

Developing a Framework for Sustainable Urban Resilience During Disasters

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Abstract

The fast-growing population in developing countries coupled with the migration of the huge mass of village inhabitants to the large cities to seek better opportunities and safety conditions have been substantially increased the pressure on the existing urban infrastructure. This, coupled with the increased frequency of the natural as well as man-made disasters, presses the need for modern societies in large cities to search for pathways towards prevention, preparedness and recovery of this infrastructure in an event of a disaster. Owing to this, urban resilience has gained importance in the scientific context so as to explore the capabilities of cities to face and withstand extreme disaster events. Cities are complex adaptive and reconciling systems with a prospect to cope with resilience towards sustainability by effective use of transformational processes.

Our study analyses urban resilience in the context of natural and man-made disasters across developing countries. In particular, this research first identifies the key elements of resilience and further studies them with a focus on different cities in developing economies as well as various types of disasters. Moreover, we investigate the urban resilience from the perspective of a case on dust storms in New Delhi, India. The outcome of the research enabled in developing an urban resilience framework with respect to urban infrastructure in the case of disasters. In particular, this framework aims to ensure an adequate level of sustainability, centred on humans and society.

Introduction

Apart from natural disasters like cyclones, hurricanes, earthquakes and volcanic eruptions, manmade disasters caused due to global warming and technological disasters pose a threat to the development of cities. Accelerated urbanization along with the mass migration of population towards the developing cities have stressed its infrastructure. Climate change and disasters triggered due to it will have the potential to devastate the livelihoods of the population and also threaten their sustenance which largely depends on security of clean water, food along with well-being and mental health (Field 2014). According to a recent study by Hallegatte and Rozenberg (2017), an increase of additional 122 million in the existing population living in extreme poverty can be seen by 2030 due to climate change. Increasing the preparedness of the world as well as its response capacity to natural and man-made disasters will enable the world to recover swiftly from its impacts thus building resilience.

Resilience derives from Latin word meaning *resilire*; to spring back or to rebound (Klein et al. 2003; Manyena 2006; Davoudi et al. 2012). The first mention and description was done by physicists explaining the elasticity of a material and its ability to sustain under external shock (Davoudi et al. 2012). In climate change, resilience is an important concept based on the adaptation of various entities. According to the Intergovernmental Panel on Climate Change (IPCC) (2014) in its 5th assessment report, resilience is defined 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.”*

Resilience of cities has gained prominence owing to the threats arising due to climate change. Different terminologies like climate resilient, resilient city provide an added impetus for cities to withstand the disasters proactively (Pelling 2003; Boyd et al. 2008; Jordan 2019). Studies exploring connections between resilience and climate change related to vulnerability, sustainability, adaptation, and transition have emerged (Turner et al. 2010; Dabelko et al. 2012; Bocchini et al. 2013; Maru et al. 2014). Similar to an organism containing various systems working in tandem to achieve the objective, cities contain numerous dependent and independent sectors and activities closely linked to one another and hence gains importance for being resilient against climate change (Seeliger and Turok 2013; Zhao et al. 2013; Randal et al. 2016). Effect of climate change on the growth, development of progress of cities are the discourses in urban resilience literature. Cities are required to mitigate the risk arising from various disasters in near future, but also build the capacity of responding to the long term vulnerabilities (Satterthwaite and Dodman 2013; Kim and Lim 2016).

Natural and man-made disasters across developing countries are analysed in the present study on urban resilience. The study further provides insights into sustainable urban resilience and the policy initiatives required for urban resilience. The study further presents and elaborated on a concept based framework for urban resilience based on the case of dust storms of 2018 in New Delhi, the national capital city of India, enabling it to tackle the disasters and limit the magnitude of immediate loss and also the ability of cities to recover quickly from disasters.

