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Article

Placing Urban Renewal in the Context of the Resilience Adaptive Cycle

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Abstract: Resilience thinking provides valuable insights into the dynamics of complex adaptive systems. To achieve resilience in urban systems, it can be fruitful to delve into the intricacies of resilience processes. This paper theorizes about how the specific characteristics of resilient systems can be integrated into the spatial design of cities. Emphasizing the importance of the built form and spatial systems in maintaining order within urban processes, we focus on how adaptive renewal cycles can be applied to various systems and dimensions where urban change, adaptation, and renewal occur. The paper identifies key resilient system characteristics applicable to urban spatial form and contextualizes urban renewal within the adaptive renewal cycle—a framework originally developed to capture temporal and spatial ecosystem dynamics. We integrate insights within 'space syntax theory', theorizing about how cities renew themselves over space and time. We discuss instances of 'compressed resilience' and the challenges posed by the 'tyranny of small decisions' in urban planning and development. In conclusion, we identify future research directions in the theory of spatial morphology and resilient urban systems, emphasizing the need for a deeper understanding of the interplay between urban processes, urban form, resilience, and adaptive renewal.

Keywords: resilience; urban renewal; the adaptive renewal cycle; compressed resilience; space syntax theory; spatial morphology

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1. Introduction

With their irregularity, cities are systems of complexity par excellence where various elements interact in unpredictable ways. The prominent urban theorist and activist Jane Jacobs made a significant contribution to the understanding of cities and their complex dynamics. Her work emphasized the organic, diverse, and dynamic nature of urban systems. Her most influential work, *The Death and Life of Great American Cities*, published in 1961, challenged the prevailing urban planning theories of the time [1]. Jacobs underscored the importance of diversity, community engagement, bottom-up growth, social interaction, and the concept of cities as self-organizing, dynamic ecosystems rather than rigidly planned structures.

The recognition of the striking similarities between urban systems and ecosystems [2], initially highlighted by Jacobs, was about a decade later rediscovered by C.S. Holling as a relevant framework for understanding urban system dynamics [3]. It is striking how Jacob's keystone ideas resemble the key principles of resilience building [4–6], where resilience signifies a typical property found in all systems of complexity, i.e., their ability to sustain steady states over long time periods [7].

While the concept of complexity is often associated with irrationality and chaos, it signifies that systems fluctuate between stable and unstable states. Therefore, complexity encompasses all the possibilities that unfold between these states as evolution progresses.

What is surprising about cities, as well as many other complex systems, given their multitude of intricate sub-systems, is perhaps not their unpredictability and irregularity, but rather that, over long time periods, they remain stable and predictable just like the climate undergoes long periods of stability, considering that the Earth has, ever since the ice age, been in an interglacial period known as the Holocene, representing a relatively stable and warm period over the past approximately 11,700 years.

Resilience thinking provides planning theory with a new way of understanding complex, dynamic, and non-linear social, economic, and ecological relationships. As a result, it represents an important sustainability framework in which sustainability is seen as a process, rather than an end-product. Resilience, in this sense, denotes the adaptive capacity needed to deal with continual change and renewal, often triggered by different types of social and ecological disruptions [4].

Urban resilience is a multidimensional concept that has garnered significant attention in theoretical research within various fields during the past two decades, such as in urban studies, geography, environmental science, and urban planning and design. Researchers have explored different aspects of resilience, including its various definitions, measurement, contributing factors, and implications for sustainable development. They often draw on interdisciplinary perspectives, integrating insights from ecology, engineering, sociology, architecture, and economics [2,8–14]. Notable contributions of pivotal resilience research include Berkes and Folke's work on social–ecological resilience [15] and the development of resilience assessment methodologies by Meerow, Newell, and Stults [16]. The importance of adaptive governance and planning in enhancing urban resilience is also emphasized in works such as Pickett et al.'s exploration of anticipatory governance [8]. Marcus and Colding [17] have moreover explored the temporal and spatial dynamics of urban resilience through the lens of spatial analysis tools and theories. Other noteworthy contributions include Adger's exploration of social resilience [18] and Cote and Nightingale's work on resilience and political ecology [19].

In this paper, we make the theoretical argument that resilience thinking could help us to enrich our understanding about how a complex adaptive system, such as a city, undergoes renewal and regeneration. It is essential to underscore that this paper primarily serves as an abstraction, delving into conceptual frameworks and theoretical underpinnings. By exploring the application of resilience thinking in the context of urban dynamics, we aim to contribute to the theoretical foundations that underlie our understanding of the intricate mechanisms involved in the renewal and adaptive evolution of cities. Considering the theme of the Special Issue to which this paper contributes, it might be useful to distinguish between 'regeneration' and 'renewal', with the former implying a comprehensive and transformative process. It may involve not only physical changes but also improvements in social and economic aspects. Renewal, on the other hand, and as we use the term, has a broader application, focusing on the extension and the enhancement of an urban system's existing state without implying a complete overhaul of it. Rather, incremental change is a distinct mark of city development [20].

