Urban Design and Planning in Adapting to Climate Change:
Advances, Applications, and Challenges

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

This thesis has six chapters, and it consists of four manuscripts, co-authored with my Advisor, Dr. Luna Khirfan. These manuscripts are sequentially presented in Chapters 2, 3, 4, and 5 (as follows). My advisor offered intellectual insight, feedback and suggestions, as well as editorial changes. In addition, the thesis has two other chapters – Chapter 1 (Introduction) and Chapter 6 (a synthesis of all the manuscripts and general conclusions) – of which I am the sole author.

Manuscript I (Chapter 2):
Dhar, T., and L. Khirfan. (2016). Climate Change Adaptation in the Urban Planning and Design Research: Missing Links and Research Agenda. *Journal of Environmental Planning and Management*. [accepted and in press]

Manuscript II (Chapter 3):
Dhar, T., and L. Khirfan.(2016). Community-based Adaptation through Ecological Design: Lessons from Negril, Jamaica. *Journal of Urban Design*. 21(2), 234-255 [published]

Manuscript III (Chapter 4):
Dhar, T., and L. Khirfan (forthcoming). A Multi-scale and Multi-dimensional Framework for Enhancing the Resilience of Urban Form to Climate Change. *Urban Climate* [under review]

Manuscript IV (Chapter 5):
Dhar, T., and L. Khirfan. Six Urban Design Measures for Assessing Climate Change Resilience: Negril, a Caribbean case study [ready for submission]

Abstract

The current sea-level rise predictions are expected to lead to a loss of anywhere between 6000 to 17000 km^2 of land area around the globe during the 21^{st} century –a loss that would force around 1.6 to 5.3 million people to migrate while simultaneously impacting another 300 to 650 million people. The rising sea-levels and the associated extreme weather events are expected to significantly impact humans in the 21^{st} century ensuing in significant damage to property, higher demands on energy, disruption of settlements, and a significant loss of both life and natural resources. Small islands and coastal areas are particularly vulnerable to these impacts.

Yet, while urban planning and design are often cited as key determinants to reduce climate change impacts, the longitudinal study of this research used 157 peer reviewed articles published in the leading urban planning and design journals revealed that there is nonetheless a dearth of urban planning and design literature that delves into climate change adaptation. Surely, while 2006-2007 represented a turning point after which climate change studies appear more prominently and consistently in urban planning and design literature, however, the majority of these studies address climate change mitigation rather than adaptation. Also, most of these adaptation studies underscore governance, social learning, and vulnerability assessments, while paying little attention to physical planning and urban design interventions. In particular, this body of literature suffers a lack of interdisciplinary linkages, an absence of knowledge transfer, a dearth of participatory research methods, and is straddled with the presence of scale conflict. In doing so, the theoretical framework of this research highlights conceptual similarities –hitherto fragmented– among three domains: urban planning, climate change adaptation, and resilience, such as the similarities between landscape ecological urbanism, the ecosystem-based climate change adaptations (or soft adaptations), and the bounce-forward model of resilience. Simultaneously, this research capitalizes on the expert and experiential knowledge in climate change adaptation whereby, methodologically, it underscores the transactive and the collaborative planning models –through public participation– in order to bridge the fragmented domains of the literature.

This research focuses on Negril, a small resort city located on the north-west coast of Jamaica –a country that is considered a Caribbean Small Island Developing State (SIDS). Of particular interest is Long Bay, a seven-mile low-lying strip of beach in Negril where almost all of the area's tourism activities are concentrated. Similar to other SIDS, a substantial percentage of Jamaica's GDP is heavily related to beach-tourism and seaside activities, rendering such SIDS particularly vulnerable to climate change, hence, in need of special planning consideration. This research is guided by the following enquiries: What climatic risks are local people and assets exposed to? How can locals adapt to the risks? What measures can be used to assess the current resilience of Negril's built environment? And what alternatives (locally preferred or expert-driven) could they also consider for future adaptation?

In order to address these inquiries, the research methods combined various tactics including a series of design charrettes with various sub-communities, which is a design-focused, hands-on, time-constrained workshop between researchers and local participants with the aim of developing a vision for a sustainable community. A total of 37 local participants partook in two day-long design charrettes. These were conducted simultaneously with a survey questionnaire with 151 respondents, which assessed the local adaptation preferences, as well as 19 in-depth interviews with planners and policy-makers involved in various aspects of urban planning and design in Jamaica. Additionally, a GPS survey documented 19 transverse sections (west to east) along Long Bay so as to model the local elevation profile and thus rank the vulnerable areas prone to sea-level rise. Moreover, the methods included personal observations and transect walks of the study area that yielded analyses of architectural and urban design typologies as well as information through casual interactions with local communities. Lastly, a combination of primary and secondary sources provided the necessary data for the study of Negril's urban morphology.

The findings reveal that Negril's adaptation planning and policies seem to be goal-oriented and rely heavily on large scale engineering interventions (i.e. hard adaptations) while mostly excluding the local knowledge and the local ecosystems. Additionally, the failure to enforce planning regulations (e.g. controlling coastal set-backs) and the lack of a long-term vision that integrates adaptation and sustainable development have together accelerated Long Bay's vulnerability. Since the scope for managing retreat is limited in many coastal strips like Negril, whose Long Bay is further limited by the Great Morass that runs parallel to the coastline, the accommodative adaptations that are flexible and reversible and that help boost urban resilience offer a better option than protective ones. The findings reveal that coastal areas in SIDS must adopt an integrated planning approach that incorporates short- and long-term planning strategies. They also reveal that hard adaptation strategies should be adopted only when the soft ones that are based on local preferences, technologies, or knowledge are deemed ineffective or inappropriate. In addition, this dissertation's findings highlight the inherent potential of ecological design, green infrastructure, and morphological design as essential tools for guiding urban forms toward incremental change that parallels the pace of climate change. This dissertation therefore recommends a paradigm shift toward uncertainty-oriented urban planning and design where adaptations would be perceived as an inherent strategy that is informed by interdisciplinary knowledge and institutional collaboration in order to enhance resilience in a sustainable way. In other words, successful adaptation responses also succeed in achieving carbon neutral, environmentally sensitive, and low-impact development and so capitalize on other benefits along with the adaptation actions. Accordingly, adaptation becomes a process that integrates sustainable development and nature-human systems but one that fundamentally integrates interdisciplinary scholarship.