Urban Resilience

Earliest mentions by Holling (1973), emphasize on resilience being a system's ability retract to the original position upon disturbance, specifically in case of engineering or equilibrium resilience. The concept of resilience since the last decade has seen a gradual shift towards adaptive, evolutionary, and social-ecological resilience compared to equilibrium resilience (Su 2016). Today in the twenty-first century the meaning of resilience is bouncing forward rather than what it used to be "bouncing back". The gradual shift towards equilibrium resilience focusing on recovery of the system paved way for an adaptive, evolutionary and socio-ecological resilience emphasizing on a strong utility which adapts to disturbances and self organizes itself. Depending on the adaptability of the systems of a city, it becomes resilient to the changes occurring therein. Such enhanced resilience towards anticipating the disasters and planning to mitigate and reduce losses proves beneficial for the city (National Research Council 2012).

The ability of any given system, network or community to resist, absorb, accommodate to and to recover quickly from the harmful properties in a competent manner by conserving and reinstating vital structures (UNISDR 2011). A community or a city which absorbs changes and disturbances and still is able to retain their vital structures and continue providing the services can be termed as a resilient community. Enabling cities to plan on dealing with disruptions yet retaining their infrastructure due to the redundancy imbibed into their system relates to disaster resilience (Jha et al. 2013).

Research has shown that operationalizing resilience proves to be difficult to practice. Urban planners addressing the risks associated with disasters in the framework of resilience provides insights into the many impacts of disasters and prepare the cities to adapt and cope with such risks (Jha et al. 2013). The breakdown of components related with urban resilience given below provides insights into the issues.

According to **Jha et al. (2013)**, the components for urban disaster resilience are as follows.

Infrastructural resilience refers to the robustness of buildings and transport systems under external stress. Under the infrastructure facilities, healthcare facilities, sheltering capacity, the vulnerability of buildings in case of disasters and the evacuation plans according to the road infrastructure are also included. In short, it is the reaction and retrieval mechanism of a city.

Institutional resilience refers to the administration of the city by various governmental and non-governmental bodies.

Economic resilience community's diversity with regards to their economic development such as, employment, the entrepreneurial culture and its ability to withstand and function after a disaster.

Social resilience is the verifiability and diversity of the demographic potential of a city.

Towards Urban Resilience and Sustainability

The change which is unstoppable is encompassed in resilience. As resilience builds any system to effectively and efficiently tackle the change. Sustainable development with reference to urban context reflect the past environmental strategies, with focus on managing the present resources so as to guarantee the future generation's welfare (Imperatives 1987). The policies in developed countries on sustainable development are been practised across the city by using means of multiple sets of indicators and instruments. Such initiatives aim to create a balanced economic development in tandem with environmental and life quality (Olazabal et al. 2012). Early researchers studied sustainability with a primary concern for the ecological well-being (Costanza 1992). After the Brundtland report of the United Nation, resilience gained importance and a building block for sustainability (Levin 1993). Resilience has gained importance in diverse domains (Turner li 2010; Bocchini et al. 2013; Seeliger and Turok 2013; Zhao et al. 2013).

Environmental shift globally due to climate change and the concept of resilience came into discussion during the World Summit on Sustainable Development in 2002 held in Johannesburg. The contention during the summit dwelled on both resilience and sustainability being preventive in nature with regards to the resource allocation and its use and also the emerging risk, susceptibility avoidance and promoting ecological and environmental integrity (Crowe, Philip , Foley, 2016; Xu, Li, Marinova, 2015).

In academic research, the concept of shockwaves and recovering mechanisms are usually explained using the term resilience, but its linkages between human drivers and environmental systems come from socio-ecological systems research. Ecological resilience can be defined as the "tendency of a system to

absorb a disturbance and alter its variables and processes as a self-control mechanism from future disturbances” (Allen, Angeler, Garmestani, Gunderson, & Holling, 2014) and “a system’s capacity withstand shocks and retain its functions, construction, responses and identity” (Walker, Gunderson, Kinzig, Folke, Carpenter, 2006). The capability to generate, check and sustain adaptive competence is included in sustainability whereas generating, testing and sustaining opportunity is the process of development (Holling 2001; Nunes, Duarte Marques, Ana Tome 2019).

