of proposed actions and identify gaps, and it also fails to acknowledge the interconnections between phases that occur across multiple scales and time frames (Davoudi S. et al. 2013).

In a continuous growth research, the Disaster Risk Management Cycle (DRMC) encompasses this linear process within a recursive Deming-style cycle, where each stage incorporates some capabilities (Bosher Lee et al. 2021). In this formalization, the notion of resilience is rooted in the idea of closing the circle and returning to the initial state. However, it is generally the initial state that gives rise to the causes of these disruptions and their consequences (Adolphe Luc 2022). The view of resilience expecting a system to return to a state of normality is problematic because normality is neither adequate nor desirable since that state is what initially caused the vulnerability (Wagemann Elizabeth, et al. 2019). Indeed, this type of formalization has been criticized by many scholars who agree that for complex socio-technical ecosystems, returning to the normal state after a perturbation is not a solution, as that state constituted the preconditions that allowed

the perturbation to develop and impact the system.

Subsequently, recognizing the need for a more comprehensive approach for operationalizing resilience, an analysis of the temporal development of resilience from short to long term was proposed. The ISO 37101 standard (ISO, 2016), as well as the Smart Mature Resilience project (SMR project, 2019), with their focus on community improvement, suggested the introduction of maturity models for operationalizing resilience.

The Sendai framework, driven by the understanding of systemic risks, i.e. that cascading effects form a single disaster event, e.g. that climate change will lead to more future disasters, further advanced the concept from "bounce back" to "build back better" (UNDRR, 2015). This evolution signifies that resilience is not confined to a specific timeframe but entails an ongoing and continuous process of improvement. Thus, urban resilience to withstand unpredictable catastrophes, now encompasses not only the ability to bounce back but also to bounce forward.

More recent Disaster Risk Management Cycles (DRMCs), such as the one outlined in CEN CWA 17727, have incorporated this perspective through a phase dedicated to reviewing the entire process and the achieved results (CEN, 2022).

However, despite the progress made, these traditional formalizations primarily serve to determine when and where to utilize resilience capabilities, assuming that they are embedded in communities, easily attainable, and clearly implementable. This perspective, however, does not provide sufficient guidance on i) how selecting the appropriate capabilities based on the specific characteristics of the problem being addressed, ii) what processes develop across the different domains of the socio-technical ecosystem that constitute a city, and iii) how capacities and processes involve the various agents in decision-making and action implementation. These crucial aspects, along with their interconnections, are precisely the focus of our investigation. The following chapter proposes an integrated framework addressing these crucial issues and their interconnection, to provide a comprehensive approach to urban resilience.

3. Method

Urban resilience appears to be usually viewed as a functional rather than theoretical concept, i.e. an operational approach that addresses the challenges of sustainability within the city (Adolphe Luc, 2022), while the resilience of urban communities from a socio-ecological perspective is frequently overlooked. Davoudi (Davoudi S. et al., 2012) also identifies this limitation in the resilience concept adopted in the draft London Climate Change Adaptation Plan. The socio-ecological aspects of resilience in the urban

context are sometimes assumed to be inherent, for example, the inherent drive for evolution, while in other cases they are neglected due to their innate complexity in the implementation. There are also instances where these aspects are misunderstood or underestimated due to a lack of clarity. Wilkinson argues that there is a gap between the advocacy of socio-ecological resilience in scientific literature and its practical implementation as a policy discourse. This raises the question of how we would govern for resilience (Wilkinson Catherine, 2012).

There is a lack of understanding attributed to an interpretation of the city that focuses only on spatial, administrative, and morphological aspects, while neglecting other crucial elements such as the environment, economy, society, and information. In simple terms, a city is more than just the sum of its buildings. The challenges related to urban system resilience extend beyond technical responses and touch upon broader societal issues. Viewing the city purely as an artifact or self-referential artificial product only allows for linear operational processes. This leads to an accumulation of increasingly challenging problems. Even if we were to hypothetically perfect the structure and functioning of the urban machine, resulting in a highly optimized city, it would remain stagnant and devoid of novelty (Michael Batty, 2017).

Through studies on the relationship between sustainability and cities, there is a growing recognition of cities as living ecosystems that strive to balance social, economic, and environmental concerns. However, this implies that the urban system, in order to evolve, must be open to risk, disequilibrium, and ambiguity. The balance to be sought can only be dynamic and transformative. This condition presents a paradox to the mainstream conception of resilience as equilibrium. Rather than attempting to resolve this paradox, it is more fruitful to embrace and learn to navigate it, or even support it. In fact, this perspective suggests that only through a conscious interpretative extension does the city become not only a source of problems but also a source of solutions. This reconstitutes the eco-systemic circularity of its functional process, as a fundamental element of the generative evolutionary path of humankind on Earth. Thus, while an urban organism is physically instantiated in a specific place defined by the built environment, addressing resilience requires consideration of other spheres, their dimensions, and their interrelationships.

The resilience thinking recognizes the urban system as a complex socio-technical ecosystem consisting of interdependent ecological, social, and technical components and informing resilience-building processes at the city scale (Folke Carl, et al., 2010). To operationalize this broad understanding, The Resilience Alliance, in an oversimplified manner, divides the urban system into four major subsystems: i) governance networks, ii) metabolic flows, iii) built environment, and iv) social dynamics, which were later elaborated by Meerow into: i) governance networks, ii) networked material ad energy

flows, iii) urban infrastructure and form, iv) socio-economic dynamics (Meerow Sara et al., 2016). This framework allows us to conceptually break down urban resilience as a process that involves different system domains in varying ways and at different times, considering their unique characteristics and interrelations.