Acknowledgements

First and foremost, I would like to extend my sincerest gratitude to my advisor, Dr. Luna Khirfan for her guidance, support, and intellectual insight throughout this study. Her unwavering enthusiasm and inspiration are most special to me. I am very grateful for the opportunities she has offered during our continued research together.

I would like to thank Dr. Johanna Wandel, my former advisor, for giving me the opportunity to pursue this research at the University of Waterloo and for her continuous advice and feedback on my research. My gratitude also goes to Dr. Pierre Filion for his prompt feedback and scholarly insight. His friendly advice and support regarding my academic and non-academic affairs have highly inspired me to concentrate on my research. I would also like to thank Dr. Colleen S.L. Mercer Clarke for her thoughtful comments and feedback.

My deepest gratitude goes to the people at the UWaterloo Writing Centre, especially to Ms. Janet Mary McPherson and Ms. Janne Janke, for their continuous and enthusiastic support to improve my writing. In addition, I gratefully acknowledge the financial support of ParCA, for pursing this research, including the field trips. I also acknowledge the university's several funds (e.g., UW Provost Graduate Scholarship and Davis memorial scholarship) and other external funding, such as the Ontario Graduate Scholarship (OGS) and Queen Elizabeth II Graduate Scholarship.

I would like to thank several organizations in Jamaica, including NEPA and NEPT, for providing logistics and support for my field survey. Specially thanks go to Ms. Jacqueline daCosta, the former president of the Commonwealth Association of Planners and the Jamaica Institute of Planners, for the support while interviewing local professionals in Kingston and Negril. Thanks go to my colleague Mr. Dellarue Howard for providing me information and contacts related to my study areas. My deepest gratitude goes to the all individuals across Jamaica, participated in the different forms of field survey, for their time and willingness to share their thoughts and experiences; I acknowledge their contribution as of the utmost value for this research.

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Lastly, I especially thank my family, particularly Ms. Shatabdi Datta, my wife, for her own ways of supporting me throughout this journey.

My sincere apologies, if this note has unintentionally missed acknowledging any person.

Dedication

To Hrick Jyotirmoy Dhar, my three-and-a-half years old son,
whose presence has given me delightful ecstasy that kept me inspired and refreshed to start every day with full of energy throughout the long and stressful period.

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List of Abbreviations

CBA: Community-based Adaptation

CBVA: Community-Based Vulnerability Assessment

DROP: Disaster Resilience Of Place

EbA: Ecosystem-based Adaptation

IPCC: Intergovernmental Panel on Climate Change

MWLECC: Ministry of Water, Land, Environment, and climate change (Jamaica)

NEPA: National Environment and Planning Agency (Jamaica)

NEPT: Negril area Environment Protection Trust (Jamaica)

NIGALPA: Negril Green Island Local Planning Authority (Jamaica)

ODPEM: Office of Disaster Preparedness and Emergency Management (Jamaica)

PAR: Participatory Action Research

SIDS: Small Island Developing States

TAR: Third Assessment Report (of the IPCC)

UDC: Urban Development Corporation (Jamaica)

UDRI: Urban Design Resilience Index

UNEPA: United States Environmental Protection Agency

UNFCCC: United Nations Framework Convention on Climate Change

UNISDR: United Nations International Strategy for Disaster Reduction

Chapter 1 : Introduction

1.1 Research Context

In 2012, more than 32 million people were forced to flee their homes due to natural disasters, mostly resulting from extreme weather events attributed to climate change – almost twice as many as in 2011 (Aulakh, 2013). Recently, hurricane Sandy, the most destructive and second-costliest for the US after 2005's Katrina, affected millions of people, including many in the Caribbean. It caused more than US$50 billion in economic loss and over US$5 billion in damage to New York's urban infrastructure (Toro, 2013). In the Philippines, 2013's typhoon Haiyan affected about 25 million people, and two years after, Typhoon Koppu affected one million with damages of US$160 million. These facts represent only a fraction of what climate change, associated sea-level rise, and extreme climatic events can do. Observed data also reveal that, since the early 20th century, the global mean sea-level increase has ranged between 1.3 and 1.7 mm per year; however, since 1993, that rate has risen to between 2.8 and 3.6 mm, varying regionally. For example, in the tropical western Pacific, this rate is four times higher (i.e., 12 mm/year) than the global average (Nurse et al., 2014). In addition to the direct impacts on humans and infrastructure, climatic impacts, and rising sea levels and temperature significantly damage natural resources and ecosystems, particularly in coastal areas, which might otherwise have natural and long-term resilience to cope with such events. Mangroves, in many coastal areas, for instance, increase resilience, naturally reducing the impacts of sea-level rise, particularly wave energy, beach erosion, and storm surges. However, climate change impacts, along with anthropogenic interventions, have caused mangrove deforestation at a rate of one to two percent annually (Alongi, 2015).