Recognizing the benefits arising from self-sufficiency due to the changing nature of decision-making in resilience and new systems of control with a focus on social parity, education and the adaption capability. Achieving sustainability (Meerow, Sara and Newell, 2016) is managed crucially using resilience and it helps in bridging the diverse disciplines, thus encouraging discourses between pure and social sciences, and between science and policy (Deppisch 2017).

Policy Narrative of Urban Resilience

Given the case of rapid urbanization, a magnified effect of climate change is likely to be witnessed among the societies thus increasing pressures on the resources (UCCRN 2011, 2018). Climate change impacts the developing countries and poses considerable challenges to cities therein (Béné et al. 2018).

Resilience considering the context has developed as a principally noticeable policy narrative (ICLEI 2011; World Bank 2012). The policy narrative of urban resilience started receiving increased attention by academicians, researchers and policymakers in the 1990s. It now underpins the frameworks associated with climate change adaptation (Béné et al. 2018). It also helps in forming policy initiatives in emerging urban issues like disaster management, partisan instability, or urban bias, with development planning and programming (Twigg 2007). All the stakeholders in a city viz., individuals, households, communities, and also the society should attempt to become resilient in wake of the challenges associated with disasters and climate change (Gaspar et al. 2011; Chelleri 2012; Boyd and Juhola 2014; Meerow, Sara, Joshua P. Newell 2016). While earlier studies and thought process in resilience was linked with environmental systems (Holling 1973; Folke 2006), recent studies have shifted the focus on to social dimensions, with possible scope to investigate the areas of governance, social justice and politics (Adger, et al., 2008).

Cities strive to be more resilient and achieve the predefined objectives and goals. For an urban city, the objective is to identify activities, intermediations, or procedures to make cities resilient. While considering the context of sustainability, for an urban city to become resilient, the city needs to acts as a self-sustaining entity with decreased reliance on imported products and services and the formation of opportunities within itself.

Second way in which the resilience concept is considered in urban literature is with the framework for the policy makers to think and discuss discourses and adapt solutions. Liao (2012) had proposed two versions of resilience (“engineering and ecological resilience”) based on which the model on flood management as an urban resilience was established considering the alternate structure for managing flood in urban setting. Researchers have proposed the use of resilience theory to help rethink the concept

of urban development in scenarios occurring due to uncertainty (Wardekker et al. 2010; Tyler and Moench 2012; Jabareen 2013).

Challenges in Sustainable Urban Resilience Framework

Anthropogenic impacts on ecological systems are becoming more evident and the increased human population has cropped up as the key cause of global variations (Rockström et al. 2009). A 25 percent increase in global population by 2050 soaring to 9.3 billion (Heilig 2012) and the world-wide sustainability challenges rest on urbanization processes (Seto and Satterthwaite 2010). Prasad et al. (2008) studied urban resilience considering the context of disasters and climate change in isolation. Irrespective of this, urban resilience as a concept is applied to a greater set of global sustainability challenges (Chelleri et al. 2015). Taking into consideration the earlier work by Prasad et al. (2008), this paper presents an interconnected sustainability framework for building resilient cities in relation with i) the urban milieu, ii) urban breakdown (within boundaries and beyond), and iii) quality of life for the inhabitants. Based on the three challenges presented above, the paper presented an interconnected framework to build resilient cities. The framework and concepts are explained using case from the real world.

The resilience of urban structure and its milieu of the services provided by the cities forms the first challenge. With a rapid increase in population (Buhaug and Urdal 2013) in developing and third world countries the issue of accommodating everyone is posing a serious threat. The accommodation must be built safely and should sustain both forecasted and unforeseen effects of climate change and natural vulnerabilities (Fünfgeld 2010; Dickson et al. 2012). With many cities in developing countries expanding without proper planning and at times sporadically, the stress on the urban structure increases stupendously. The challenges for the policymakers requires spatial planning rooted resilience perspective (forming added resilient and protected structure systems) plus being well inside the purview of legal and policy frameworks aiming to reduce the vulnerabilities experiences of the urban poor residing in dingy homes or slums (Baker 2012).