While ample research has been devoted to urban resilience, there has been a noticeable gap in efforts to bridge urban studies with the resilience adaptive renewal cycle proposed by Holling [21] for the renewal and dynamics of ecological systems. This paper takes a theoretical approach, primarily situating the urban form and urban renewal within the context of the adaptive renewal cycle. Holling and Goldberg [3] highlighted striking parallels between ecological and urban systems. They underscored how these systems operate as interdependent entities, relying on a sequence of historical events, exhibiting spatial connections, and possessing a nonlinear structure. Both systems seem to possess significant internal resilience within a specific range of stability [17]. Furthermore, they did not perceive a city as a uniform structure; instead, they saw it as a spatial mosaic of social, economic, and ecological variables that are connected by a variety of physical and social dispersal processes" [3] (p. 227), or what later Gunderson and Holling [21] termed 'panarchy', representing a nested set of adaptive cycles operating at discrete spatial and temporal scales. The adaptive renewal cycle functions as an elucidative framework for comprehending the dynamics of ecosystem renewal with potential for providing insights also into urban renewal processes more generally. As proposed in this paper, this implies a translation of temporal process into spatial structure, which also will demand support from spatial morphology [22].

Article Outline

This paper is organized as follows: Sections 2–5 delineate the essential theoretical foundations of resilience thinking, crucial for understanding the adaptive cycle. Section 2 outlines the definition of ecological resilience utilized in this paper. Section 3 presents theories of ecosystem renewal, shaped by resilience analytical thinking, originating from Holling's seminal paper, 'Resilience and Stability of Ecological Systems' [23]. Expanding upon these concepts, in Section 4, we interlink them with the adaptive renewal cycle—a pivotal framework in resilience science initially designed to capture temporal and spatial ecosystem dynamics [23,24]. Section 5 delves into situations where resilience may be diminished in the management of complex adaptive systems. In Sections 6 and 7, we scrutinize the intersection of resilience theory with spatial morphology as more specifically formulated in 'space syntax theory' and extensions of it [17,25]. The paper concludes by highlighting potential future research directions within this analytical research domain.

2. Ecosystem Renewal Insights: A Theoretical Framework for Understanding Urban Renewal?

The order or steady state typically found in complex adaptive systems, notwithstanding their intrinsic unpredictability, is in the resilience literature described as a 'regime' within an 'attraction domain'. This steady state is not a state of absolute equilibrium, but a state allowing for fluctuation within the boundaries of the attraction domain [26]. Fluctuation in cities occurs within the boundaries of a dominant attractor state that is generated by subsystem changes occurring at multiple spatial and temporal scales, referred to as 'panarchies' [21]. Thus, the multi-scale dynamics of urban systems are continuously renewed within these fluctuations through a mixture of intentional planning policies, informal self-organized processes, or a combination of both, as they interact with each other. In this sense, they represent self-organizing, complex adaptive systems that hold the opportunity to be managed in resilient ways towards sustainability through processes of transformation, just like any complex adaptive system [27]. The renewal of ecological systems, just as in the case of social systems (but in contrast to the systems of spatial urban form), is dynamic, which we can observe at an elementary level during the reoccurring seasonal changes. The spatial and temporal dynamics of ecosystems can be found in the succession cycle, which addresses the renewal and recuperation of ecosystems after a disturbance, such as fires or storms. Such processes, intrinsic to complex systems, can be contained within a given regime in the form of a dynamic steady state. However, if the domain boundaries of a regime are exceeded, the system may flip into a new regime, i.e., lose resilience, limited by a new attraction domain that changes the properties of the system—often radically [28]. Such a new regime may, moreover, prove difficult or even impossible to reverse [28]. A typical example from ecological studies is how a lake can change from a clear water regime to a turbid regime [29], where both may prove equally resilient, but where the properties and functions fundamentally differ, for instance, the abundance and diversity of fish in the lake. Similarly, degraded forests can turn into desserts, savannahs into shrub lands [30], and coral reefs become algae-dominated [31]. Such shifts may, from the point of view of humans, prove devastating.

Although an entire city rarely experiences a regime shift, except in war situations, the subsystems of a city undergo continuous regime shifts. For example, urban renewal projects can bring about significant changes in the dynamics of a city's subsystems [32], and these changes can have both positive and negative consequences [33,34]. Urban renewal projects may, for instance, lead to increased property values and more attractive living conditions, but they may also lead to gentrification processes through the displacement of existing residents and/or the loss of historical and cultural heritage. Hence, while it may make economic sense to increase property values in a city, it may have negative social effects. Thus, the reduction in social resilience may occur as an economic efficiency tradeoff.