The description of the system domains is as follows:

- Infrastructure: This domain encompasses the physical structures, material resources, cognitive agents, and all other constituent elements of the urban system. These elements are described based on their specific properties and characteristics and differences between them. The infrastructure serves as the prerequisites that must be fulfilled for the system to exist. The domain involves the process of categorization and grouping into sets.
- Flows: This domain represents the flow of resources within the urban system, such as energy, economy, water, waste, and more. These flows enable the mechanical-like functioning of the system. The flows serve as possibilities, allowing multiple mechanisms within the system to operate. The domain consists of parallel and overlapping horizontal layers, each traversed by linear input-output flows. The domain is formed through the additive overlay of functional layers.
- Networks: This domain comprises the data networks that provide information for decision-making processes, including governance dynamics and formalized knowledge creation. It includes three-dimensional networks that traverse the system and establish external connections through predefined main paths. The networks play a power role in activating and focusing the system's energies. The domain is generated through the formation of networks across different scales.
- Community: This domain encompasses the tangible and intangible qualities that bind the community together, such as social connections, cohesion, learning, and the cognitive abilities of individuals and groups. It also includes creativity that supports innovation and/or survival, through phenomena like exaptation.

The community domain has two forms: either as individual independent particles or as a single system dynamically moving as a coherent wave along a path of successive and increasingly frequent bifurcations. It serves as the potentiality for the system, offering prospects for overcoming crises and fulfilling desires for change. Thus, it is dual and circular, changing its shape depending on the perspective from which it is observed, as Max Planck famously wrote, "If from the outside the world appears to be bound by a causal relationship, from an internal, subjective point of view, the will appears free" (Planck, Max, et al., 2022).

On a temporal scale, the nature of the urban system as a complex system operating in a

state of non-equilibrium along a single oriented temporal direction suggests that a return to the pre-disturbance state is effectively impossible. Resilience is understood as a combination of persistence, transition, and transformation (Chelleri Lorenzo, 2011). It encompasses the complementary capacities of bouncing back, building back better, and bouncing forward (Graveline, Marie-Hélène et al, 2022). Therefore, when an urban system undergoes a disturbance or upheaval, it transforms into something different, which should not be seen as a failure in terms of resilience but as an inherent possibility within the system (Reghezza-Zitt Magali et al., 2021). Thus, resilience is not an achievable target but a quality of change that fosters the evolution of the system, and that can never be definitively achieved. This implies that the concept of normality itself, even without disruptive events, is already a condition that should be improved through the pursuit of resilience.

This understanding demonstrates why it is not possible to identify an optimization point for the various properties through which resilience could be realized. It is not feasible to determine specific percentages for qualities such as redundancy, flexibility, connectivity, and resistance, or any combination thereof, as a measure of a resilient urban system. The development of such a resilience perspective is qualitatively different from the search for optimal efficiency. The schematic figure 2, adapted from Linkov, visually illustrates this distinction (Linkov Igor, 2018).

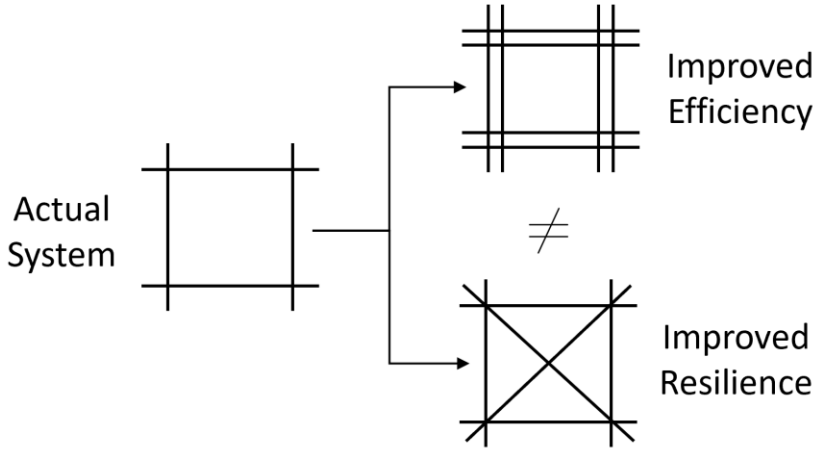

Figure 2. Representation of the difference in improving the efficiency or resilience of systems

Nevertheless, to define a progression toward resilience, it would be ideal to have a unit of measurement. One approach could be to identify several dimensions corresponding to the multiple qualities associated with resilience, drawing a single multidimensional

representation. However, this representation would not result in a continuous, or complete form because progress towards resilience does not follow a constant grow, along a consistent and measurable surface. Instead, resilience crosses thresholds of discontinuity, which act as transitional steps between different states of dynamic equilibrium in the system. At each step, a new quality emerges in the system, similar to climbing the steps of a ladder. This new quality is not simply equal to a greater quantity of the previous one but rather a new emergent quality that follows the previous one in a coherent process.