Efficient breakdown of urban resources available for consumption by the population pose another challenge. Due to the telecom connections present in the cities, any inefficient and unsustainable resource use increases the consumption rates and generates waste/pollution (Newman 2006; Pelling 2012). With discrepancies in the accounting methodologies and the methods of reporting ascertaining the precise figures of global emission from cities is estimated between 30 and 80 percent of the total emissions across the globe (Reckien et al., 2014). A long term view of sociotechnical transition towards sustainability utilizing the available resources mandated by ethics and monitored using guiding mechanisms can be achieved using the resilience perspective (Loorbach 2010). The ethical use means synchronization of innovation, development, and consumption and production sequence along with political, socio-economic and behavioural changes.

Another challenge of a sustainable urban structure related to the social aspects of the city with its liveability and quality of life. In developing countries, rapid urbanization and globalization in the recent

decades has increased in inequality and stratification due to the rich and poor divide, conflict arising due to differences in social aspects and inequitable distribution of resources. In developing countries, the predominant social impact of rapid urbanization has resulted in the rapid emergence of the slum in urban cities, increasing the social vulnerability of different group. The developing countries are dependent on a majority of factors for the shaping of their urban dynamics. The shaping of global financial markets impacts the urban centres leading to their growth and shrinkages, with a direct consequence towards development potential of the region/city and also the resident's well-being. Such challenges require resilient local responses to these external stresses. For the perspective of social justice, it requires, empowering the groups exposed to these situations, so as to effectively manage the transition and also foster sustainable innovation. (Leach M, Rockström J, Raskin P, Scoones IC, Stirling AC, Smith A, Thompson J, Millstone E, Ely A, Arond E 2012).

Responding to these sustainability challenges requires, we argue, urban resilience integrated framework with incorporation of sustainability (Chelleri, L., & Olazabal 2012), effectively dealing with trade-offs across dimensions and time periods and systems.

Case - Dust Storms in New Delhi, India

Dust storm- a meteorological phenomenon is most common in semi-arid and arid regions. Sand and dust in large amounts lifted into the atmosphere due to strong winds results in dust and sand storms. Dust storms are a regular phenomenon in India's seasonal weather patterns and climatic conditions (Gibbens 2018). Due to the dry weather in the summer months, the passing winds picks up the dust leading to storms. Since February 2018, 16 states in India have witnessed dust storms of varying magnitude and scale causing 423 deaths and injuring 785 people.

Agra was the worst hit city by the dust storms. The city is located in the northern state of Uttar Pradesh, India. Agra features in the list of Uttar Pradesh's most populous city and is also 24th in terms of populous city in India (Registrar General India 2011). The population of Agra was 1,585,704 (1.55 million) according to the Indian census of 2011. Agra is a well-known tourist destination in India having UNESCO World Heritage Sites, notably old architectural monuments, the Taj Mahal, Fatehpur Sikri, and Agra Fort. The city constitutes of semi-arid weather with closeness to subtropical and humid weather. The city witnesses mild winters followed by hot and dry summer season and also has rainy season. The monsoon in Agra city are not heavy when compared with the other parts of the country. A semiarid climate against the humid subtropical climate is the city's primary factor.

The peak days of the dust storms were experienced between the second and third day of May 2018 in the northern states of India. The north India was swept by high velocity dust storms resulting in more than 124 deaths and injuring over 200 people in the states of Rajasthan and Uttar Pradesh. The worst affected city was Agra in Uttar Pradesh followed by Kheragarh which is 50 km away from Agra. Considering the dust storms that swept across the Northern parts of India, Agra was the worst affected with a death toll

of 43 followed by Kheragarh which saw 21 deaths. Table 1 provides information of deaths as a result of dust storms in India.

