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Urban Resilience in Climate Change Adaptation: A Conceptual Framework

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Academic Editor: Vincenzo Torretta
Received: 5 February 2016; Accepted: 21 April 2016; Published: 23 April 2016

Abstract: This study presents a conceptual framework for analyzing urban resilience in the context of climate change. The key conceptual elements of resilience are first identified and then reorganized with a focus on cities and climate change adaptation. This study covers not only ecological and engineering resilience but also resilience as a sociopolitical process from an evolutionary perspective. The study's conceptual framework centers on resilience as it relates to cities and climate change. Its findings are expected to shed light on future urban planning and policies for adapting to climate change.

Keywords: urban resilience; climate change adaptation; resilience building; evolutionary resilience; sustainability

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1. Introduction

"Resilience" comes from the Latin verb *resilire*, meaning to rebound or spring back [1–3]. Physicists first used the notion of resilience to explain elasticity and describe a material's ability to withstand external shock [3]. The term, which originated in the fields of ecology and natural sciences [4], came to be used in various other disciplines, such as psychology and the study of psychiatric illnesses [5], the social sciences and community development [6], and engineering design [7].

Recent discourse on resilience has sought to move away from the traditional view of a system for which a linear progression and singular equilibrium are assumed towards the dynamics and evolution of a network based on a nonlinear progression and multiple equilibria or the lack thereof. A social structure is considered a complex adaptive system full of uncertainties that are difficult to forecast. In this context, resilience is regarded as a network's ability to successfully reorganize, adapt, change, and improve in the face of internal and external stimuli [8–10]. The resilience approach emphasizes flexibility, diversity, and adaptive learning to replace established socioeconomic management commandments, such as optimality, efficiency, stability, and risk management [11].

Resilience has been an important concept in the contemporary debate on climate change and adaptation. The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) [12] defines resilience as "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." The report recommends creating a climate-resilient pathway as a measure to respond to climate change risks that may be concentrated in urban areas. This recommendation implies that, in terms of sustainable development, we must change our decision-making and behavior pertaining to the economy, society, technology, and politics.

Cities are important targets for the concept of climate change resilience because they contain numerous interdependent, closely linked sectors and activities, as is the case with an organism [10,13]. Resilience addresses how cities can sustain progress and development in the face of climate change. Not only must cities mitigate the risk of various disasters in the short term, but they must also build their capacity to effectively respond to a systemic transformation [14]. Developing this ability requires a new approach that pursues a fundamental shift in urban planning and management as future uncertainties and urban complexity intensify [15–17].

Although resilience is discussed in various fields, it is vaguely defined. Brand and Jax [18], who analyzed reports on resilience published over the past 35 years, found that the concept has been used in an increasingly ambiguous manner. They emphasized that resilience should be understood as a perspective, rather than a notion that can be neatly defined. This view reflects the direction of today's research, which focuses on the term's social, political, and institutional implications [19,20]. Although the use of resilience in an increasing number of fields may enrich our conceptual discussion, it can also limit our attempts to apply the idea. In particular, technical and normative elements that intersect in various debates tend to exacerbate the problem [21]. In the midst of climate change, the notion of resilience intersects with the perennial issues of vulnerabilities, risks, and adaptability. In terms of cities, which are an important element of climate change discussion, resilience is intertwined with sustainability and disaster management.

This study presents a conceptual framework for analyzing urban resilience in the context of climate change. First, the key conceptual elements of resilience are identified, which are then reorganized with a focus on cities and climate change adaptation. This not only covers ecological and engineering resilience but also resilience from an evolutionary perspective and as a sociopolitical process. This study's conceptual framework centers on resilience as it relates to cities and climate change. As such, its findings are expected to shed light on future urban planning and policies for adapting to climate change.

In building the conceptual framework, the study includes a diverse range of perspectives obtained from a comprehensive literature review. The first section examines existing resilience research, considering traditional ideas as well as ecological and engineering resilience. This examination is followed by a closer look at evolutionary resilience, a more developed notion that encompasses social elements and specific processes of resilience. The second section begins with an exploration of why a debate on urban resilience and climate change adaptation may be necessary in today's world and incorporates the first segment's discussion to establish the concept of urban climate resilience. The third section presents the study's conceptual framework on urban climate resilience, which is followed by a detailed analysis of its structure and processes during each stage. Finally, the study concludes by exploring the conceptual framework's implications and how it might be utilized in future research.

2. Theoretical Discussions on Resilience

2.1. Ecological Resilience

The idea of ecological resilience took shape in the 1960s as ecology adopted resilience and systemic thinking [3]. Holling's [22] seminal paper launched a discourse that focused on the resilience of ecological networks. From this perspective, resilience is a structure's environmental and ecological ability to absorb a temporary disturbance and then reorganize itself to fully recover its previous state [22]. The degree of temporary disturbance that a system can handle before it has to restructure itself is the amount of disturbance that it can withstand until it reaches a certain threshold [23]; the degree of temporary disturbance reflects a system's ability to sustain itself by adapting to the environment [24]. Within the notion of ecological resilience, multiple equilibria (as opposed to a single, stable equilibrium), as well as the potential for regime change, may be present; this notion reflects a system's transition process to a new equilibrium and its ability to "bounce forth" [3,25].