The reason why the system follows a step-by-step path, here represented as ladder steps, rather than alternative or parallel branching paths from the status quo, is related to the knowledge progression that can be formalized between the domains of the problems being addressed and which apply the adjacent possible principle, which explains how organization propagates from diversity in biosphere (Stuart A. Kauffman, 1991). At an intuitive level, we can represent this progression as a gradual learning process that follows several steps. For an exemplification, the first two are visualized in the figure 3: the first step involves a simpler replication requiring analogical duplication through parallel and specular series, and the second step involves a transformation requiring a second-degree modification through rotation in the plane, thus also necessitating a change in perspective.

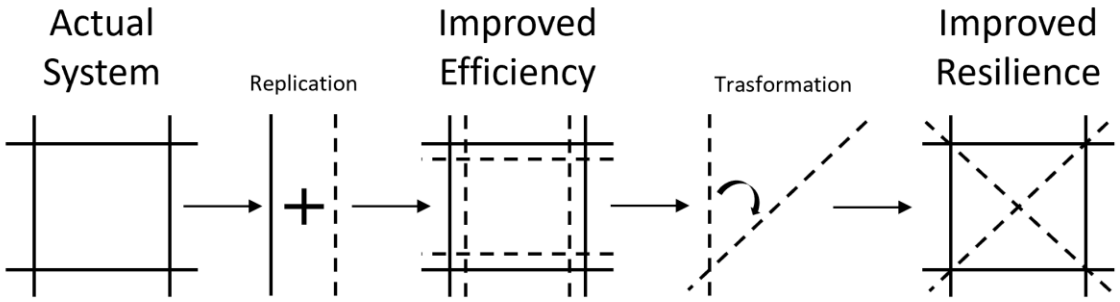

Figure 3. Representation of the incremental improvement process from efficiency to resilience in systems

Indeed, ecosystems can become increasingly complex, i.e. evolve, through the systemic increase in the quantity and diversity of interactions among their constituent elements, giving rise to emergent properties that are qualitatively new (Lobo Ingrid, 2008). This wonder resembles fractal formation, which nature is replete with, enabling complex systems to develop new qualities out of quantity growth, which can be followed by selection. The ladder image depicting the evolution along a scale towards urban system resilience, as shown in figure 4, formalizes this evolutionary path through successive

bifurcations, having evolution on the y-axis and time on the x-axis. It also reflects the schematic representation of evolution through successive levels of organization in living systems and innovation in business systems (Bettencourt M. A. Luís, et al., 2007; Novikoff, Alex B. 1945; Webster Ken, 2013), as well as the shift in scientific paradigm (Kuhn, Thomas S., 1962).

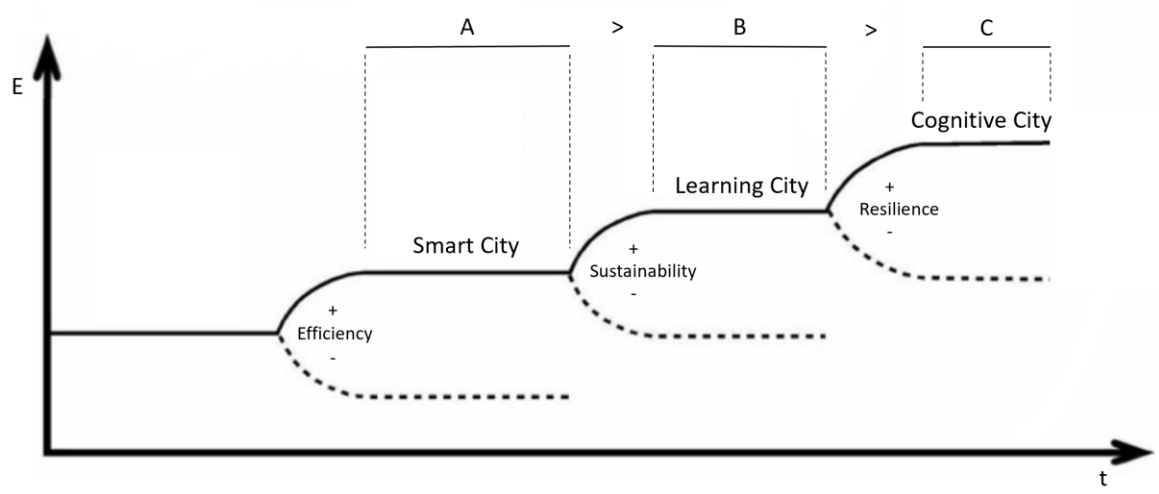

Figure 4. Qualitative ladder model of system evolution toward resilience

Within this framework, which views the man-made environment as a complex socio-technical ecosystem, our interest lies in understanding how capabilities can be selected and applied according to the type of situation (which cannot be known in advance) that requires the system to employ resilience. Therefore, we present a typological analysis of the situation as it is based on the degree of simplicity, inversely related to its complexity. This conceptual framework echoes the four-part structure of the Cynefin framework for decision making proposed by Snowden (Snowden, David J., 2007).

The integrated matrix presented below in table 1, illustrates the order in which different domains of the system are activated depending on the type of situation requiring some form of resilience. This matrix aims to explicitly outline how capabilities are developed and activated, which actions follows decisions, and who and how to involve based on the type of problem being faced. By following this matrix, urban resilience processes can be better understood, as well as determining the power of communities according to Arnstein's scale (Arnstein, Sherry R. 1969), the type of practice experts are called upon to implement following the series proposed by De Roo (de Roo Gert, 2015), and the nature of the system in accordance with the definitions provided by Weaver (Weaver, Warren, 1948).