Table 1. Deaths due to dust storms in India in 2018

Date	Region	Death Toll
11 April 2018		19 dead
2 May 2018	Uttar Pradesh state	Total 73 dead, 91 injured Agra - 43 dead Kheragarh - 21 dead Bijnor – 3 Saharanpur – 2 Kanpur - 3 Rest areas - 13
2 May 2018	Rajasthan State	Total 35 dead, 205 injured Bharatpur -19 Alwar – 9 Dhaulpur – 6 Jhunjhunu -1
2 May 2018	Uttarakhand State	4 dead
3 May 2018	Andhra Pradesh State	14 dead

Government of India has set up Indian Meteorological Department (IMD) a warning system and nodal agency to raise alarms in severe climatic conditions like norwesters, dust storms, flooding due to rains, heat waves, snowfall and cyclones etc. causing life and property destruction. In above-mentioned case of dust storms of 2nd and 3rd May 2018, the Indian Meteorological Department had issued warning in their routine weather bulletin. The first warning specifically mentioning dust storms occurred on 30th April 2018, 1400 hours. Similarly, the department issued further warnings in subsequent bulletins details of which are mentioned in table 2.

Table 2. Warning Issued on Dust Storms (Government of India)

Date and Time of weather bulletin	Warning issued for date	Regions
30 April 2018; 1400 hours	30 April	Isolated places over East Rajasthan
	1 May	No specific mention of a dust storm
	2 May	Isolated places over Rajasthan
	3 May	Isolated places over Rajasthan
	4 May	No specific mention of a dust storm
2 May 2018; 1645 hours	2 May	Isolated places over West Rajasthan
	3 May	Isolated places over West Rajasthan

From the above table, it can be seen that warnings were issued well in advance considering the actual occurrence of dust storms on 2nd May 2018. This left the government agencies with 48 hours to prepare and mitigate the possible calamity. Looking at the topography of Rajasthan and Uttar Pradesh, Agra city lies near to Rajasthan state and both regions have almost similar geographic and climatic conditions.

The above case presents a unique perspective in the development of urban resilience for New Delhi. Though the area affected due to dust storms were large with greater impact on daily lives and society, building urban resilience framework can be studied using it.

Building Urban Resilience

The talk on urban resilience in the paper focused on different aspects like engineering resilience, ecological resilience, environmental resilience, sustainability and policy initiatives. A conceptual framework for urban resilience can be based on climate change occurring due to the slow degradation of climate due to a variety of reasons and factors like pollution, exploitation, etc. On the other hand, disasters can occur any moment and shatter the urban lives putting them in dismay. Disasters can be manmade and natural as well, related or unrelated to climate change and can occur without previous warnings (e.g. earthquakes).

The conceptual framework can utilize climate change as the starting point which may occur due to variability in climate and the changes in climatic conditions. The disturbances caused due to it affects the cities directly with a hard impact. Such phenomena invariably affect and impact the city systems. In a developing country like India, its capital city New Delhi is stressed due to the ever-increasing population and scarcity of resources. New Delhi has extreme weather conditions related to heat, cold and rain. Such constant changes on the city stress their infrastructure and at times abrupt change and dismantle and shock the city system. Many internal and external factors were responsible for the dust storms in New Delhi and early warnings by the MET department were known but did not percolate across the complete system of the city thus leading to uncertainty and unpredictability.

The second section of the process framework provides system transition of an urban system due to the continuous changes experience by the system (Kim and Lim 2016). In the present case of dust storm the city of New Delhi can work on evolutionary resilience leading to regime change, with a focus centring on the continuing variation and alteration, reflecting on system evolution, sluggish parameters, and the threshold (Ernstson, H., Van der Leeuw, S.E., Redman, C.L., Meffert, D.J., Davis, G., Alfsen, C. and Elmquist 2010). Continuous shifts leading to invisible change to cities are experienced due to irregular and unforeseen occurrences of disasters due to climate change. The changes to cities here refers to the shifts occurring due to climate change. These shifts are primarily slow and steady in nature like the rise in temperature, destruction of seasonal crops further hampering the diet of population and industrial nuances. Such changes contrast the highly visible changes related to infrastructure damage caused by natural phenomena like heat waves, dust storms, flooding due to rains and typhoon. This forceful transformation leads to alteration of the basic fabric of cities encompassing socioeconomic diversity, ecosystem and the environment.