In response to climate change and the need to reduce reliance on fossil fuel transportation, urban renewal in the form of planning frameworks, such as 'transit-oriented development', 'smart growth', and 'new urbanism', is often promoted by urban planners and policymakers. However, the adaptive capacity of cities cannot rely on static urban development paradigms, since social, economic, and ecological challenges evolve over time, presenting new and often complex challenges that demand new innovative solutions [35]. Rather, and in theory, we see the need for more adaptive management of urban development based on more contextually based governance principles.

3. Resilience Categories: Engineering vs. Ecosystem

The conception of resilience by C.S. Holling makes an important distinction between ecological resilience and engineering resilience [26]. The latter is measured as the time it takes for a perturbed system to return to its original state of equilibrium, often illustrated by a ball in a bowl being released after lifting up the side of the bowl. In contrast, Holling illustrates the idea of ecological resilience as: "a landscape of hills and valleys with a ball journeying among them, in part because of internal processes and in part because exogenous events may flip the ball from one stability domain to another" [36] (p. 72). In this case, resilience is measured as the magnitude of disturbance that an individual attraction domain, or valley, can absorb before the ball flips over into another valley or domain of attraction. This presents a different universe constituted by, first, broad valleys where the system's dynamics can play out without the loss of its intrinsic functions, and second, a landscape with multiple equilibria, where ecosystems (because of both internal and external forces) can shift from one steady state to another with the serious effect that their basic properties and functions change, as illustrated in the example of the clearwater lake.

Hence, a steady state in ecosystems does not imply an absolute equilibrium but can exist within a frame of fluctuation, where these fluctuations essentially support the system by staying within its regime. Hence, the idea of resilience significantly differs from the conventional conceptions of stability, or rather, ecological resilience fundamentally differs from engineering resilience [23]. As a matter of fact, one of Holling's key messages—not least true for natural resource management, but potentially equally important for urban management and development—is that keeping an ecosystem or resource management system close to an absolute equilibrium may over time undermine the resilience of the system, i.e., it may wear down the ridges defining the attraction domain so that the ball is more likely to flip into another domain, often with devastating results [37].

Adaptation is an important property of ecological resilience that makes it possible for an ecosystem to undergo change over time while retaining structure and function, and in extension, not only to change but to adapt, which can be described as a process of learning and involving ecological memory [36]. In the ecological conception of resilience, the system does not just bounce back after disturbance, but neither does it fluctuate aimlessly; what it does is to change and adapt. Whereas the ball in the bowl returns to its original position, we do not regain the same forest after its recovery from a fire; it is likely to have adapted. There is, for example, evidence of plant species subjected to repeated fires becoming distinctly more combustible, which helps the survival of their plant community, but is not true for species in communities not subject to a fire [36]. Keeping this analogy in mind, we may also see how cities after fires, for instance, the Great Fire of London in 1666 [38], are rebuilt in the same spatial form, but in brick rather than wood to better endure the next fire.

4. Connecting Processes: The Adaptive Renewal Cycle

C.S. Holling's work laid the foundation for the understanding of adaptive cycles within ecological systems, which can be related to the broader concept of adaptive renewal.

It is not only relevant for ecosystems but is intended as a framework for the understanding of complex adaptive systems generally, from cells to ecosystems and societies. Such all-embracing aims call for caution, but this means that the model was created from the perspective of general systems theory [39], the study of systems per se, with the aim to disclose the role of resilience in systems in principle, not explain the mechanisms of individual systems. Therefore, the adaptive renewal cycle has proved illuminating for a wide range of systems in many fields. At the same time, the reason for caution when comparing natural and human systems remains, as underlined by Holling himself [21].

In Holling's model of ecological succession, ecosystem dynamics are driven by the interaction of four basic functions: exploitation, conservation, release, and reorganization [36]. The first two come close to earlier conceptions of this cycle, often referred to as Clementian succession, where a progressive change in the composition of a community of organisms, either by colonization by species of a disturbed area or an established community, over time leads to a conditional stability identified as a climax community [40]. There are two stages in this progression, where 'exploitation' concerns a process of rapid colonization of disturbed ecosystems by r-strategists, which are species good at capturing dispersed resources, which is why it is often called the r-stage. The other stage, 'conservation', concerns a slower process of resource accumulation by late succession species associated with climax communities [41], which typically builds and stores increasingly complex structures. During the slow sequence from exploitation to conservation, connectedness and stability increase in the system, and nutrients and biomass are slowly accumulated. This stage is referred to as the K-stage. The first two stages are, moreover, referred to as the fore-loop of the cycle.