Ecological resilience has extended into the domain of socioecological systems. The theory of adaptive co-management has emerged, which blends cooperative management and adaptability [26]. In particular, the concept has expanded into the debate on adaptive governance [27,28]. Various socioeconomic tools are needed to stretch resilience beyond its ecological roots and into the societal realm [29]. The "planning-by-doing" approach is one of those tools. It links resilience to collective learning and refers to a system's basic capacity to change regimes while resolving complexities and uncertainties [28,30]. In other words, by integrating existing knowledge, engendering new understanding through deliberation, and exploring new opportunities, a system will naturally acquire the ability to adapt to a changing environment.

Ecological resilience is also discussed in light of climate change adaptation policies; it assumes that a system is able to transform and reach an alternative equilibrium through a dynamic process in the event of a disturbance, namely, climate change. Furthermore, it links resilience to adaptation policy as an opportunity for positive change [31]. This view can provide a valuable framework for interpreting the relationships within a network facing complex uncertainties in relation to climate change adaptation. Ecological resilience also suggests that resilience must be considered in connection with changes and values that are pertinent to elements such as social structure, ecological services, health, quality of life, and cultural awareness [32,33].

2.2. Engineering Resilience

Holling [22,34] defines engineering resilience as a system's ability to return to a steady state or equilibrium after a disturbance [3]. From this angle, a disturbance occurs when a peaceful and orderly state is interrupted due to a perturbation, which can range from natural disasters (such as floods and earthquakes) to social fluctuations (such as financial crises, riots, and wars). Based on this notion of resilience, the degree of resistance that a system demonstrates in the event of a disturbance and the speed with which it can recover to an equilibrium become the key targets of measurement. A structure that can quickly recover its previous state is resilient, and the recovery speed highlights its efficiency and predictability.

Engineering resilience can be expanded to various disciplines from the perspective of equilibrium theory. In the field of economic geography, resilience is used to explain a local economy's trajectory and encompasses the processes of punctuated equilibria and path dependency [35]. In the area of disaster research, resilience refers to a city's capacity to recover from damage and destruction. Topics in the general discourse on resilience include the economy, populations, and building structures [36]. In psychology, resilience refers to an individual's ability to maintain a psychological equilibrium while maintaining a certain degree of mental stability and physical function in the event of an external shock, such as trauma [37]. These views focus on a system's "bounce-back ability" and underscore the importance of buffer capacity in absorbing shocks [3].

Engineering resilience can also be used to discuss climate change adaptation policies [31]. In such debates, the time it takes for a system to recover to its original state is an important issue. Adaptation measures designed to protect assets, people, and spaces against climate change impacts must be deduced from the angle of engineering resilience [38,39]. This notion focuses on producing tangible adaptation outcomes and physically improving communities, spaces, and infrastructure, which are vulnerable to the effects of climate change.

2.3. Evolutionary Resilience

The traditional approach to resilience is evolutionary resilience from a socioecological angle [3], which examines a society's evolutionary process [35]. This notion is mainly concerned with a socioecological system's capacity to change and improve in response to stress and less so with a system's ability to bounce back to a steady state before an external shock [3,40]. Evolutionary resilience is based on a complex, chaotic, and unpredictable state, as opposed to the existing paradigm of rational prediction, order, and mechanical workings. Thus, a sudden shift to an alternative state can occur, and future forecasts and interventions (which are used as response strategies within the existing paradigm) may be rendered useless [29,41].

In the discussion of evolutionary resilience, the term "evolutionary" has a different meaning than it does in generalized Darwinism, which emphasizes the process of variety, novelty, and selection. The term evolutionary is used to show the limitation of an engineering resilience approach [25]. In the concept of evolutionary resilience, the term evolutionary includes flexibility, diversity, and adaptive learning [11,42] and explains the adaptability to changed circumstances [43,44]. This approach focuses on improving capacity through the process of adaptation and "evolving" or "developing" in industrial, institutional, and economic systems [45,46].

The panarchy model of the adaptive cycle, shown in Figure 1, can explain resilience from an evolutionary perspective [47]. The model, which contrasts a hierarchy, views resilience in terms of a cycle consisting of four phases: rapid growth (*r*), conservation (K), creative destruction (Ω), and reorganization (α). The recovery level varies according to the system's level of maturation. The point at which creative destruction takes place is also where the opportunity emerges for an alternative regime, which Holling and Gunderson [47] expresses as Ω. To transition into a regime with a greater amount of resilience, the system must produce an adaptive cycle that continually evolves. A great deal of preparation is required for a network to transform a crisis into an opportunity; the degree of preparation can vary according to the system's ability to imagine a different future.