Fulfilling the preconditions associated with the effective planning and utilization of urban land, the business and economic activities of New Delhi will lead to urban resilience. The transformation of the city for urban resilience stems out of the calculated risk to change the existing systems and making the inhabitants of the city aware of the changes and transformation. The inhabitants are very important for urban resilience as they perform exchanges and act based on the situation. In this condition, direction of the shift will be determined by the transformation and adaptation capacity of the network also determining the nature of system's improvement; positive or negative. The abovementioned potential is the baseline capacity of a given urban system formed due to the adaptive learning process. For any given urban city the capacity gets accumulated and built steadily as the city responds to the changes around its infrastructure thus adapting to these changes. Based on the changes in its capability, shifts in a system's work ethic is noticed thus leading to improvement of the regime termed as adaptability.

The last part holds a lot of importance as in the case of dust storms in New Delhi the city was unable to cope with disaster. Though the loss of lives was minimal, the damage to property and the disruption of daily necessary services brought the city to a standstill. The city of New Delhi was not ready with a pre-emptive and lacked a response to tackle the disaster at hand, thus leading to disaster risk reduction. This is usually termed as disaster resilience of a city based on the short-term, physical response emerging from engineering technology. Climate change will eventually increase the disasters and the risks associated with it transforming the planet and its urban and rural areas by excessive floods, droughts, famines, among others. The occurrence of such a phenomenon is not regular and tends to abrupt in nature making the responses more visible in response situations within a given urban system. For example, to tackle the dust storms in New Delhi, the city administration can undertake activity to sensitize its inhabitants with help of the knowledgeable and experienced individuals. Various models can be implemented to tackle such changes and act on them well in advance in cases where the warning monitoring systems provide information on disasters in advance. This prepares the cities for visible responses in case of repetitive destruction. This materializes as disaster resistance to an incoming threat and is also included as its physical robustness in earlier discussion. Moreover, individual capacity

building processes point towards the socioeconomic ability, forming the basis for evident retorts and preparation. Such ability leads to generating awareness and also reinforcement of preparation determinations during emergency situations. Mitigation of disaster risk can be achieved with the help of three elements viz., visible responses, visible preparation, and capacity-building making responses more efficient.

Conclusion

The study began with a discussion over urban resilience with an explanation of the various aspects of urban resilience. The engineering and ecological resilience were explained as well as the key concepts encompassing urban resilience. Further, the study explored the linkages between urban resilience and sustainability highlighting the importance of sustainable development while building capacity for urban resilience. The notion of urban resilience as discussed as a policy narrative wherein the policymakers need to understand the importance of urban resilience and acts towards implementing it successfully. The study presented the challenges in building a sustainable urban resilience framework. The present study used a wide arrange of viewpoints to investigate resilience, analyse it, often overlooked by studies in the past.

Urban climate resilience was studied with the case of dust storms or 2018 in New Delhi, India. This provided climate change which is abrupt in nature while the other changes arising due to slow and steady change. The examples of the formals includes irregular patterns of weather and severe meteorological conditions, affecting the cities. The study did not focus on the slow and gradual climate changes due to the nature of work for the study. The research studied the application of the concept of resilience considering diverse forms of climate change. It also paved a way for creation of the conceptual framework enabling the explanation of urban climate resilience. Cities act as independent entities containing the systems for urban resilience. Nevertheless, unparalleled shocks and disturbances can be caused by climate change to urban networks. Furthermore, the discussed extension of urban climate resilience presented in the form of structure and framework may be implemented to other cities in developing countries, in conjunction with the functions and also the performance parameters. Cities being independent units in nature differ from territories or regions based on the diverse functions provided by them. Considering the diverse functions carried out by cities like production, innovation and other individual activities by its inhabitants serve as a good indication to prioritize the resilience building in them.