Holling then introduced two novel stages that are distinct additions to and are even in conflict with the Clementian model. The first is a stage that he called release, or the omega stage (Ω), which erratically occurs when the conservation phase has created an elaborated tightly bound organization that has become what in systems terms is called over-connected. The system then becomes fragile and vulnerable to disturbances, which makes it easily triggered into rapid change when its stored biomass is released, and the tight organization lost. This means an abrupt internal destruction of the system caused by an external disturbance, such as fires, storms, or disease. But this rapid process of destruction to the organization also creates opportunity for the fourth stage in the cycle, reorganization. In this stage, also called the alpha stage (α), the materials released in the previous release stage are again mobilized and made accessible for a new stage of exploitation.

In summary, the stability and productivity of the system are found in the slow exploitation and conservation sequence, whereas its resilience is determined by the last two phases, also referred to as the back-loop. Hence, reoccurring disturbances (or incremental changes and disruptions) are an important part of ecosystem succession and evolution and are crucial for sustaining resilience and integrity in such systems. This also means that, if disturbances are blocked out, e.g., through fire prevention, the ecosystem will over time accumulate biotic material and become over-connected, which creates an opportunity for large-scale perturbations with extensive destruction that can flip the system into a new attraction domain that profoundly changes its properties [15]. To evade this, creating conditions for the back-loop step in the succession cycle is critical for shifting the system into a new stage of exploitation rather than to change into a new regime. In Figure 1, this possibility is marked X.

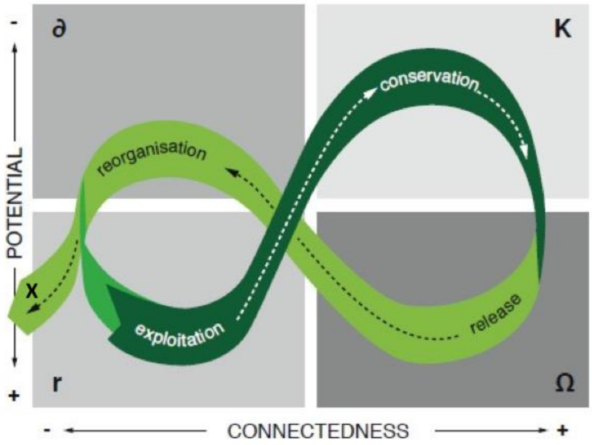

Figure 1. The adaptive renewal cycle. The figure illustrates how ecosystems evolve over time. The y-axis represents the amount of potentially stored nutrients, while the x-axis represents the degree of connection among the variables. The 'r-phase' denotes the establishment/exploitation of unvegetated land, such as land cleared by fire or by a heavy storm. During this stage, the land has significant potential for the redevelopment of biodiversity, reaching the 'K-phase'. The 'omega phase' symbolizes disturbance, involving the loss of energy, such as heat during a forest fire. In the 'alpha phase', the renewal of the system occurs after the disturbance. If the right conditions (nutrients, pioneering species, etc.) are not accessible in the alpha phase, the system risks tipping into a new stability domain, marked with an 'X' in the figure.

5. Optimization and Compressed Resilience

Efficiency is often viewed as a positive attribute in the governance of many systems, including economic, industrial, natural resource management, and organizational systems. However, it is important to balance efficiency with resilience to ensure that systems can respond and adapt to changing circumstances and avoid what can be referred to as 'compressed resilience', where options are successively reduced. This requires a shift in mindset from maximizing output to building the capacity for change and adaptation [42]. To promote resilience, resource managers and policymakers need to be aware of the potential trade-offs between efficiency and adaptability and to design policies and strategies that take both factors into account. This, among other things, includes adopting resilience principles, such as balancing strategies for managing connectivity and redundancy, building social networks and trust, and promoting learning and innovation [42].

As is generally known in natural resource management, planning that prioritizes optimization and efficiency often occurs at the expense of long-term adaptation or transformation [37]. To achieve a greater efficiency, many systems are streamlined to eliminate redundancies, meaning that there is little or no backup in place if the system as a whole or an element or component of the system fails. This can make the system more vulnerable to shocks and disturbances of different types and origins, like natural disasters, economic downturns, or equipment failures, which can have far-reaching and long-lasting consequences [21]. An illustrative case in natural resource management is the production efficiency in agriculture that often occurs at the expense of long-term agricultural resilience by degrading soil conditions and making the production system, in the long run, more vulnerable to pest and disease outbreaks as well as climate variability [43].