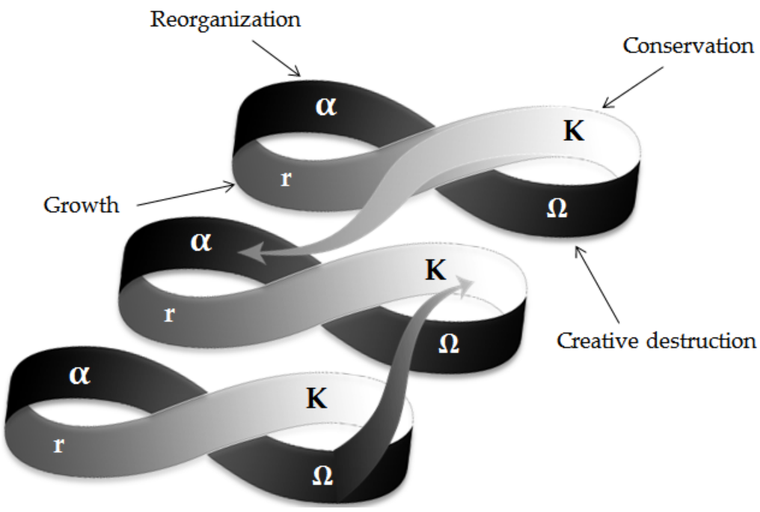

Figure 1. The panarchy model of the adaptive cycle.

From an evolutionary standpoint, resilience is a constantly evolving process; it is not something that exists in the present, but rather it needs to be pursued. In contrast to engineering or ecological resilience, which tend to revolve around a single dimension, evolutionary resilience focuses on the interactions between various elements, adaptability, and transformability [43,44,47]. From the angle of evolutionary resilience, a disturbance is not so much a sudden shock as an ongoing change. For this reason, the roles of institutions, leadership, social capital, and social learning comprise the discussion of evolutionary resilience [20].

2.4. Identifying the Processes of Resilience Building

In identifying the processes of resilience building from the standpoint of evolutionary resilience, this section will discuss collective decision-making, cooperative behavior and planning, and governance as a political process involving society at large. First, the process of resilience building will be considered in connection with decision-making. From this angle, collective decision-making procedures are seen as the product of an intended proactive process initiated for effective risk reduction [48]. In the course of collective decision-making, resilience is a cumulative activity that builds over time via a variety of interactions, decisions, and interventions that take place within a system [14]. That is to say, resilience is not so much a temporary response to external shocks as it is an ongoing process of change aimed at "moving beyond resilience" [49].

Second, resilience building can be placed in the context of cooperative behavior and planning; these are part of building resilience and are presented in a more specific form. Following a disaster, cooperative behavior and mitigation comprise a system's ability to enable effective recovery [50]; this ability is connected to social capital, which can facilitate cooperative behavior and mitigation. Cooperative planning emphasizes local knowledge and includes issue integration, as well as complex system analysis and management [51–53].

Third, governance is examined as a political process that involves society at large. This is discussed as an overall cumulative activity that encompasses everything from building a city and infrastructure investment to socioeconomic progress [54]. Governance means that quality infrastructure and services must be steadily provided and maintained at the city level; the political process involved in decision-making is critical. In the context of resilience building, governance is a discourse whose aim is a desirable state and a political process that includes fairness and justice [3]. In other words, resilience building should be open to exploring a society's internal issues, such as power structures and political views [55]. In terms of governance, measuring resilience is a collective endeavor involving experts, citizens, government, and scientists, a process that is linked to the aforementioned discussion on cooperative behavior and planning [56].

Fourth, the adaptive learning process identifies resilience building with a focus on collective learning as experienced by society as a whole [28]. It is an action that promotes fluidity and diversity and incorporates adaptability and transformability in the discourse as part of efforts to adapt to the changing environment [11,43,44,57,58]. A wide variety of social tools are applied in adaptive learning. Over the course of collective learning, existing knowledge is integrated, new understanding is created, and opportunities emerge that can be explored. All of this can help cultivate a system's capacity for greater resilience [28,30].

3. Expanding the Conceptual Discussion for Urban Climate Resilience

3.1. Rationale for the Discourse on Urban Climate Resilience

The need to discuss urban climate resilience lies in the threat against the ongoing prosperity of cities. Thriving cities are closely associated with human society's development, progress, and growth, and climate change is considered a disturbance that endangers our continued advancement. Although cities generally possess an inherent capacity to survive, they are not immune to the enormous gravity of external changes, an inertia that interferes with the process of systemic shifts, despite some believing that cities already possess a great degree of resilience [14].

The discussion on urban climate resilience concerns future uncertainties, unpredictability, and the complexity of cities [59,60]. Complex systems within a city make it difficult to address future problems with existing planning, methods of regulations, and zoning. In the face of future uncertainties and unpredictability, elements such as local knowledge are necessary, in addition to connections between experts and those who represent community interests and a mechanism for cooperative planning and scenario development [51,53]. These elements are being discussed as a way to tackle both the complexity of cities and the uncertainties of climate change [15–17]; they are associated with the processes of adaptive learning, cooperative learning, and decision-making. In the previous section, these processes were presented as the embodiment of resilience building.

Another argument is that the notion of resilience must be incorporated when explaining the variability of urban equilibrium. The equilibrium perspective has long been discussed in our aim to build flourishing cities. However, empiricists' assumptions regarding space and planning are not well suited for the future, and resilience must therefore be accepted as a response to the possibility of change [3]. The argument relates to the critical approach to the basic assumptions of empirical social sciences inherent in urban planning and policies [61,62]. Evolutionary resilience reassesses the basic assumptions to which the existing empirical social sciences hold on. Including resilience in policies and planning means questioning the prevailing approach based on certainties, predictions, and equilibrium. This implies that we are shifting away from the existing perspective, which assumes stability and explains changes, to one that assumes changes and explains stability [63].