Table 1. Integrated Urban Resilience Framework

System domains →				Infrastructures	Flows	Networks	Community
↓ Problem domains							
Simple Causality	Techno-rational	Non participation	Simple	2	3	1	-
Organized complexity			Complicated	3	2	1	-
	Communicative	Degrees of tokenism	Complex	2	1	3	4
Disordered Complexity	Adaptive sel-organizing	Degrees of citizen power	Chaotic	2	3	4	1
Weaver	*De Roo*	*Arnstein*	*Snowden*				

The figures 5 and 6 illustrate a formal schematic representation of the creation and combination of each domain within the urban system. They depict how these domains interact and function as interdependent multiplex networks. The ultimate outcome is the emergence of a complex sociotechnical eco-system, which is a multilevel and nested complex system that proceeds within the evolutionary framework previously described.

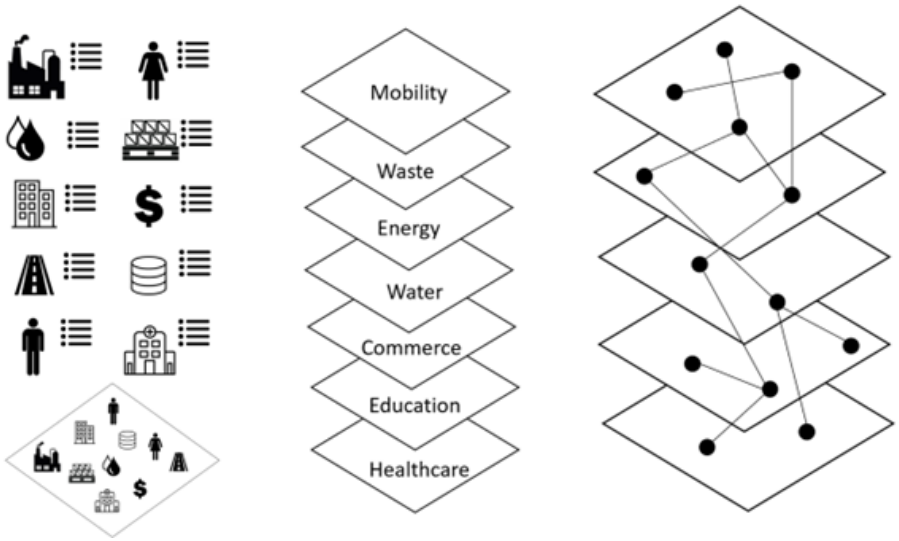

Figure 5. Domain formation for: i) Categorization, Description, Grouping; ii) Additive Overlay; iii) Inter-scalar Networking.

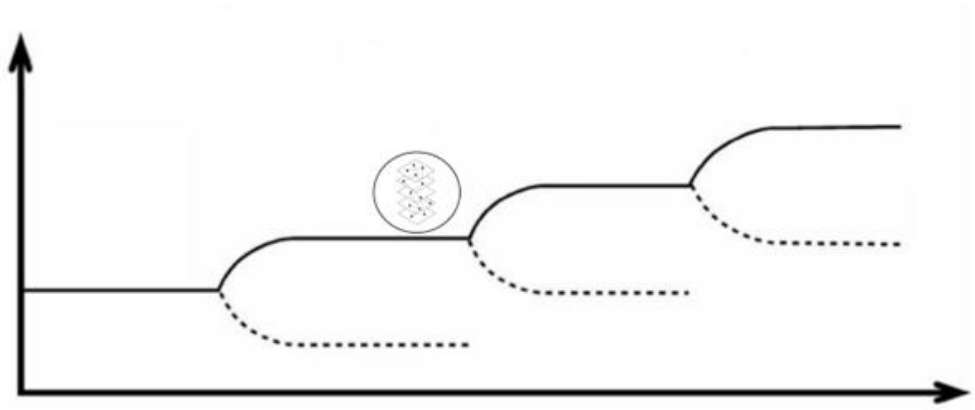

Figure 6. Representation of the evolutionary resilience of a complex sociotechnical eco-system

According to the four-part typological structure, below is described how problems are addressed using a sequential activation process of the system domains, following the order of steps proposed in the matrix. It is also discussed the implications for the agents involved.

- Simple: In this scenario, the community adheres to a predetermined hierarchical structure, and they are mostly passive participants. Decision-making is centralized, as is the form of the network representing the system. The necessary resources have

been allocated in advance and are readily available. The activation process involves following a codified procedure in a repetitive manner or replicating a proven best practice.