In urban development, a similar argument can be made, for example, for the neighborhood unit concept, in which new housing areas tend to be optimized for a particular size of inhabitants in regard of public and commercial services, but also for apartment sizes as well as for the measurements of individual rooms in apartments. This makes it hard to rearrange and restructure such legacies. Another well-known and illustrative example of this is building and construction legacies associated with the Olympic games [44]. Another example is modern traffic planning and its emphasis on individual road designs for different traffic modes and speeds. Whereas there are obvious arguments for such optimization, it does also create the vulnerability of change, such as changing demographics or new traffic technologies.

Hence, a narrow focus on efficiency and optimization can reduce resilience through both the creation of tightly coupled systems [45] and the lack of redundancy [46]. Thus, when a system is optimized to facilitate a specific function, it can become extremely difficult and costly to change. Tight coupling in the K-phase of the adaptive renewal cycle refers to a situation where the components of a system are highly connected, interdependent, and operate in a synchronized manner to provide a certain function. A lack of redundancy generally makes a system more vulnerable to unexpected events, such as natural disasters or economic downturns, which can cause cascading failures [23,47]. While tight coupling can increase efficiency in normal conditions, it also means that a disturbance or failure in one part of the system can quickly spread and affect the entire system, leading to greater chances for management failures (Figure 2). We refer to this situation as 'compressed resilience' in the adaptive renewal cycle, denoting a phase with the progressive loss of a system's ability to adapt to changing circumstances and recover from shocks or disruptions. Uncontrolled city growth represents a prime example of compressed resilience. A prime case is when local policymakers try to attract new inhabitants to their municipality to increase the tax base [48]. Over time, and due to changing circumstances, such a policy may lead to long-term social, ecological, and economic problems.

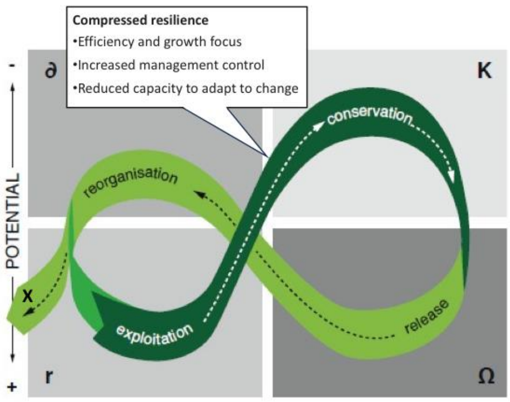

Figure 2. Compressed resilience illustrated through the framework of the adaptive renewal cycle. As the progression of the forward loop continues over time, the capacity to adapt to change and disturbance is declining—a situation that, in this paper, we refer to as 'compressed resilience'.

Tight coupling, however, may at the same time yield tangible benefits, such as urban densification for tackling climate change, which is endorsed by several international organizations, including the Intergovernmental Panel on Climate Change (IPCC) [49]. Densification is an important planning strategy to avoid urban sprawl, representing a leading land-use problem in many city regions. Hence, 'smart growth planning', often fused under the heading 'smart growth' or 'transit-oriented development', is a common urban design strategy for mitigating urban sprawl [50]. Yet, densification can, in some cases, also lead to situations of compressed resilience. With the tight coupling of the built urban form, often through taller buildings and packing more people into smaller spaces, comes an increasing risk of more severe consequences of disturbances [51,52]. Open spaces, such as plazas and parks, provide places of refuge during severe heat waves, new pandemics, for stress reduction, and other ecosystem services. Therefore, it is important for urban planners and policymakers to consider the potential risks associated with densification and incorporate measures that promote long-term resilience and adaptive capacity [53].

Compressed resilience also means that cities have fewer opportunities to renew themselves in a cost-effective way. One example of this is the restoration of skyscrapers, which often are the hallmark of dense urban areas and house many businesses and residential units. While some demolition and replacement of such buildings may be necessary for climate-proofing, studies indicate that there are significant opportunities to reduce carbon emissions by retrofitting them rather than constructing new ones [52]. However, the high cost of restoration may lead to a lack of investment in damaged areas or a reluctance to rebuild at all. This can have long-term economic and social impacts on the affected area and on the city itself. An emerging example is areas that are faced with sea-level rise due to climate change, leading to climate-induced gentrification [54,55].

A typical response for managers to deal with cases of compressed resilience is to resort to the imposition of new rules to implement more of the same policy solution, increasing the level of efficiency (Figure 2). This type of response is something that the economist Alfred E. Kahn warned about and coined as 'the tyranny of small decisions.' Kahn specialized in regulation and deregulation policies and presented the tyranny analogy to represent a situation in which a number of decisions, individually small in size and time, result in non-optimized and socially undesirable outcomes [56].