In the sense that the blueprints offered by current plans are unable to reflect the realities of essentially nonlinear, complex, and dynamic systems, existing methods are viewed as fundamentally useless. Our strategy for urban resilience must focus on the potential for improvement and capacity-building, rather than on recovering a pre-existing equilibrium. Just as development drove the urban policies in a growth-oriented paradigm, development combined with resilience can serve as a complex driving force for future urban policies. In particular, urban resilience policies demand open, multidisciplinary planning for the future, which requires the participation of various stakeholders and their perspectives [64,65].

The importance of approaching resilience building at the city level has been recognized in connection with reducing disaster risk pertaining to climate change. The increasing concentration of populations and assets and the embedded conditions of socio-economic and spatial vulnerabilities make urban centers more susceptible to the risk of being severely affected by natural disasters than rural settings. With the potential adverse impacts of climate change, vulnerability in urban areas deserves special attention for disaster risk reduction [54,66]. From this point of view, cities are important as spatial units; they are well equipped to acquire capabilities needed to effectively implement risk-reducing measures.

A city's ability to sustain the direct and indirect impacts of climate change and natural disasters is especially highlighted. Thus, urban climate resilience needs to be seen as the degree to which cities can tolerate stress before they must restructure and reform [53], and urban climate resilience and related discussions must constitute a significant portion of policy design [67]. This leads to a discourse about maintaining a system designed to lessen disaster risks and about cities and local governments' executive power to successfully implement changes [54,68]. Local governments' executive power means they have the ability to design comprehensive resilience policies with participation from various stakeholders during the decision-making process to bring about innovative changes.

Furthermore, the discussion of resilience reawakens interest in the concept of urban sustainability. As a challenging goal of development, urban sustainability has been discussed in the field of urban and regional planning since the UN Rio Conference in 1992 [69,70]. Recently, the idea of resilience has become highly relevant to the concept of sustainable development in response to vulnerability from external shock and stress (including climate change) [71–74]. The conceptual link between resilience and urban sustainability can be explained in terms of disaster risk reduction. As the 2002 UN Summit on Sustainable Development emphasized, it is important to include the capacity of society to manage natural disasters and mitigate their adverse impacts in the sustainability framework [75]. In light of this, contemporary cities need to be resilient in the face of natural disasters if they are to be sustainable. A city will be more sustainable if it is able to minimize the adverse impacts of potential disasters in terms of the environmental, social, and economic burdens they impose on all actors involved. Thus, resilience becomes one of the characteristics of urban sustainability [70].

A resilient city is a sustainable network of physical systems and human communities. A city without resilient physical systems will be extremely vulnerable to disasters. However, building a disaster-resilient city goes beyond changing land use and physical facilities. A city without resilient communities will be extremely vulnerable to disasters. Human communities are the social and institutional components of the city, directing its activities, responding to its needs, and learning from its experience. In light of this, policy intervention for resilience requires social capacities to manage natural disasters and mitigate their impacts on cities [75]. Planning for resilience in the face of urban disaster requires designing cities that are made up of dynamic linkages of physical and social components. Thus, building a disaster-resilient city must encompass creating a broad base of social capacity for the multiple involved communities to respond to disasters and enhance long-term contributions toward sustainable development [76].

3.2. Expanding the Existing Discourse to Establish the Concept of Urban Climate Resilience

Various arguments considered in the previous section have been utilized to establish the concept of resilience for the current study. The traditional arguments of ecological and engineering resilience concern the theory's true nature, whereas evolutionary resilience views it as an ongoing process of adjustment and adaptation.

Ecological resilience and engineering resilience, which represent the traditional arguments in this area, are linked to urban climate resilience from an equilibrium perspective [70]. A city's complex system is capable of sustaining multiple equilibria from an ecological standpoint, and this means a positive equilibrium in the face of an external shock. From the view of engineering resilience, a city with a complex network can return to the equilibrium it held prior to a disturbance. From both angles, regardless of whether cities strike a new and positive equilibrium or recover their previous one, it is assumed that cities are inherently resilient. Here, resilience refers to a situation where there is no loss or damage to a city's physical system or to its residents' quality of life in the face of an extreme incident [15]. However, the notion of resilience varies depending on the definition of a positive equilibrium and the criteria for determining recovery to a prior state, which prompts the question: "What is true resilience?" [70]. This reasoning leads to a discussion of what qualifies a new and "positive" equilibrium as an improvement from the past. If not an improvement, would a full return to a prior state be more beneficial, and to what degree does it reflect the socioeconomic dimension?

According to Holling [22,34], engineering resilience refers to the ability of a system to return to an equilibrium or steady state after a temporary disturbance. Engineering resilience considers ecological systems to exist close to a stable steady state. By contrast, ecological resilience rejects the existence of a single equilibrium; instead, it suggests that there are multiple equilibria and emphasizes conditions far from any stable steady state, where instabilities can flip a system into another regime of behavior [3,25]. Despite this difference, what engineering and ecological resilience have in common is the existence of an equilibrium in systems, "be it a pre-existing one to which a resilient system bounces back or a new one to which it bounces forth" [3].