Apart from these observed facts, the projected sea-level rise and the increased rate of extreme weather events are expected to significantly impact human settlements, with anticipated increases in property damage, higher demands on energy, disruption of settlements, and significant loss of both human life and natural resources. Small Island Developing States (SIDS) are particularly vulnerable to these impacts (Kizos, Spilanis, & Mehmood, 2009). For example, by 2100, 21 airports, 35 ports, and at least 149 multi-million dollar tourism resorts will have been lost in the Caribbean region alone (Ali, 2014). With the expected sea-level rise, global land loss would amount to about 6000 - 17,000 km^2 during the 21st century, contributing to the forced migration of an estimated 1.6–5.3 million people (Hinkel et al., 2013).

Confirming the chance of such occurrences with a high level of confidence, the Intergovernmental Panel on Climate Change (IPCC) (2014) has asked for multidisciplinary approaches to facilitate climate change adaptation. Whereas climate change adaptation contends with current and emerging impacts of climate changes, climate change mitigation primarily focuses on the cause of climate change (i.e., greenhouse gas emission). Today's increased climatic impacts (e.g., storm surges and sea-level rise) are indeed the end results of greenhouse gases produced many years ago. Since the 1980s, several international agreements, such as Agenda 21, the Kyoto protocol, sustainable development goals, and the recent Paris agreement, have continued to highlight the adverse impacts of climate change on human wellbeing. They have also raised global consciousness about using alternative energy sources to replace fossil fuels, stabilising and reducing greenhouse gases and global temperature, and promoting sustainable development. Studies claim that even the full implementation of Kyoto targets for 2012 would delay the temperature rise anticipated by 2100 by only six years (Peake & Smith, 2009). Thus, decades of waiting would be required to see the success, if any, of these international agreements. Until then, the only ways to deal with climate change impacts and uncertainty are through adapting and coping. Therefore, experts recommend exploring every opportunity for multidisciplinary and multi-sectoral approaches to facilitate climate change adaptation (IPCC., 2014; Pizarro, Blakely, & Dee, 2006).

Urban planning and design are often cited as the key determinants to improving the resilience (coping ability) of built environments in order to reduce the increasing impacts of climate change (Jabareen, 2015; Lennon, Scott, & O'Neill, 2014; Steiner, 2014). However, the urban planning and design literature has hardly addressed climate change adaptation, particularly at the neighbourhood and district scales (Dhar & Khirfan, in press; Roggema, Kabat, & Van den Dobbelsteen, 2012). From the perspective of environmental change, over decades, the primary focus of planning research has been on achieving sustainability, a branch of which advocates several strategies to reduce greenhouse gas emissions and thus facilitate climate change mitigation. Despite this fact, only since 2006-07 has the planning discourse witnessed a growing tendency to explore climate change adaptation separately from mitigation. The unavailability of climatic information in terms of precision, format, and scale has created challenges for planning scholars wishing to advance climate change adaptation (Davoudi et al., 2012; Hunt & Watkiss, 2011; Pizarro, et al., 2006) (see Chapter 2). In particular, the information on climate change impacts on cities, representing as it does complex interactions between human and natural systems, is not sufficient (Revi et al., 2014). As a result, current adaptation planning includes only normative strategies from a hypothetical point of assessing risks and proving expert-driven adaptation actions. The process of developing such actions often overlooks two aspects: i) highlighting the theoretical and methodological links used in both planning and adaptation literature and ii) assessing and prioritizing the climatic problems and their solutions by incorporating local experiential knowledge.

Both the urban planning and climate change literature equally emphasize the concept of resilience, which is a system's ability to self-organize and its capacity to adapt to stress and change while retaining its same basic structure and ways of functioning (IPCC, 2007; Walker & Salt, 2006). This socio-ecological concept also refers to the capacity "for renewal, re-organization and development [and] to cope with, adapt to, and shape change" (Folke, 2006, pp. 253-254). The research on resilience and vulnerability shares common goals, such as learning how to cope with stresses and shocks experienced by socio-ecological systems (W. N. Adger, 2006). In other words, resilience is often viewed as the opposite of vulnerability: "the more resilient [a system is], the less vulnerable" (Pelling, 2011, p. 42). In the context of climate change, the concepts of vulnerability and adaptive capacity are closely associated with adaptation (B. Smit & Wandel, 2006). Climate change literature defines adaptive capacity as a system's ability "to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences " (IPCC, 2007, p. 869). Scholars across disciplines highlight these conceptual similarities between adaptive capacity and resilience since both manifest coping ability and flexibility (Beatley, 2009; B. Smit & Wandel, 2006). Along this line, resilience holds the potential to facilitate pre-emptive actions to deal with uncertainty over time, whether posed by climate change or not, similar to proactive adaptation (see Chapter 4). It is because resilience is "anticipatory, conscious, and intentional in its outlook [that] planning ahead becomes a key aspect of resilience" (Beatley, 2014, p. 127). Planning scholars, aware of the above similarities, consider resilience and its potential as concepts that bridge urban planning and design and climate change adaptation, even though the evidence and application of resilience have only recently emerged in planning discourse (Davoudi, et al., 2012; Stead & Taşan-Kok, 2013). Likewise, this research explores resilience as a means to bridge adaptation and urban design and planning, as Davoudi et al. (2012) advised. Nevertheless, resilience has long been discussed in planning literature, including in ecological design but not directly related to climate change adaptation (see Chapter 5). Additionally, the concept of green infrastructure that has recently emerged in planning and design also holds the potential to enhance the resilience to climate change. Green infrastructure refers to "an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions" (Benedict & McMahon, 2006, p. 6). Frederick Steiner (2014) highlights the benefits of green infrastructure to ameliorate the consequences of natural disasters, while improving the environment, economy, and general well-being of those living in coastal areas. He also argues that, in addition to facilitating carbon neutral developments, well-designed green infrastructural interventions can lead to "more climate-change resilient" urban environments, thereby being conceptually associated with resilience but from the perspective of physical and environmental (ecological) planning (Steiner, 2014, p. 307). In contrast, adaptation discourse considers resilience merely from the socio-ecological perspective, which seldom links resilience to the physical form of a city and its design. To contribute to this scholarly debate and to address these shortcomings, this research includes a triad of concepts – resilience, adaptation, and urban design and planning (Figure 1.1).