- Complicated: The decision-making process involves initiating an analysis phase where the actively involved community consists of experts who study the best approach to solve a specific case. The network structure remains hierarchical but decentralized, with multiple parallel verticals in various fields of interest stemming from a central decision-making body. The necessary resources are mobilized to identify and implement good practices that can be continuously improved through the analysis of results and iterative approximations, toward a knowable optimal.
- Complex: In situations characterized by uncertainty and ambiguity, often referred to as "wicked" problems, one or more parallel trial-and-error and safe to fail experimental processes are considered. The necessary resources are estimated and allocated to initiate these processes. Decisions are made regarding which processes to nurture and which to dampen, and learning from mistakes is emphasized. The process involves analyzing and internalizing the practices that emerge, incorporating useful insights, and embracing serendipitous discoveries. Communities are formed around the shared purpose of addressing the situation, creating distributed networks that are guided by the coherence of the situation acting as an attractor.
- Chaotic: In chaotic situations, the community takes immediate action to address an emergent situation, such as the need for innovation or overcoming crises. Planned coordination between agents usually lack and if arises is a unpredictable or random result. Available resources are utilized for survival or repurposed to drive change, for example like exaptation in biology, by which a causal consequence of a part of an organism that might turn out to be useful in some environment and therefore be selected. The decision-making process is new, and the decision is focused on avoiding catastrophic consequences, or it may simply acknowledge the new state of equilibrium that the system autonomously achieves. The collective effort binds the community into a recognizable and holistic systemic entity, yet each agent feels individually free. From an external perspective, the system can be observed both as a cohesive wave and as a collection of different particles.

In the evolution of human civilization, both in terms of tangible development and epistemological understanding, there is a shifting significance of the system domains along the horizontal and vertical directions. Horizontally, the weight of the domains moves progressively towards potentialities, from the preconditions that form the foundation of the system. Vertically, the shift occurs downwards, starting with processes

driven by predetermined ends in the case of simple and complicated problems, through a shift to processes driven by underlying causes for complex problems, and finally, to processes driven by means, where for chaotic problems the means themselves become the ends due to compelling circumstances, and opportunistically serve as cause to act.

The recognition of the complexity of the urban system and the realization that prediction is impossible has prompted a shift in spatial planning approaches. In the latter half of the previous century, there was a backtracking on planning methods that relied heavily on standards, performance measures, and predetermined outcomes. Instead, there has been a growing emphasis on process-oriented planning and the use of tools to navigate and respond to the dynamic nature of urban systems (Wildavsky, Aaron, 1973). This shift acknowledges the need for adaptive and flexible planning approaches that can better accommodate the inherent complexity and uncertainties of urban development.

As communities navigate the complexities of urban systems, they find themselves in a dynamic equilibrium state between order and disorder, striving for a delicate equilibrium at the edge of chaos (Normandin, Julie-Maude, et al 2016). In this context, communities must adapt to a paradigm shift where multiple and fast innovations become an integral part of the process, rather than an afterthought. However, traditional institutions that were designed to manage simple and complicated problems struggle to effectively address the complexities and chaos of contemporary reality. They lack the necessary tools to navigate this new terrain. This growing discrepancy between how the system is structured and how reality functions exacerbates the challenges at hand. While new forms of governance, capable of embracing this evolving framework, have yet to fully emerge, existing institutions still hold formal power. They are tasked with endorsing and internalizing all forms of change, including those that spontaneously emerge from the grassroots level. However, without proper reception and support, these grassroots initiatives run the risk of fading away, even if they hold potential for the system's evolution.

In summary, the current gap between the functioning of reality and the institutional structure highlights the need for new forms of governance and decision-making processes that can effectively respond to the complexities of unexpected situations and chaotic facets of the urban system. In order to foster a flexible and agile urban management system that transcends traditional managerialism and embraces a community-based approach, it is crucial to delve into the necessary insights. By understanding these insights, governance can adapt and redefine its means and scopes, aligning with the ladder pattern proposed for achieving resilience starting from community-level. This shift enables governance to effectively address unsustainable situations and support communities when faced with conflicting choices.

4. Discussion

In biological systems, species evolve in response to changes in the external environment. For example, the ongoing natural selection of bacteria enables them to develop resistance to antibiotics. In social systems, individuals have the capacity to communicate, imagine, invent, and strategically act in anticipation of future situations. System components and agents possess the ability to learn and generate new knowledge, thereby influencing the behaviour of the system through their interventions.

Complex and chaotic situations give rise to emergent solutions, prompting significant efforts to understand and harness the process of innovation in place. There is a quest for that elusive "magic formula" composed of numerous qualities also those mentioned to define resilience. It is through this resilience that individuals, groups, and humanity as a whole have historically managed to succeed, even in the most challenging and desperate circumstances. The state of confusion, the questioning of established ideas and perspectives, and the need to solve overwhelming problems serve as the driving forces behind creative inspiration.

The ultimate aspiration is to transition from foresight to anticipation, systematically guiding the system in the desired direction that resonates at a profound level as if it were already present, but unknown. This perspective offers a positive reinterpretation of the human inclination for control, with the expectation of greater awareness regarding the limitations of prediction and effective emergency management. By recalibrating the concept of management from government to governance, there is a growing understanding of the necessity to collaborate closely with communities in order to establish the preconditions for spontaneous emergence of what is sought.

Based on the framework presented in the previous chapter, this section proposes guidelines for accompanying communities and their contexts in developing resilience from within, particularly in complex or chaotic problematic conditions. To facilitate this, a progressive breakdown is identified, comprising three interdependent levels, each building upon the other, for as many scenarios.