These two equilibristic views of resilience are suitable for a situation where recovering a prior equilibrium or reaching a new one is the clear objective, rather than responding to a slow variable or an ongoing process. However, from a socioecological perspective, resilience is conceived of not as a return to equilibrium but rather as the ability of complex socioecological systems to change, adapt, and transform in response to stresses and strains [44].

The discussion of socioecological resilience may have to do with the standpoint of evolutionary resilience, which focuses on a city's gradual process of change. In contrast to engineering or ecological resilience, which tends to revolve around a single dimension, evolutionary resilience focuses on the interactions between various elements, adaptability, and transformability [43,44,47]. From the angle of evolutionary resilience, a disturbance is not so much a sudden shock as it is an ongoing change. For this reason, the roles of institutions, leadership, social capital, and social learning comprise the discussion of evolutionary resilience [20].

From an evolutionary point of view, resilience is a process of continuous change and can be used to establish the concept of urban climate resilience. As suggested by Ernstson *et al.* [62], resilience is discussed around the trajectory of change from regime A to regime B to examine how slow variables can bring about a regime change. The path of change from A to B progresses slowly up to the threshold value, at which point a rapid restructuring takes place to bring in a stable regime. An external shock is not necessary at the threshold because slow and gradual shifts (such as climate change) can also catalyze such a transformation. Long-term variations (such as rising sea levels and temperatures and ecological change) slowly but steadily lead the regime to the threshold. Via such transformations and other incidents along the way, the system's regime shifts from A to B.

Urban resilience as an ongoing adjustment process driven by slow variables can be considered in connection with several principles. These principles more specifically embody the evolutionary resilience suggested by Ernstson *et al.* [62] previously discussed. The principles can be broken down into eight different types: diversity, redundancy, flexibility and adaptability, modularity, interdependency, stabilizing buffering, mobility, and planning foresight. The elements of each principle may conflict with each other and can sometimes be inherently challenging tasks [21]. Diversity, in addition to ecological diversity, concerns social, cultural, and economic heterogeneity and serves to reduce a city's or region's vulnerabilities [77–79]. The redundancy argument implies that multiple copies must be present in a system as a way to secure its diversity [79]. For a network to sustain its function, alternative backup resources must be present [15,78]. Flexibility and adaptability require an open and multifunctional city form that can accommodate changing conditions. While redundancy can increase flexibility and adaptability, conflict may arise if redundancy takes on a form of fixed assets.

Modularity refers to the ability to function independently of external impact and the potential to operate independently [78–80]. However, this may conflict with the interdependency between a society's interconnected elements. Stabilization and buffering refer to urban societies that can resist or absorb external perturbation. Stabilization and buffering factors are manifested in various planning-related elements within cities and regions (such as construction materials and multi-purpose parks). Mobility concerns the migration of people and has many restrictive elements, which can impede resilience [79]. Furthermore, because migration is tied to the socioeconomic dimension, migration can have secondary effects. Planning and foresight are meaningful in terms of preparing for the future and indicate that matters concerning constant shifts, such as climate change, must be included [81].

The notion of urban resilience as a continuous process of adjustment and response to disturbances focuses on building the capacity for adaptation and change and can be understood as a dynamic action [21,82]. Noriss *et al.* [83] analyzed the various definitions of resilience to confirm two important characteristics: dynamics and adaptability. The dynamics of resilience concern the cities and regions that continue to change throughout the course of history [84]. Adaptability (in contrast to stability) refers to the process of various sectors connecting to carve out a new trajectory to adapt or maintain their function in the face of a disturbance [83]. Within these definitions, resilience can be considered an ongoing process of maintaining function and adaptation [15]. Pike, Dawley and Tomaney [85] also distinguished between adaptation and adaptability; the former is about steadily maintaining function, and the latter is about establishing a new trajectory.

Resilience as it pertains to slow changes in urban areas is sometimes discussed in connection with the capacity of urban planning and governance. It builds the ability required to withstand disturbances and to find the direction for change and allows for the adoption of innovative resources when facing uncertainties [62]. From the standpoint of resilience, urban governance is understood as collective behavior and promotes the maintenance and improvement of the existing regime or shifting to a new and better regime. Such a capacity is transformative.

Evolutionary resilience has limitations in terms of specifying and measuring capacity. It is not clear just how the ongoing process should be measured as an essential element and ability of resilience. From the perspective of evolutionary resilience, patterns and structures based on regionalized interactions within cities can be utilized to provide the discourse with a more tangible context [47,62,86]. Therefore, societal resilience as a specific form of regionalized interactions may apply. Societal resilience sees physical factors as being managed with communities in the center, where it is possible for communities to determine a city's regime [70].