Figure 1.1 The three interlocking domains of this research

1.2 Research goals

Climate change is increasingly posing risks to urbanisation, which itself represents a complex interaction of biophysical, socio-economical, and environmental agents. Urban design and planning are thus made more challenging. Climate change adaptation literature has hardly ever addressed this complexity of urban areas due to the lack of information, particularly related to extreme events and their possible impacts on cities (Hunt & Watkiss, 2011). A better understanding of these challenges and long-term climatic impacts on human settlements and wellbeing is thus necessary. The recent IPCC (2014) report highlights ecosystem-based management and the innate potential of the built environment to be transformed incrementally so as to cope with climatic change over time.

Driven by the emerging need to better understand climate change adaptation and its application through urban design and planning, this research offers new conceptual and methodological tools to meet challenges and facilitate local adaptation planning–a combination of autonomous, planned, and proactive adaptation. This combined approach first incorporates local ecological potential (e.g., the role of mangroves to reduce the impacts of storm-surges) into adaptation planning, while preserving and maintaining a system for long-term sustainable benefits. Then, it involves people and communities affected most, thereby prioritizing local knowledge and indigenous technologies, as is highly recommended by climate change literature. Next, these approaches to adaptation are viewed through a lens of advanced urban planning and design research, which still seems to be top down and often expert-driven in the context of adaptation (Davoudi, et al., 2012). In addition, in order to meet practical challenges, this comprehensive approach also contributes to linking climate change adaptation to urban planning and design. The knowledge obtained will help urban development stakeholders be better prepared, not only to cope with climatic impacts and their resulting uncertainty in urban areas but also to exploit other benefits of climate change adaptation actions.

The overarching goal of this thesis is to advance climate change adaptation through the physical planning and design of built environments while exploring different characteristics of local ecosystems and knowledge. In other words, firstly, upon investigating three broad interdisciplinary concepts – urban planning and design, adaptation, and resilience – this research identifies and establishes potential theoretical links among them. Secondly, this study examines the commonality among research designs and methods deployed in these concepts, in order to develop integrated methodologies grounded in public participation. Lastly, based on current research, practice, and empirical evidence, this study devises several operational frameworks to facilitate decision making for adaptation planning and practice in the context of coastal areas and Small Island Developing States (SIDS), which are particularly vulnerable to sea-level rise, erosion, and storm surges.

1.3 Research objectives

- To identify theoretical and methodological opportunities for urban planning and design research to link climate change adaptation and resilience
- To establish potential research trajectories of urban planning and design research that will advance climate change adaptation while promoting resilient and sustainable development
- To develop physical planning and design approaches that appreciate and incorporate indigenous and ecosystem-based adaptation in areas similar to the study area.
- To develop urban design frameworks that can measure and enhance the resilience and adaptive capacity of coastal settlements

1.4 Research questions

This research investigates the central overarching research question:

> How can planning and design of coastal settlements enhance adaptive capacity and resilience to sustainably cope with climate change and its resulting uncertainty?

This central question leads to a number of additional questions:

i) To what extent does the planning literature on climate change adaptation currently exist, particularly in relation to urban design and planning?
ii) How can climate change adaptation be advanced–theoretically and methodologically–to integrate knowledge from urban planning and design and resilience?
iii) How can knowledge of green infrastructure be advanced to facilitate the design of human settlements that enhance resilience and are adapted for climate change?
iv) How can the design of urban form influence resilience to climatic uncertainty?

v) What urban design tools are needed to measure and enhance the resilience of an existing settlement to climate change and how would they work?

1.5 Geographical focus and the case study

This study focuses on Negril as a case study. This small resort-based city, located on the north-west coast of Jamaica, a Small Island Developing State (SIDS), is highly vulnerable to sea-level rise and its impacts. In the Caribbean, sea-level rise in association with beach erosion greatly impacts the tourism industry, which represents 12.2% of total employment and 14% of the region's total GDP (WTTC, 2014). Negril is one of Jamaica's major tourist destinations (e.g., Ocho Rios and Montego Bay), but Negril generates more income than either (Otuokon, 2001). Rhiney (2012) estimated that Negril currently has over 7,600 guest rooms representing about one quarter of all accommodations within Jamaica. Beach tourism alone in Negril contributes approximately 5.5% of Jamaica's GDP (UNEP, 2010c).

This research focuses on Long Bay, a seven-mile low-lying narrow strip of Negril (Figure 1.2). Long Bay along with its neighbour Bloody Bay, represents the island's densest built environment, primarily resulting from tourist establishments that focus on sand, sea, and sun. Geographically, the area along the seven-mile beach (Long Bay) represents a unique topography. To the north, its built environment and habitable area are confined by the sea, and to the south by the Great Morass, the wetland that represents one fifth of Jamaica's wetland and one of the major habitats for invasive and natural species (Town and Country Planning Development Order, 2013). Additionally, because of important marine resources, including reefs and ecosystems, the entire Negril area has been declared one of the large Environmental Protection Areas (EPA) of the island. The rising sea levels and anticipated extreme weather events may impact Long Bay's built environment and tourism industry, national and local economy, as well as Negril's ecosystems.