6. A Spatial Morphology for the Adaptive Renewal Cycle

Cities are rarely only dense or dispersed; they constitute landscapes of continuous variations in density, so that each location in principle is unique, allowing for parallel trajectories to develop. This not only concerns the local properties of individual locations, but more importantly, is applied to each locations' accessibility to other locations at different radii. This emphasis on relative location (location in relation to other locations, often defined by infrastructure) rather than absolute location (location on the surface on the Earth given by nature) is essential for understanding cities as well as for creating policies for sustainable urban development.

To understand the role of the adaptive renewal cycle in an urban context, it is crucial to translate such dynamics into the spatial urban form to fully understand how such processes play out in urban spaces and, by extension, to be able to inform urban planning and design how to create the spatial settings that can support and sustain them. For this, we need a spatial morphology through which urban space can be described and analyzed. In this paper, we provide a brief outline of such morphology [17], for which we identify three basic variables. First, 'accessibility' from each location to all other locations in an urban landscape, which typically is facilitated by a street network. This should not be seen as a neutral support system but defines the relative location of each location in a city, creating a greater or lower accessibility to the rest of the city, which can also be measured at different radii. Second, the 'density' of the built fabric, which allows for variations in the volume of activity at different locations by means of the built floor space. This can also be measured as accessibility to the floor space, meaning how much floor space one can access within a certain radius of a location, preferably measured following the street network. Third, the 'differentiation' of urban space into individual parcels and their adherent property rights, which creates opportunity for different forms of proprietorship (e.g., public, private, common, and their mixture) to develop individual strategies that, in turn, and in principle, can support social and economic diversity in urban space. Lessons from sustainable resource management suggest that policy efforts should concentrate on creating a diverse array of property rights frameworks tailored to the cultural, economic, and geographic contexts [57,58].

A spatial morphology based on resilience thinking offers an alternative to conventional top-down urban planning by adherence to a given set of resilience principles, such as redundancy and response diversity [46]. Framed within the context of the adaptive renewal cycle and beginning with the front-loop step, evolving from the r-stage to the K-stage, we argue that this phase is a transition from a stage that demands high spatial accessibility in the street network, high spatial differentiation in the parcel system, and moderate spatial density in the built fabric. This phase also provides 'spatial capital' [17] because it offers spatial support to the need for proximity between a large group of diverse actors, which is characteristic of the r-stage. These actors can, for example, be firms and business enterprises, people that meet and bond in social and public spaces, or actors facilitating different types of cultural amenities. In socio-economic terms, this can be interpreted as a need for rapid exchange between small, agile, and innovative firms and other types of actors [36]. From the r-phase, it proceeds to a state demanding lower accessibility and lower differentiation but increased density, due to the need for efficient accumulation and concentration within a few large firms, as typical for the K-stage, meaning firms or various urban service providers that are less agile and innovative, but highly competitive due to their accumulated capital. In resilience terms, it describes a shift from a stage of high resilience to a stage of low resilience, because the K-stage becomes increasingly exposed to disturbances, in part due to the system's reduction in diversity, where the loss of every actor has considerable effects, and in part due to the system's lower accessibility, which means less opportunities for invigorating input. But, at the same time, the potential for increased activity is improved due to increased density, or spatial volume, which affords a greater leverage to all action, including mistaken. Together, this amplifies the system's instability and vulnerability, which may prove devastating in times of disturbances of a more severe kind, such as an economic recession.

In the transition from the K-stage to the Ω-stage, connections are broken, and resources dispersed, not least because changes in the spatial form supporting it destabilize the resilience of the system. In spatial terms, it means a shift from the low spatial accessibility of the new regime to the need of increased accessibility, since actors, infrastructure, and other resources are unbound and need new connections. For similar reasons, it also demands an increase in spatial differentiation, since these actors and resources, previously connected in large organizations and clusters of spatial urban form, now are dispersed as individual entities in need of new spaces of their own to form spatial form clusters that promote the close interaction of these individuals. The demand for spatial density, on the other hand, plummets because many activities and resources were lost in the destruction of the previous organizations.

This Ω-stage forms the basis for a phase of reorganization, a shift from the Ω-stage to the α-stage, where the landscape of low spatial accessibility and differentiation, as well as low density, sees a surge in demand for all these variables. This is due to the process of self-organization of the dispersed actors, who, step by step, increase both their connections and differentiation. This is accelerated in the transition from the α-stage to the r-stage, where the organization of these activities both intensifies and proliferate, which increases the demand for spatial forms that facilitate diversity and exchange as well as volume. This rapid shift from the K-stage back to the r-stage also implies a transition from low spatial support for resilience to high support, as in general, all the spatial variables are inverted. Finally, the r-stage leads over to the slow transition into the K-stage where the cycle began, the front-loop evolving from exploitation to conservation, and the cycle starts over.