It is essential to clarify from the outset that this community-centered perspective should not be misconstrued as an excuse to absolve governments of their responsibilities. Instead, it calls for a renewed role of institutions that can actively support communities throughout this progression, providing less constraining assistance. By doing so, administrations can ensure that communities are not burdened with the sole responsibility of building inherent and self-sustaining resilience, along with the associated risks and consequences (White Iain et al., 2014; Beilin Ruth et al. 2015; Evans

Brad et al., 2014).

In the baseline scenario, the priority to involve and to empower community members in the planning and decision-making processes. This includes engaging residents, local businesses, and other stakeholders in the development of strategies and policies, ensuring that their needs and priorities are considered. Additionally, several complementary aspects are encompassed within this scenario, ranging from intangible to tangible measures. Some examples include:

- Developing social networks and enhancing community cohesion, as stronger social connections and a sense of community can foster mutual support during emergencies.
- Improving access to information and resources, ensuring that people have access to accurate and timely information, as well as essential resources like food and emergency shelter, enabling effective responses to unforeseen disasters.
- Promoting and encouraging sustainable practices, such as recycling, reducing energy consumption, and preserving green spaces, to ensure resource availability for future generations.
- Cultivating a culture of preparedness through education and awareness campaigns, equipping residents with the knowledge and skills to better prepare for emergencies and mitigate their impact.
- Building diverse and redundant urban systems, including multiple transportation options, diverse energy and water sources, and a variety of housing types.

By implementing these adaptive and reformist measures, communities can foster resilience by empowering their members, promoting cooperation, and developing sustainable practices. It is crucial for governments and institutions to actively support and collaborate with communities in these efforts, recognizing the shared responsibility and the benefits of a collective approach to resilience building.

However, resilience is not solely determined by vulnerability, where an increase in one necessitates a decrease in the other. It requires careful attention to contextual analysis and the elicitation of local knowledge regarding both the intricacies of the problem and the resources available within the local context to address it. This becomes even more critical in circumstances giving rise to dilemmas, such as the case of Taranto, where the roots of the disaster lie within the structure and functioning mechanisms of the system itself. Hence, it is hard to identify and address structural dysfunctions without jeopardizing the system's survival, as doing so may lead to unintended consequences more challenging than the original problem, e.g. social unrest. Moreover, constructing alternative strategies that are acceptable to all system agents without undermining

established organizational structures, often fortified by long-standing personal interests, proves to be equally arduous.

Resilience-building needs to adopt an approach that surpasses the baseline scenario. This enhanced approach can be seen as an upgrade specifically tailored for a system grappling with conflicting choices, it becomes evident that a comprehensive and adaptable resilience approach is vital. This involves considering a range of potential risks and opportunities while striking a balance between competing priorities like economic development and environmental protection. Active involvement of diverse stakeholders in the planning and decision-making process becomes crucial (Borri, Dino et al., 2015).

In this critical scenario, cities should embrace a participatory approach to foster collaboration and dialogue among stakeholders, enabling the evaluation of alternative solutions that balance competing priorities. Additionally, efforts should be made to align regulations and contextual constraints with the overarching goal of urban resilience. This may entail revising or reinterpreting regulations or devising new ways to incentivize behaviour that enhances resilience. It is important to recognize that urban resilience in such variable conditions is a dynamic and continuous process. Cities must continuously adapt and evolve in response to changing circumstances and priorities, rendering the mere application of best practices or guidelines insufficient. Internal monitoring systems should be established to track progress and evaluate the effectiveness of regulations and policies over time. This enables the identification of decisions which contribute to resilience and those that require further modifications or changes.

In this context, several useful measures can be implemented:

- Identifying the root causes of the problem, e.g. understanding the underlying factors that contribute to the conflict situation, and developing effective solutions to alleviate it.
- Establishing close collaboration with stakeholders by engaging a diverse group, including community members, administrative officials, and business leaders. This not only aids in identifying potential solutions but also builds strong support for change.
- Emphasizing the development of multiple complementary and flexible solutions that can adapt to changing circumstances and contexts, rather than pursuing a singular approach.
- Exploring alternative bottom-up approaches, such as self-governance, community-based solutions, or legal challenges to regulations that perpetuate the deadlock.
- Establishing a coalition of community members, organizations, and leaders to generate political will for change, which is pivotal in overcoming conflictual situations.

It is important to note that implementing inclusive decision-making processes does not

guarantee the achievement of resilience. However, they can be instrumental in identifying new areas of opportunity and catalysing momentum for change, which are prerequisites for resilience.

In this incremental journey towards resilience of complex urban environments Information and Communication Technologies (ICTs) can play a crucial role, offering the advantage of continuous service. Indeed, all the aforementioned aspects can benefit from technological innovations that extend and enhance the capacities of individuals and communities (Esposito Dario, 2021). New technologies and ICT platforms, coupled with data analytics, can help identify patterns and trends, providing valuable insights for decision-making and suggesting opportunities for change Esposito Dario, et al., 2020). However, in the context of supporting urban, social, and environmental resilience, the technological component should address three fundamental aspects:

- Improving awareness of the role of individuals in relation to their communities and vice versa, fostering collaboration and information sharing.
- Assisting communities in identifying and achieving sustainable social and environmental balances.
- Influencing and accompanying behavioral change, particularly in response to risk factors and unpredictable events such as disasters.