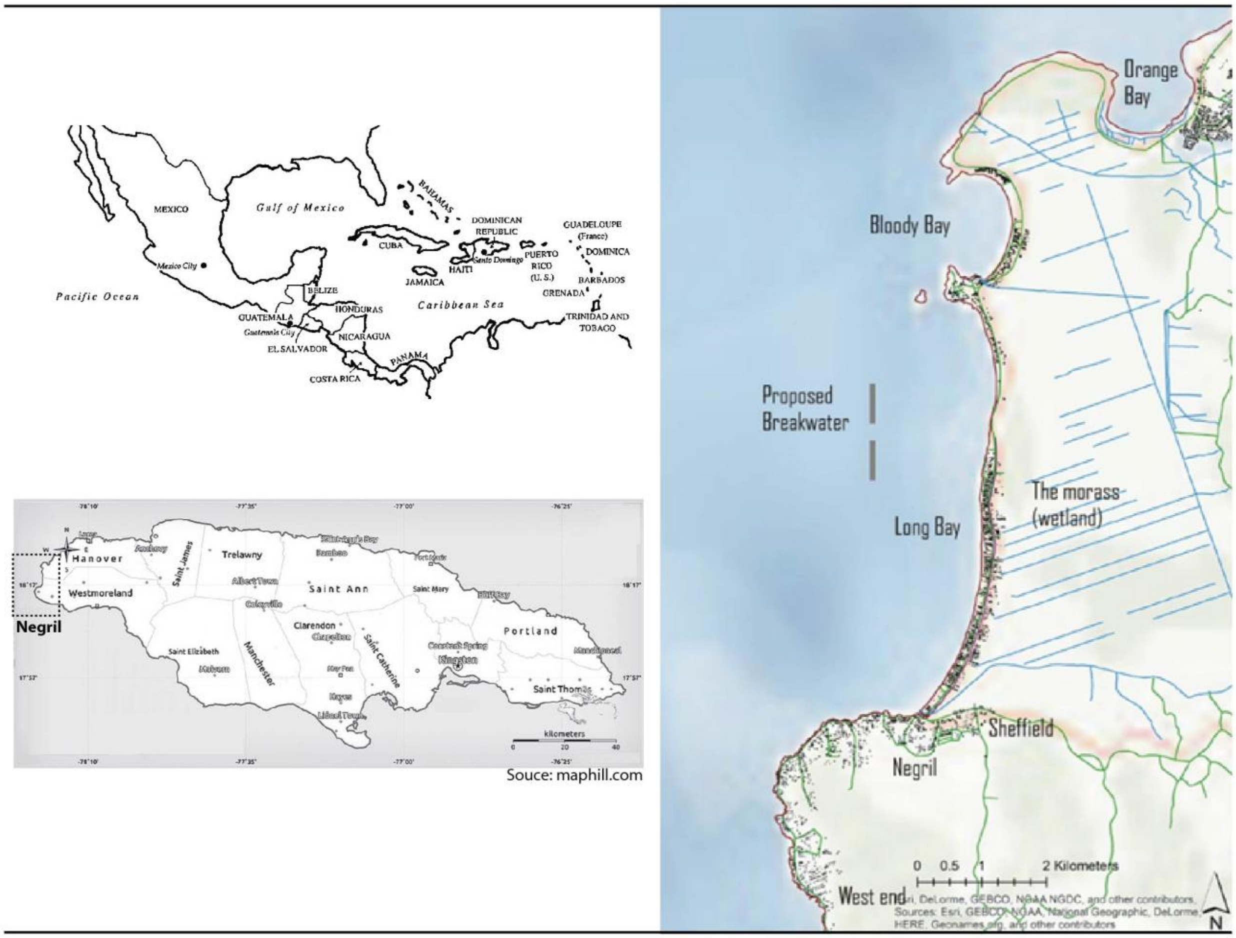


Figure 1.2 Negril, a small city on Jamaica's north-west coast

1.5.1 Problems of study areas

Negril and its tourism infrastructure remain fairly underdeveloped. The emerging impacts of climate change, particularly sea-level rise, hurricanes, and storm surges, put the shorelines, tourism, and entire ecosystems at risk. Because of Negril's heavy economic reliance on beach-tourism, i.e., sun-sea-sand, such impacts not only result in environmental and social degradation but also harm the tourism industry and eventually the local and national economies (Waite, 2012). In addition to sea related hazards, Jamaica's two rainy seasons (May - June and October - November) also put Negril's population and infrastructure at risk from flash floods and inland flooding, the incidence and intensity of which are increasing.

According to the IPCC's estimate, by the end of this century, the global sea-level, ranging between 0.19 and 0.58 m in small islands, will wash away over 38% of Caribbean coastal areas (IPCC, 2007). Particularly in Negril, UN data reveal that by 2060, a 50-year storm would cause 35% of Negril's total beach to be lost, and about 50% of beaches would lose their current width (UNEP, 2010a).

Amongst the threats to Negril, many reports consider beach erosion as a key challenge, particularly to Long Bay beach and its settlements. Studies indicate that Long Bay has been losing beach at between 0.2 and 1.4 m/year for the last few decades, and this loss is occurring at a higher rate even compared to neighbouring bays, for example, about 1.5 times higher than Bloody Bay's (CEAC, 2014; Veira, 2014).

According to Robinson et al.'s (2012) study, Long Bay's normal pace of beach erosion would result in 12 to 21 meters beach lost by 2050. Additionally, the design of the built environment along the coast in most of the Caribbean islands, including Jamaica, fails to follow planning and land use guidelines (Ishemo, 2009; Lewsey, Cid, & Kruse, 2004). Poor/no physical planning combined with climatic variability is putting Long Bay's entire settlement in jeopardy.