7. Synthesizing Resilience Theory and Urban Form: A Space Syntax Perspective

The adaptive renewal cycle is a representation of a process through time, whereas the spatial morphology mentioned above is a representation of spatial structures. However, up to this point in our discussion, we treated our spatial variables as part of a process through time so that spatial form changes as the process changes, which seems unlikely due to the extremely high costs of rebuilding the spatial urban form. It also undermines the argument that the spatial form can build resilience in urban systems since it changes only slowly over time and therefore, is able to control faster urban processes. For instance, whereas some processes change continuously, such as the intensity of the movement of people in a city, which typically varies over the course of the day, other aspects of this process remain quite constant, such as the relative distribution of movement in space. This constancy is due to the spatial form, in particular street networks, the configuration of which changes very slowly.

A fundamental property of the spatial urban form is not only that it is a slow variable that can influence faster variables, but that it, due to its very spatiality, can harbor several processes at the same time, that is, many trajectories occurring in parallel over time and in different places. This concerns not only different processes in different places but also different sequences of the same process, such as the different stages of the adaptive renewal cycle. For instance, we often see retail firms shift location as they grow, from the back street to the main street and into the mall, since each location is more suited to the different phases of the firm's growth. This ability to carry several processes in parallel is of course fundamental for cities, but as argued by British geographer Doreen Massey, we have an inclination to see space as a dimension of time—as in our treatment of the adaptive renewal cycle above—which she sees as part of our Western mode of thinking broadly, in which we continuously let time dominate over space [59]. Given the fundamental spatiality of cities, we should look for spatial support for the adaptive renewal cycle in the urban landscape as a whole and not in one and the same place—this would be to try to turn space into time.

To fully address this issue, it is important to realize that adaptive renewal cycles take place on several levels, as emphasized by Gunderson and Holling [21], since resilient systems consist of a hierarchy of interconnected systems, known as a 'panarchy', which is crucial for understanding how complex systems function and adapt to change over time. The panarchy model recognizes that systems exist at different scales, with each level of the hierarchy influencing the behavior and resilience of the systems on the other levels. At the same time, each level of the hierarchy operates on a different timescale, with faster cycles of change occurring at the lower levels and slower, more stable cycles of change occurring at the higher levels. The panarchy model can help us to better comprehend the dynamic relationships between different elements of an urban system and the interdependence between these elements at different levels of the hierarchy. This understanding is essential to predict how a system will change over time and how it will respond to various disturbances, shocks, or other types of changes that may occur in a city.

While high levels of connectivity can facilitate recovery after disturbances in ecosystems, it can, as argued, also spread disturbances much faster. Therefore, 'modular' or compartmentalized structures and patterns in ecosystems, such as in food webs, may offer resilience by isolating and retaining the impacts of a perturbation within a single module, and thus, minimize impacts on the other modules in the system [60]. Modularity calls for increased attention on how to configure and structure spatial urban form. For example, the integration of green spaces or other open public areas could help to mitigate the environmental stressors and alleviate urban challenges, making them modular elements in an otherwise highly connected urban fabric.

This challenges us to take another step in our translation of resilient systems to spatial form, again to fully understand how they play out in urban spaces, and by extension, how to support them through informed urban planning and design. In space syntax research, Hillier has presented a theoretical argument about the relation between the spatial form of cities and the evolution of society [61]. Urban street networks, which are the primary components of the spatial form for the distribution of accessibility in cities, often present a duality, he argues. In part, they are a foreground network covering the city, a kind of super-grid of high accessibility that facilitates quick connections and supports socio-economic exchange and innovation. In part, they are a background network in the shape of patches of sub-ordinated streets in this super-grid that are less accessible and therefore create more segregated spaces, which in contrast facilitate socio-cultural continuity and reproduction (Figure 3) [62]. Acknowledging that this may be manifested in different ways in different cities, the spatial form of cities may in principle be described as an entity that fundamentally supports both processes. In Hillier's words: "We call the first the generative use of space since it aims to generate copresence and make new things happen, and the second conservative since it aims to use space to reinforce existing features of society" [63] (p. 150).

Importantly, the processes supported by these networks, generation and conservation, are close to the processes identified by Holling and colleagues as fundamental for the sustainability of adaptive complex systems:

> "The adaptive cycle [. . .] shows two very different stages. The front-loop stage, from r to K, is the slow, incremental phase of growth and accumulation. The back-loop stage, from Ω to α, is the rapid phase of reorganization leading to renewal. [. . .] It is as if two separate objectives are functioning, but in sequence. The first maximizes production and accumulation; the second maximizes invention and reassortment. We have no theorem to prove it, but our intuition suggests that any complex system, if it is adaptive, must generate these two phases in sequence, at some scale" [21] (p. 47).