Aligned with these overarching objectives, the reCITY project has been actively involved in the co-design and impact assessment of technological tools following these principles:

- WHY: Designed and created to empower city users, providing training, information, and activation opportunities.
- WHO: Targeted at all stakeholders involved in territorial governance to support resilient political-administrative decision-making.
- WHAT: Aimed at identifying and enabling everyday resilience practices within communities, enhancing existing practices, and amplifying and spreading them vertically and horizontally throughout the territory in an open innovation perspective.
- HOW: Achieved through the development and dissemination of ICT tools that are:
  - Sentient: Capable of capturing, processing, and responding to data in a customized manner.
  - Customizable, updatable, and reusable: Allowing for adaptability and scalability.
  - Citizen-centric: Focused on providing accessible and user-friendly interfaces and services to individuals.

- Equipped with ubiquitous sensory networks: Creating an 'intelligence' layer for physical infrastructure and communication systems, forming an urban nervous system.

By adopting this approach, ICTs can support the resilience-building process, facilitating knowledge sharing, enhancing decision-making capabilities, and fostering a more proactive and responsive approach to urban challenges and conflicts.

Notwithstanding these two steps, the analysis conducted at the operational level of various case studies, including the one under consideration, reveals that this complex and interconnected picture often becomes fuzzy and instable. Consequently, chronic crises and structural disorders emerge, surpassing the scope of the measures proposed in the initial two levels of approach. In such cases, the pursuit of resilience becomes intertwined with the need to develop capacities for addressing paradoxes, hidden levers, and lock-in mechanisms that subtly or invisibly undermine the efforts of urban communities in enhancing territorial resilience. These challenges may prevent the results of their efforts from materializing, leaving populations trapped in a state of limbo with no viable, tangible, or feasible way forward.

Indeed, for communities grappling with the impossibility of contradictory choices, it is insufficient to independently implement an adaptive and flexible reformist approach aimed at improving community organization, or to favour informed and risk-aware democratic processes of decision-making and action to resolve conflicts arising from opposing interests. This is due to the near impossibility for communities to navigate the complex and sometimes contradictory information, norms, and contextual constraints that characterize these paradoxical no-win situations, regardless of the decisions made. Moreover, different choices often do not represent mutually exclusive possibilities but instead create a false sense of choice that merely binds the system to a predetermined outcome, lacking transformative potential. It is a scenario in which the involved agents seem to be playing a strange game, where the only winning move is not to play.

In such obstructive situations, promoting resilience requires agents to develop a profound awareness of the current structural crisis condition. Once the acceptance of the impossibility of contradictory adaptation is acknowledged, it becomes necessary to foster a paradigm shift in how agents perceive themselves as propositional and decision-making agents (Esposito Dario et al., 2020). This involves reflecting on their own circumstances, constraints, and dilemmas, reinterpreting available resources, and discovering and harnessing energies to creatively generate opportunities and entirely new alternatives. Consequently, the reform efforts employed for managing complex systems must give way to a more revolutionary approach that embraces chaos generativity. A coherent and purposeful effort is required to construct an alternative

escape route in a creative manner, enabling the breaking free from the opposing logical demands of the existing double constraint and the tertium non datur limit. To quote Scott Fitzgerald, "Intelligence is given when in the mind there are two contradictory thoughts. One proof of it is that mankind knows that it is lost, and although it does everything it can to save itself". To address this type of disorder, planners should move away from attempting to control and predict the future of cities through traditional plans and models. Instead, they should aim to invent or design it in direct collaboration with communities (Ackoff Russell, 1994). The co-generation of innovation entails working with communities to create the necessary and sufficient conditions that allow for the emergence of a desirable future from the bottom-up, thereby provoking a required shift in the system.

Therefore, the previously identified measures, presented in a clear and didactic manner, must be complemented by processes that enhance local knowledge and social creativity. These processes should be supported by external experts who are not directly involved in or affected by the current crisis but possess the ability to recognize and unleash resilience resources if they are enabled and trained to do so.

At an early stage of the process, these experts can gain an understanding of the complexity of the situation to dispel contrived confusion. They can then engage in discussions with communities, e.g. share the results of preliminary desktop analyses. By capitalizing on social diversity, which is seen as a repository of diverse knowledge rather than a source of fragmentation and conflict, these experts can involve individuals with diverse skills and widespread capacities in the collaborative generation of alternative solutions.

One opportunity for generating new ideas is through the use of urban lab and other forms of open innovation (Scozzi Barbara, et al., 2017). Cities can also leverage online platforms, hackathons, and other methods to engage as many stakeholders, businesses, and other participants as possible in the development of new solutions. Additionally, cities can promote innovation through methodologies such as design thinking, which encourages human-centred design to generate customized perspectives. By involving residents and other stakeholders in the creative design process, cities can create opportunities to shape the development of their communities in ways that not only meet their needs and priorities but also uphold principles and values of sustainability and resilience. This perspective also emphasizes the importance of believing in and investing in education and training programs that equip residents and community organizations with the necessary skills and methodological knowledge to actively contribute to the development of their communities.

Finally, in order to pursue urban resilience through the co-generation of innovation to

envision an escape route from the double constraint posed by opposing logical demands, the creative design of social and community organizations themselves, and their concrete implementation, should not be overlooked. By promoting new forms of organization and collaboration, cities can create opportunities for stakeholders to come together and discover new, more effective ways and solutions that address multiple challenges simultaneously. One example of this is the emergence of community-based organizations such as community land trusts, cooperatives, and social enterprises. These organizations can empower residents to take ownership of their neighbourhoods and foster more resilient communities that can develop local solutions to diverse issues, including affordable housing, economic development, and environmental protection.