Adger [6] was the first to introduce the concept of societal resilience and considered it "as the ability of communities to withstand external shocks to their social infrastructure". This ability includes not only the capacities of social entities to protect themselves from external shocks but also the absorptive capacities in the face of perturbation and stress and from opportunities for new things [87]. Societal resilience connects to the discussion of resilience building in Section 2.4 with respect to collective decision-making, cooperative behavior and planning, and governance. In societal resilience, deliberation, collaboration, participation, and governance are included in the process of resilience building as the political, planning, and adaptive learning processes through social capital and relations [88,89]. This approach connects to the specified discussion of evolutionary resilience as the evolving or developing process of an urban system through an adaptive cycle.

Societal resilience is discussed in terms of three key characteristics: resistance to an external shock, the ability to recover from an external shock, and the ability to adapt to new circumstances [90]. Similar arguments include coping capacity (the ability to sustain an external shock), adaptive capacity (the ability to sustain the relationships within a regime in the face of an external shock), and participative capacity (the ability to self-organize to respond to an external shock) [89]. Such debates on social resilience provide a direction toward determining what type of capacity may be linked to resilience, which can be divided into short-term and long-term processes. In addition, the discourse on resilience, as it pertains to capacity, is linked to a comprehensive perspective on cities and regions. Participation by various stakeholders is required to build capacity, and complex arguments and deliberation between various fields must follow [53,91]. Elements such as environment-related quality of life, ecological services, and conservation can be considered in connection with health and residential environments. These settings can be viewed from the angle of a future society and accompany changes in social structure, cultural awareness, and new values [32,33].

Cities feature complex systems, which grow together as an organic unit while responding to external disturbances and shock. For this reason, cities may inherently contain resilience. However, cities' progress has taken an exceedingly complex form in the post-industrial era, and climate change can pose ongoing challenges to their ability to transition. This study's analysis of urban climate resilience concerns what type of framework should be used in approaching the topic of continued urban development and progress, and from what perspective we should assess cities' capacity. Considering the short-term changes, the traditional notion of resilience based on equilibrium theory may be encompassed, and, considering the continual nature of the transition, the argument of evolutionary resilience may also be included. In discussing specific capacities, the concepts integral to social resilience may be incorporated. In the following section, the discussion regarding the expansion of concepts is structured such that it will be possible to take a closer look at urban climate resilience.

3.3. Conceptual Framework for Discussing Urban Climate Resilience

Urban climate resilience consists of three elements: the "city", "climate,", and "resilience". The "city" is the goal of climate resilience. As an organism, a city contains a regime and an ability to solve issues to preserve prosperity. The question of how we will handle climate change and other future uncertainties is in line with how a city's constituents and sub-elements will accept changes. Sub-elements of a city include various stakeholders, residents, the environment, land use, infrastructure, inner networks, and industries.

"Climate" refers to future changes. Climate is the precondition of basic human life, urban planning, and socioeconomic composition; it more or less determines elements of lifestyle, such as people's eating habits, hours worked, and industrial conditions. It is predicted that changes in climate resulting from human activities (such as greenhouse gas emissions) will cause a rapid shift in the environment within just half a century, not several hundred years [12]. Rising temperatures and sea levels, intensifying meteorological phenomena, and their growing frequency call for a fundamental change in how human society addresses environmental transformations.

The discourse on resilience is about what concept should be referenced in our efforts to prepare and respond to future changes. Although various discussions surrounding sustainability, vulnerabilities, and adaptation have been held, the prevailing concepts fall short of wholly incorporating the arguments of uncertainties or ongoing change. The notion of resilience as a response to future uncertainties not only includes returning to a previous equilibrium as a short-term resolution but also the mid- to long-term response pertaining to the regime's constant transformability. Therefore, the debate on urban climate resilience seeks a fundamental change in our response, which is required to ensure ongoing urban progress in the face of future climate change. In this vein, it is essential to take stock of what needs to be prepared and how the changes will be identified and measured. This means that the conceptual composition and elements of urban climate resilience must be clearly established, as well as our viewpoint in approaching it.

The discourse on urban climate resilience can be structured as displayed in Figure 2. The conceptual framework of urban climate resilience consists of three parts: the climate change disturbance system, the process of system transition, and the preemptive and responsive process. These three parts cannot be separated because they interact with each other while moving the current regime to a future one. This section can be divided by subheadings. It provides a concise description of the probable results, their interpretation, and the tentative conclusions that can be drawn.