1.6 Research design

Researchers' own assumptions, knowledge, and experience about the nature of reality collectively inform their particular research designs. According to Groat and Wang (2002), research design consists of four interrelated research components: philosophy, theory, research strategy, and tactics (Figure 1.3). The first two, which represent the philosophical foundation of research, highlight how a researcher's philosophical assumptions and position control the investigation of a thing being studied, as well as the extent to which s/he is involved with the subject matter of the thing. This foundation offers a logical basis that establishes a researcher's role and guides the selection of appropriate research strategies and tactics – the latter two components of research – both of which belong to the domain of research. This domain underscores the operational strategies of research. The following sections discuss the two domains, focusing on the specific investigation of this thesis.

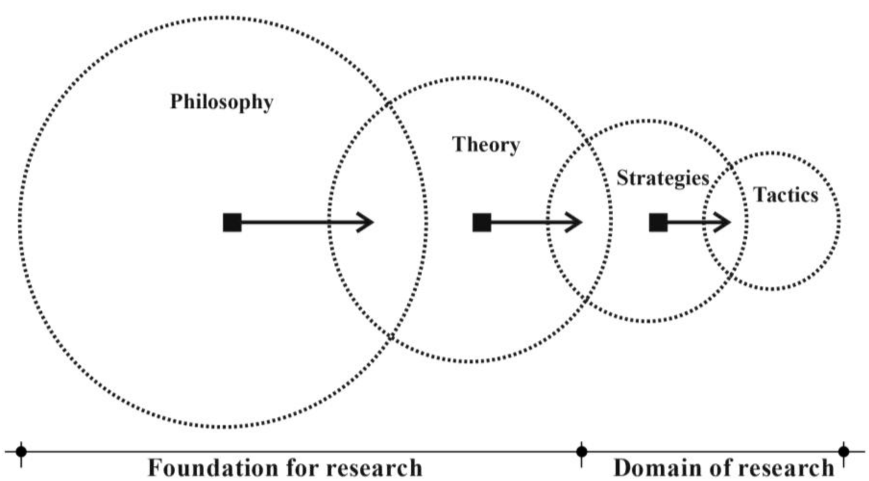


Figure 1.3 Interrelated components of research (adapted from Groat & Wang, 2002)

1.6.1 Foundation of research: System of inquiry

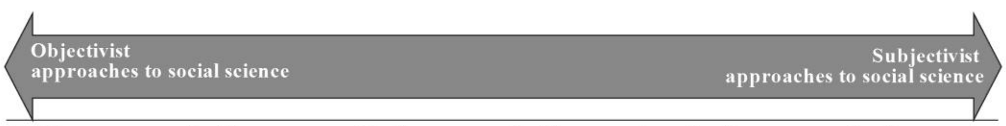
No one framework can standardise research protocols to develop a general set of assumptions for the breadth and elasticity of research as a whole. Every investigation requires its own specific set. This set of assumptions, also called a paradigm or a system/element of inquiry (Creswell, 2009; Groat & Wang, 2002), depends on the knowledge and past experience of a researcher as well as his/her ontological assumptions (which is related to knowing ***what*** reality is). These assumptions reflect the researcher's role, whether as an observer of the subject matter being studied or as an active participant controlling the research. Such assumptions and human nature greatly vary because of the different views in social science about human beings and their world (Morgan & Smircich, 1980). In particular, one of the major challenges for researchers is to determine a research paradigm (in association with methodological approaches) that falls within a design-based discipline intending to include both sciences and arts (de Jong & Van der Voordt, 2002; Swaffield & Deming, 2011). For example, this dissertation investigates an area between the climatic impacts projected by the climate change science and community responses to those impacts, whether practiced or preferred.

With regard to setting the paradigm for this research, the researcher's epistemological position, i.e., about "how we know what we know" (Swaffield & Deming, 2011, p. 36), is reflected in the investigation of the implicit meaning of context-specific human interventions and local adaptation experiences with enhancing resilience to climate change, rather than factual data. The challenges of climate change to a particular area are often considered unique when combined with the complex interaction between the socio-ecological and physical infrastructural characteristics of that area. Hence, initially, the research paradigm of this thesis involves investigating the reality of ***what*** climate change risk is (in terms of its types, intensity, frequency, and contextual characteristics and its relationships to the design of infrastructure). It also seek to understand ***how*** to know a community's perception and experience of the risk and the reduction of risk. This paradigm has guided the researcher (of this thesis) to define his role, which indeed lies in between post-positivists and emancipatory; however, the latter is more appropriate (Figure 1.5). The reasons are threefold:

- First, unlike most positivists, who assume that reality can be fully known, post-positivists believe in multiple realities of a subject matter being studied and acknowledge that experimental models used in natural science are not always appropriate in research that involves human beings. "Context" is a key of adaptation. Recent adaptation literature and the IPCC highly recommend context-specific and bottom-up adaptation interventions that i) ensure the best use of local ecosystems, ii) involve impacted communities in adaptation decision making, and iii) are reversible so as to cope with the pace of climate change. Thus, this context-specificity and reversibility, both of which rely on multiple realities and often lead to contemporary urban design discourses, influence the paradigm of this research.

- Second, reality is constructed and determined by specific processes of a society (Morgan & Smircich, 1980). With regard to meeting climate change challenges, this researcher believes in multiple realities, similar to the ontological premise of constructivist (also called interpretive or naturalistic) research. In other words, these multiple realities, which reflect the dynamics of the social dimension of climate change, disregard the idea of one-size-fits-all or "best" practices. This epistemological position has helped the researcher of this study avoid the blinkered view of "value-free objectivity" (Groat & Wang, 2002, p. 33). Instead, this position appreciates value-added subjectivity, which includes the norms and values of interactive dynamics between the researcher (of this thesis) and participants/setting being investigated in the Negril context.