It is important to emphasize that the three stages discussed — adaptive and reformist strategies, inclusive decision-making processes, and co-generation of innovation — are interdependent. They must be built upon one another to enable communities to ascend the ladder of city resilience.

5. Conclusion

In conclusion, the concept of resilience has gained significant importance in the urban context due to its alignment with the complex socio-technical ecosystem inherent to cities. This article has explored the multifaceted nature of urban resilience and the challenges faced by communities in fostering resilience in the face of chronic crises and structural disorders. We have highlighted the need for a comprehensive approach that combines adaptive and reformist strategies with informed and inclusive decision-making processes.

Throughout the discussion, it became evident that urban resilience goes beyond mere adaptation and requires the development of capacities to navigate paradoxes, hidden levers, and lock-in mechanisms. Communities must reflect on their own conditions, constraints, and dilemmas, and creatively generate opportunities and entirely new alternatives. This calls for a shift from traditional planning and control to a more revolutionary approach that embraces chaos generativity.

Moreover, planners and experts must work collaboratively with communities to co-create the necessary conditions for a desirable future. Enhancing local knowledge, social creativity, and diversity is crucial in dispelling confusion and generating innovative ideas. Open innovation methodologies, such as crowdsourcing and design thinking, can empower stakeholders and residents to shape their communities and foster sustainability and resilience.

The creative design of social and community organizations should not be overlooked, as

they play a vital role in addressing multiple challenges simultaneously. By promoting new forms of organization and collaboration, cities can create resilient communities that take ownership of their neighbourhoods and develop local solutions.

In summary, the endless journey towards urban resilience is complex and requires a holistic and participatory approach. By embracing the principles of resilience and working together, communities and stakeholders can navigate the intricate web of challenges and create cities that are capable of adapting, transforming, and thriving in the face of uncertainty.

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Annex - Definitions of urban resilience

2007, Resilience Alliance: Urban resilience is the ability of a city or urban system to absorb disturbance while retaining identity, structure, and key processes (Meerow Sara et al., 2016)
2009, United Nations Office for Disaster Risk Reduction: 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, 2015)
2014, 100 Resilient Cities by the Rockefeller Foundation: Urban Resilience is the capacity of individuals, communities, institutions, businesses and systems within a city to survive, adapt and thrive no matter what kinds of chronic stresses or acute shocks they encounter. (Rockefeller Foundation, 2015)
2014, Intergovernmental Panel on Climate Change (IPCC): "The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation" (IPCC, 2014).
2016, URBACT: Urban resilience is the capacity of urban systems, communities, individuals, organizations, and businesses to recover or maintain their function and thrive in the aftermath of a shock or a stress, regardless its impact, frequency, or magnitude (Poli Irene, et al., 2022)

2016, Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity (Meerow Sara et al., 2016).
2017, European Commission's Joint Research Centre (JRC): resilient system (or society) as being able to face shocks and persistent structural changes in such a way that it keeps on delivering societal well-being without compromising that of future generations. This approach focuses on individual and societal well-being and emphasises the role of social capital. It can therefore be adapted to complex 'human' systems, such as cities (Manca Rita A. et al., 2017).
2019 Local Governments for Sustainability ICLEI: A resilient city is prepared to absorb and recover from any shock or stress while maintaining its essential functions, structures, and identity as well as adapting and thriving in the face of continual change. Building resilience requires identifying and assessing hazard risks, reducing vulnerability and exposure, and lastly, increasing resistance, adaptive capacity, and emergency preparedness (Bizzotto Matteo, et al., 2019).
2019, The capacity of urban citizens, settlements and nation-states to respond to different forms and levels of stressors and shocks (Michael Burayidi et al. 2019)
2019, Resilience is the ability of cities, communities, and households to adapt to changing conditions and to withstand shocks and chronic stress while maintaining essential functions (World Bank, 2019)
2020, ISO /TR 22370: Urban resilience is the ability of any urban system, with its inhabitants, in a changing environment, to anticipate, prepare, respond and absorb shocks, positively adapt and transform in the face of stresses and challenges, while facilitating inclusive sustainable development (ISO 2020).
2021, Urban Resilience refers to a multidimensional dynamic process among stakeholders aiming to prepare and adapt the urban environment to absorb and recover from external and internal disturbance and reduce urban vulnerabilities (Kapucu Naim, 2021)
13. 2022 UN HABITAT: Urban resilience is the measurable ability of any urban system, with its inhabitants, to maintain continuity through all shocks and stresses, while positively adapting and transforming toward sustainability (UN HABITAT 2022)

14. 2022 Resilience is the capacity of urban systems to first adapt and then overcome various disruptions. Thus, it is considered as the possibility that the complex urban system contains, on the one hand, the ability to absorb a disruption but, on the other hand, able to recover its former functionalities as quickly as possible (Adolphe Luc 2022).
15. OECD*:* Resilient cities are cities that have the ability to absorb, recover and prepare for future shocks (economic, environmental, social & institutional). Resilient cities promote sustainable development, well-being and inclusive growth (OECD, 2023).

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