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Figures

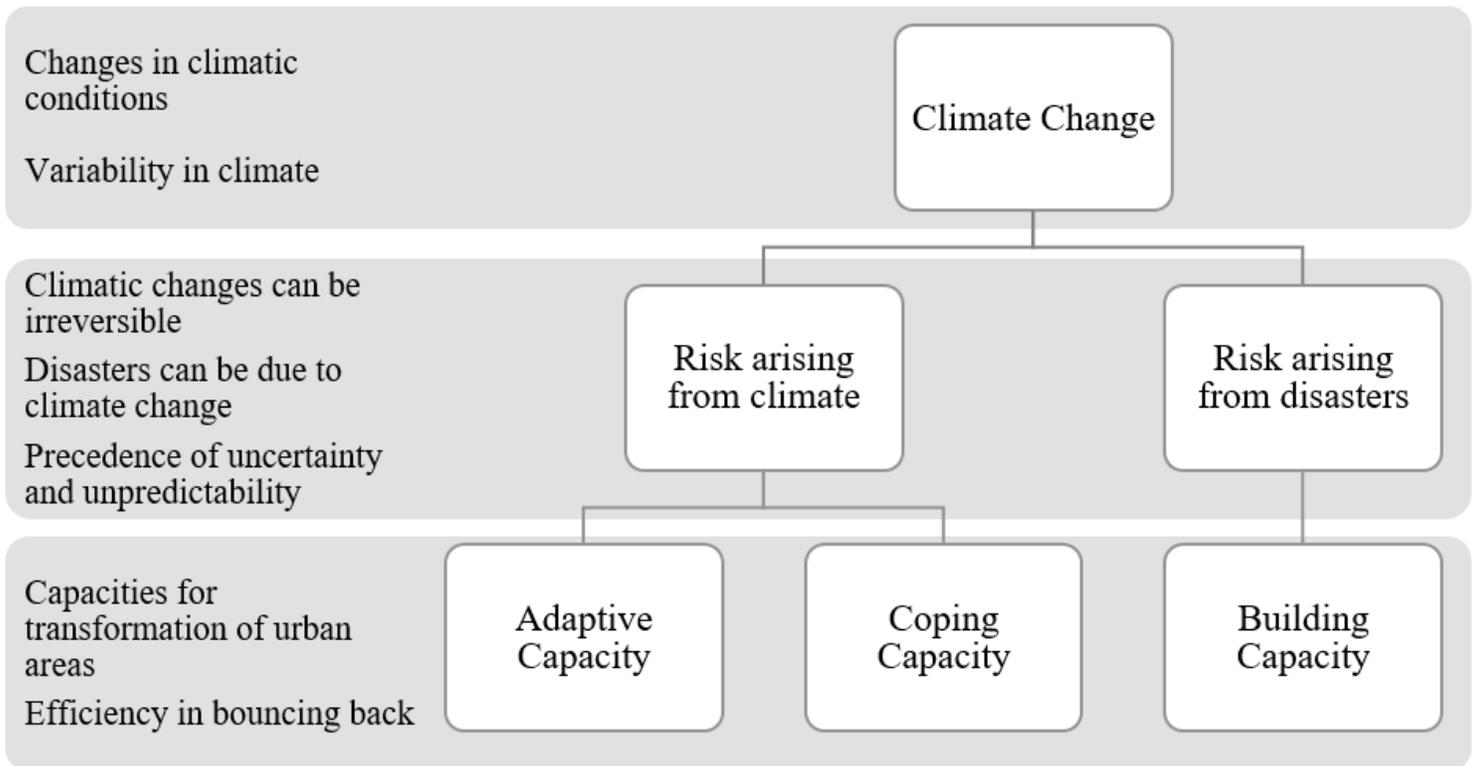


Figure 1

Conceptual Framework for Urban Resilience