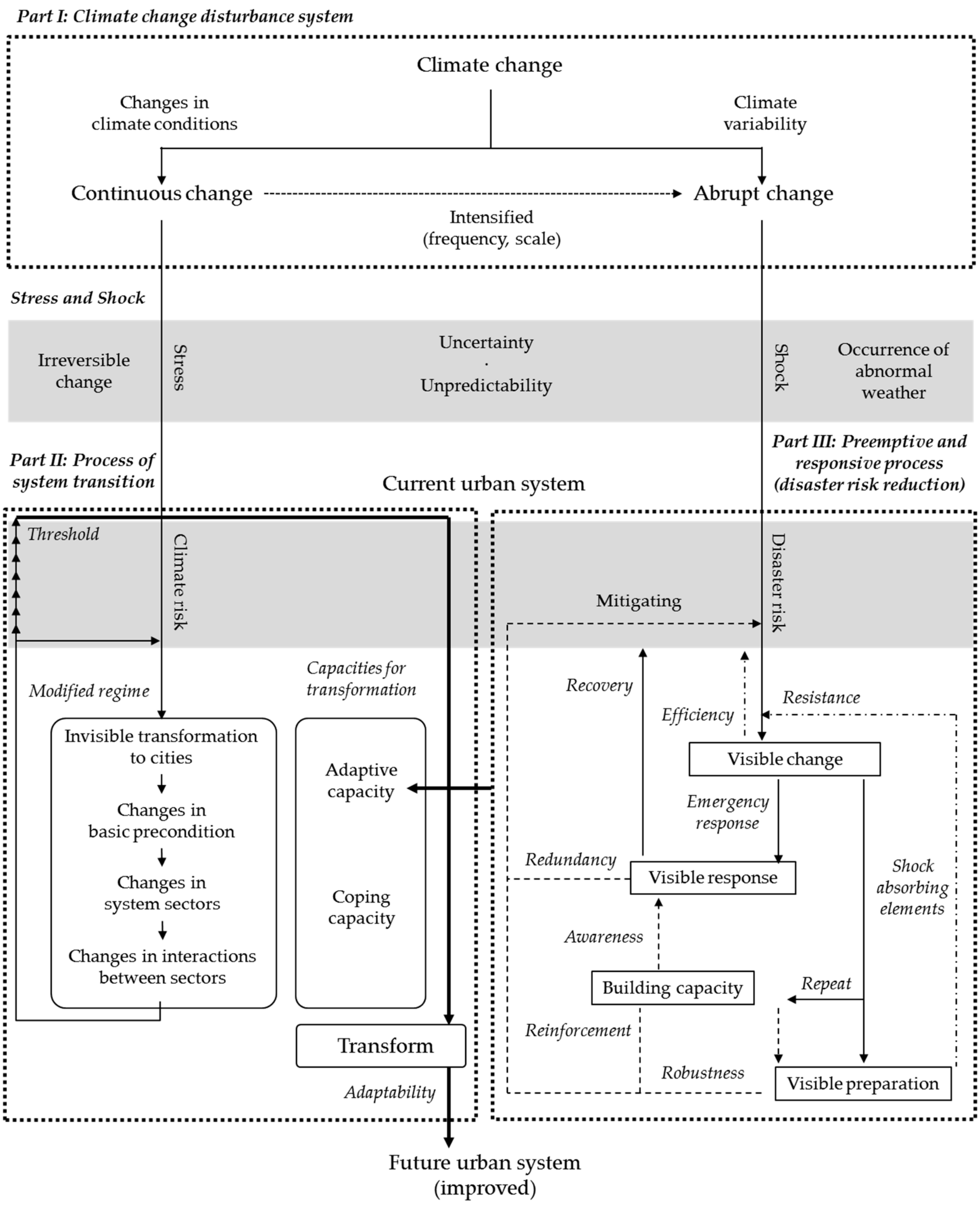

Figure 2. Conceptual framework for urban climate resilience.

The first part of the conceptual framework—the climate change disturbance system—concerns climate change itself, which affects cities. The climate change disturbance system is subsequently divided into: variations in climate conditions (which pertain to ongoing shifts) and climate variability (which relates to abrupt change). Shifts in climate conditions concern phenomena such as rising temperatures and sea level, along with a steadily increasing precipitation rate (these phenomena have been steadily transforming, albeit in insignificant amounts). Although these changes may not be immediately detrimental to our society, they could cause serious damage in 50 to 100 years; furthermore, they are irreversible once they occur. Abrupt changes resulting from climate variability include damage from storms, flooding, and other types of destruction due to unusual weather patterns. Climate change could cause typhoons, heavy rain, drought, heat waves, and snowstorms of unprecedented magnitude in the near future.

These phenomena inevitably impact city systems. Constant change is understood as stress on a system, whereas abrupt change can be understood as a shock. Stress relentlessly burdens a network and can emerge from both internal and external factors. A shock refers to a sudden and sizeable external perturbation. Current city systems tend to be greatly affected by the stress and shock of climate change. Such impacts are bound to exhibit uncertainties and unpredictability. It is nearly impossible to predict what type of frequency and severity may be expected from such shocks or what types of change and interactions may result from mid- to long-term stress. Climate change stress can be considered in terms of climate risks facing urban systems, and shock resulting from an abrupt change can be analyzed in terms of disaster risk. Climate risk is linked to the second part, which is the process of system change, whereas disaster risk is linked to the third part, which is the preemptive and responsive process, *i.e.*, disaster risk reduction.

The second part concerns the process of system transition that an urban system may experience because of continuous changes. Through this transition, the current system can transform into a better one. In this study, evolutionary resilience was applied as a process of regime change, and the focus can be observed as centering on ongoing change and adaptation. This reflects a regime transition, slow variables, and the threshold suggested by Ernstson *et al.* [62]. The shifts that cities continuously experience due to climate change are represented as climate risk, which brings invisible transformations to cities. In this context, invisible transformations to cities refer to slow and steady shifts due to climate change (such as the effect of steadily rising temperatures on crops, diet, and industry); these are in contrast to highly visible, sudden damage caused by phenomena such as typhoons, heavy rain, and heat waves. Such transformations change the preconditions of various socioeconomic forces, the environment, and the ecosystem, all of which comprise cities.