- Third, in regard to understanding the value of a subjective reality, context and real setting are as important in social science research as in climate change adaptation research (which may greatly differ from mitigation research). In this research, this role provides the best-suited position for addressing the research questions. Specifically, the Negril community's experiences and adaptation preferences in shaping the physical form of their settlements justify this researcher's position toward the subjective end of Morgan and Smircich's scale (Figure 1.4). Similarly, the emancipatory paradigm also acknowledges these beliefs of constructivists (i.e., the socially construct realities) but underscores **context**–situated socially and historically – which represents the participants and the unique setting of this study.



Core ontological assumption	Reality as a concrete structure	Reality as a concrete process	Reality as a contextual field of information	Reality as a realm of symbolic discourse	Reality as a social construction	Reality as a projection of human imagination
Assumption about human nature	Man as a responder	Man as an adaptor	Man as an information processor	Man as an actor, the symbol user	Man as a social constructor, the symbol creator	Man as pure sprit, consciousness, being
Basic epistemological stance	to construct a positivist science	to study systems, process, change	to map contexts	to understand patterns of	to understand how social reality	to offset phenomenological
Research methods	Lab experiments, surveys	Historical analysis	Contextual analysis	Symbolic analysis	Hermeneutics	Exploration of pure subjectivity

Figure 1.4 Subjective and objective assumption within social science (Adapted from Morgan & Smircich, 1980, p. 492)

In a research context, particularly in design disciplines, Swaffield and Deming (2011) report that the philosophical domain of research that represents an overall system of inquires reflects two fundamental dimensions: the relationship to theory and epistemology. The former distinguishes between deductive and inductive research strategies. Deductive research – a theory-driven approach – employs top-down approaches and tests theories by employing experimentation and evaluation, while inductive research – a data-driven approach – builds theory based on the understanding and description of things and their contextual relationships to the world. A reflexive approach, positioned between inductive and deductive dichotomies, describes a researcher's role when shifting back and forth between empirical evidence and theoretical propositions (Castells, 1983; Swaffield & Deming, 2011). For example recently, to link climate change adaption and urban planning in the context of Tobago, Luna Khirfan (in press) adopts such a reflexive approach, whereby the literature review processes indicate deductive approaches, and the methodologies for obtaining empirical information represent inductive ones. Likewise, the reflexive roles of the researcher of this thesis seem to be favourable for linking urban planning to adaptation and resilience. The latter, epistemology, considers a researcher's position, to answer the question with **how**. Depending upon a researcher's epistemological position, the knowledge may greatly vary from objectivist (typically associated with science) to subjectivist approaches (typically associated with arts and humanities). Nevertheless, within social sciences, an epistemological position may vary based on how a researcher perceives (or likes to perceive) reality (Figure 1.4).

In particular, this research aims to build theory based on the conceptual links among the three fields – adaptation, resilience, and urban planning and design (Figure 1.1) – while operationalizing their links through urban design and planning. In other words, the study of physical characteristics of Negril's settlements plays a greater role in understanding, investigating, and representing the subjective reality of local adaptation responses. Accordingly, an urban morphological study (described in following sections) often leads to choosing a research paradigm and operational domain. Thus, this research combines urban morphological approaches with others that appreciate the engaged role of a researcher in shaping new knowledge.

Moreover, the philosophical assumption of the system of inquiry of this research is inclined to constructivist and emancipatory paradigms that support an inductive-deductive approach and acknowledge multiple and subjective realities of social, political, cultural, economic values. Figure 1.5 illustrates the philosophical positions chosen in this research and describes the role of this researcher.