In our argument, in cities, such phases of a process will by necessity require support from the physical structure of the spatial urban form. Hence, it is interesting that Hillier, in a similar manner, explains his idea of the foreground and background networks:

> "by some as yet unknown process [...], cities of all kinds, however they begin seem to evolve into a foreground network of linked centres at all scales, from a couple of shops and a cafethrough to whole sub-cities, set into a background network of largely residential space" [63] (p. 139).

Holling and colleagues first seemed apt to think about the process they address in terms of time. Fearing the engineering principle of optimization, they underlined how: "The two objectives cannot be maximized simultaneously, they occur only sequentially" [21], but subsequently, they conceived a road forward, which we interpreted as being spatial:

> "attempting to optimize around a single objective is fundamentally impossible for adaptive cycles, although optimizing the context that allows such a dynamic might be possible" [21] (p. 47).

We quote Hillier, again, in support of our interpretation of the context that Holling and colleagues refer to as the spatial form:

> "The foreground structure, the network of linked centres, has emerged to maximise grid-induced movement, driven by micro-economic activity. Micro-economic activity takes a universal spatial form and this type of foreground pattern is a near-universal in self-organised cities. The residential background network is configured to restrain and structure movement in the image of a particular culture, and so tends to be culturally idiosyncratic, often expressed through a different geometry which makes the city as a whole look spatially different" [63] (p. 150).

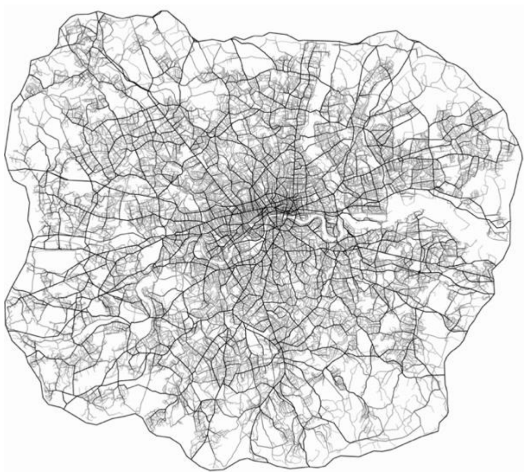

Figure 3. The foreground network (dark grey), according to Hillier, facilitating socio-economic exchange and renewal through high accessibility, and the background network (light grey), facilitating socio-cultural continuity and reproduction through low accessibility. The pattern is produced by measuring the betweenness centrality for all street segments in the complete street system. Source: Hillier and Vaughan [61].

Again, different processes, or different phases of processes, can take place simultaneously in cities, albeit in different places. At a closer scrutiny, the large and high-resolution analysis of a street network in Figure 2 make us realize that we are not really referring to only two networks, but to a continuous hierarchy of spaces, from the most local to the most global, and that each street segment in a street system has unique properties, with these segments producing an exceptionally rich landscape of locations together. It may actually bring to mind an agricultural landscape, where the experienced farmer, knowing the land, recognizes exactly what crops work best and where.

Hence, we argue that the spatial urban form has a direct influence on urban systems and therefore, in principle, can be used to direct, through its design, such systems towards increased resilience. In the spatial morphology framework mentioned above, we also add the variables of spatial density and differentiation to the variable of accessibility primarily discussed by Hillier, which together offer a rich palette for the analysis of the spatial form of cities, as a means to increase our understanding of its role in building resilience and, in turn, inform practice in urban development.

8. Conclusions and Future Directions

As theorized in this paper, resilience thinking offers a novel approach to enhance our understanding of complex adaptive systems, with cities serving as prime examples. To foster resilience in urban systems, it is imperative to enhance our comprehension of the key characteristics inherent in resilient systems, translating these insights into the spatial urban form and understanding the processes of urban renewal. By integrating the adaptive renewal cycle and aligning it with spatial morphology and 'space syntax theory', we proposed in this paper several theoretical postulates that elucidate how cities undergo renewal, across both space and time. Additionally, we translated these postulates into spatial form, trying to present a more comprehensive understanding of their manifestation in urban spaces. While further research is essential to explore urban renewal through the analytical lens of resilience, future investigations in this domain should be oriented towards:

- Exploring the potential trade-offs between efficiency and adaptability for the development of design strategies that take both factors into account.
- The development of strategies for managing connectivity and redundancy, including improving understanding regarding the role of the modularity of urban spaces to mitigate environmental stressors and alleviate other types of urban challenges.
- Improving the understanding of both the generative use of space, which aims to generate co-presence and make new things happen, and the conservative use of space, which aims to use space to reinforce the existing features of society.
- Processes in cities that will need support from the spatial urban form and that confer resilience.

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