Climate-related items, which are the basic precondition of various forms of planning pertaining to urban land use, the economy, and business activities, will gradually shift. The sectors most directly influenced by those gradual changes will start to transform first; then, the impact will spread as other sectors within the system respond to changes and interact with each other to eventually affect the entire network. The gradual changes will push the existing urban system across the threshold, at which point a new urban structure will emerge. In this sense, the network's capacity for transformation and adaptation will determine the direction of the shift and whether it will be positive. The capacity for transformation becomes the basis for improvement. The capacity for adaptation is about developing the competence to prepare for a similar future shock through repeated exposure to a present shock. The potential for transformation particularly refers to the baseline capacity, which is formed throughout the course of change via an adaptive learning process that takes place within the urban system. Capacity is steadily built while the city responds to the shifting interactions between the system and subsectors under changing conditions. Driven by the two types of capacity, a system will shift its regime in a particular direction. The process of a regime's improvement can be called adaptability.

The third part concerns the preemptive and responsive process, which relates to resilience in terms of disaster risk reduction. As such, it is also referred to as disaster resilience, a notion that emerged from engineering technology that is based on a short-term, physical response. The disaster risks inherent in climate change can bring about visible transformations, such as 100-year floods and the most severe heat waves in history. However, these phenomena do not occur successively or constantly. These incidents are external shocks that cause short-term, visible changes. Responses to disaster risks will become visible within an urban system. For example, riverbanks may be built higher to prepare for flooding, cooling shelters may be built to prepare for heat waves, and slopes may be reinforced to prepare for landslides. This includes the process of disaster recovery as well as emergency responses. In addition, visible responses are devised to prepare for recurring damage. This will materialize as resistance to disaster risk and is included in the discussion of resilience as physical robustness. Furthermore, parts of the process that concern capacity-building indicate socioeconomic capacity, which forms the basis of visible responses and preparation. Such ability means raising awareness and reinforcing preparation efforts for emergency situations. Visible responses, visible preparation, and capacity-building are factors that mitigate disaster risk; these three elements aim to make responses more efficient.

4. Conclusions

This study's discussion of urban climate resilience began with various concepts of resilience. We examined it from engineering, ecological, and evolutionary perspectives, as well as the key elements that compose these concepts. The notion of resilience has increasingly been tweaked and adopted by various academic fields. Because it takes on various meanings, the current study incorporated the views of all key angles, including the evolutionary (which focuses on regime change), the engineering (which focuses on equilibrium and recovery), and the ecological. In particular, the current study distinguished between short-term and ongoing changes to more clearly present the implications of responses and preparation as they relate to urban planning. Next, the study examined capacity, which can be used in the discussion of urban planning. This study is meaningful in the sense that it used a wide range of views to analyze resilience, which has often been pigeonholed by many existing and prior discourses.

Urban climate resilience begins with two important types of climate change: phenomena resulting from abrupt climate change, and those resulting from slow and steady change. The former includes abnormal weather patterns and severe meteorological conditions, which affect cities. Abrupt climate change has been explored in the context of disaster risk reduction. From the standpoint of engineering technology, resilience comprises the conceptual discussion required to respond to these phenomena. However, this fails to reflect the ongoing, gradual nature of the changes caused by rising temperatures and sea levels, in addition to ecological transformations. The impact of slow and steady climate change reshapes the urban system while demanding a shift toward better quality. This reflects the view of evolutionary resilience and is concerned with the type of preparation that is needed in the long term.

This study applied the notion of resilience to these two different types of climate change and created a conceptual framework explaining urban climate resilience. Cities are independent organisms that exist as systems that possess resilience. Nevertheless, climate change can bring unprecedented shocks and disturbance to urban networks. This fact is directly in line with the dilemma humans currently face: "What type of existence should cities maintain from here on out, and what type of preparation should be taking place to build climate resilience?" A variety of perspectives are available when discussing urban climate resilience. The conceptual framework suggested in this study is one of many, and thus contributes to the basic body of knowledge that lays the groundwork for future research on climate resilience, which is expected to be robust. Certain research topics (pertaining to measuring urban climate resilience, developing indexes that reflect capacity, and urban planning techniques that take urban climate resilience into account) may be able to help us glean knowledge from this study's findings.

Furthermore, the structure and framework for urban climate resilience suggested in this study may be expanded when discussing cities' functions and performance. Cities are distinguished from regions in the sense that they possess and steadily provide various functions. The various functions of cities designed to support production, innovation, and numerous other human activities provide a good indication as to what needs should be prioritized in terms of resilience building. Functions referred to here include those in the socioeconomic realm, in addition to physical functions. A discussion is necessary to determine the way that various urban functions are classified and what measures are required to ensure these functions are maintained in the face of climate change. Finally, further research is needed to examine how these functions and their performance should be assessed; the findings should be discussed in connection with urban climate resilience.

Acknowledgments: This research was supported by the basic research project of the Korea Environment Institute (R2015-14).

Author Contributions: Donghyun Kim designed the research and drafted the manuscript. Up Lim guided this work and provided extensive revisions during the study. Both authors wrote, read, and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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