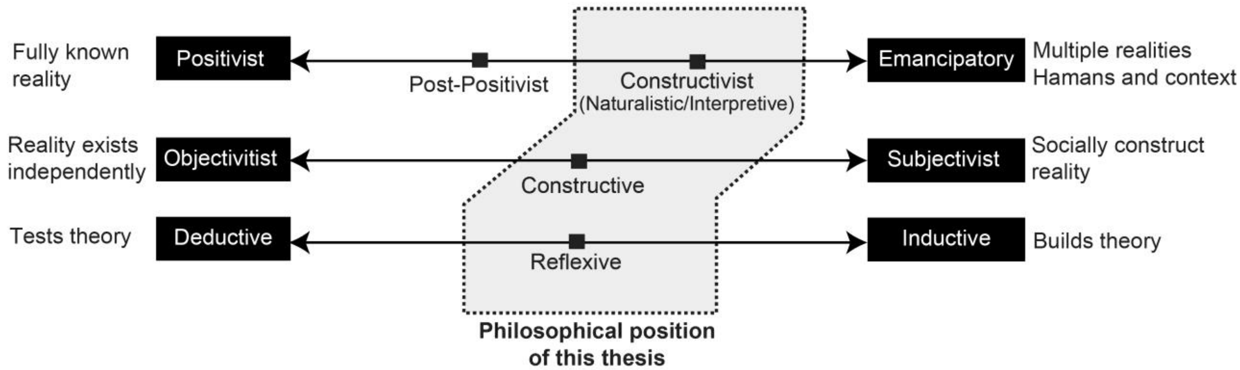


Figure 1.5 The philosophical position of this research

<u>*Trustworthiness of research*</u>

In general, because objectivist approaches assume that reality exists independently from researchers, they encourage methodologies that minimize biases in the subject matter under study. In contrast, subjectivist approaches accept multiple realities depending on the viewpoints of an individual and a society. Additionally, in subjectivism, all viewpoints imply different ways of approaching and understanding a thing; however, none includes information on the thing itself (Ratner, 2002). The research paradigm chosen for this research belongs to subjectivist approaches but also adopts a constructivist (and emancipatory) viewpoint. In general, this qualitative paradigm often persuades researchers to be involved with the subject matter and thus might create issues related to the trustworthiness of research (Groat & Wang, 2002). Egon Guba (1981) describes four aspects in dealing with the trustworthiness for such an investigation. Table 1.1 illustrates these aspects and briefly explains how this thesis addresses them. The first is credibility, also referred to as internal validity, which underscores the "truth value" of the findings of a study. The verisimilitude between the data and the phenomena represented by those data determines the internal validity. With regard to ensuring internal validity, many researchers advise "member-checking", i.e., crosschecking information with other human sources, and use of multiple data sources (Creswell, 2009; Groat & Wang, 2002). The second focuses on the external validity (commonly known as "generalizability" among positivists) or applicability of research. In regard to this aspect, "truth statements are context-free that hold in any context" (Guba, 1981, p. 80). The use of rich and "thick description" to convey findings on subject matters might ensure the applicability of research (Creswell, 2009). The third, dependability (or reliability) focuses on consistency of findings and thus underscores that, under an unchanged condition, repeating a measurement renders the same result. In other words, it expects the same conclusion judged by the same or other investigators in the same (or similar) situation more than once (de Jong & Van der Voordt, 2002). Research that relies on multiple realties and uses humans as instruments must consider the possibility of observed instability which is "real" (Guba, 1981). Being prepared to tackle such instability in data with alternative instruments is often recommended for ensuring dependability. The last, confirmability, highlights the neutrality of research. It makes sure that researchers' potential biases, interests, and motivations do not influence findings. Thus, neutrality is often termed objectivity, and it is usually ensured by methodology–the operational domain of research (see the next sections). Reflexivity and *triangulation* of data are particularly suggested to control such biases and subjectivity (Groat & Wang, 2002; Guba, 1981). The term triangulation underscores the use of multiple data sources, a variety of perspectives (theories), and different methods compared against one another to verify and cross-check data as well as interpretations (Denzin, 1971). The following sections discuss how the rigorous research design of this thesis uses multiple data sources along with necessary measures to overcome the possible flaws of subjectivity and biases at different levels research tactics.

Table 1.1 *Aspects of trustworthiness dealt with this research*

Aspects	Scientific terms	Focus	How addressed in this research
Credibility	Internal validity	Truth value of findings of an inquiry	Member-check and triangulation of data (to verify and confirm data with other relevant respondents during design charrette and interviews) (see Chapter 3 and 5)
Transferability	External validity (Generalizability)	Applicability in other contexts or subjects	"Thick description" and abstract (urban) design guidelines (which are often context-free and applicable to other contexts similar to Negril)
Dependability	Reliability	Consistency if repeated with same subjects and contexts	Tackling the expected instability in data (availability of alternative instruments/tools, such as discussion note was an alternative to doodling on maps during design charrette) (see Chapter 3)
Confirmability	Objectivity	Neutrality that is free of inquirers' biases, motivations, and interests	Triangulation of data (the following sections discuss the number of sources that this research has used)

1.6.2 Domain of research: research approaches and tactics

<u>The exploration of context-dependent knowledge</u>

Adaptation scholarship often prioritizes locally based actions even though the choice of adaptation depends on a system's exposure and characteristics at various scales. Thus, to achieve successful adaptation, context-specific and place-based planning has a major role (R. Klein et al., 2007; Measham et al., 2011). In particular, human dimensions and social phenomena surrounded by context-dependent knowledge also reflect socially construct realities rather than epistemic theoretical constructions (Flyvbjerg, 2006). Certainly, ***case study*** research prioritizes this context-dependent knowledge and helps researchers understand local communities' awareness and knowledge of adaptation, particularly when researchers have little control over the setting and the context of a study area (Yin, 1989). Similarly, the research paradigm chosen is a subjective-inductive research approach in which case study research highlights researchers' direct social engagement and participation. Thus, Swaffield and Deming (2011) acknowledge participatory action research and design charrettes as such approaches, both of which have been applied in this research (see Chapter 3 and 5). This reasoning greatly supports the case study – a research strategy that dominates this study's (operational) research domain – for explorative and explanatory inquiry and for gathering empirical evidence.

According to Robert Yin (1989, p. 23), such inquiry investigates "a contemporary phenomenon within its real-life context" and in situations where "boundaries between phenomenon and context" are ambiguous. Eventually, multiple sources of evidence are most common to support the inquiry of a case study. More specifically, the questions that guided this case study are as follows: *What* climatic risks are local people and assets exposed to? *How* can locals adapt to the risks? And w*hat* alternatives (locally preferred or expert-driven) could they consider for future adaptation planning? In responding to these questions, this research adopts a single case design because of Negril's unique topographical and ecological features as well as its unique urban morphological characteristics. More specially, Negril's coastal settlements and its entire tourism industry are highly exposed to climate change (Robinson et al., 2012); however, detailed information on vulnerability and adaptation has yet to be revealed in the context of Negril. These reasons also validate Yin's (1989) three rationales of considering a single case design. The first is related to significance, particularly when a case symbolizes the *critical case* to test a theory whose propositions are assumed to be true. In other words, the purpose of a single case is to verify the acceptability and accuracy of such propositions. The second highlights a case's *extreme or unique* nature. Failure to identify common patterns and characteristics for describing a case requires a unique investigation for this single case. The third justifies the *revelatory* nature of a case, particularly when a case remains inaccessible and unexplored for scientific investigations.

Adaptation decision making and policy implementation are frequently driven by experts (Davoudi, et al., 2012; Roberts, 2008). In the context of the study area, this statement hypothesizes that Jamaica's local planning agencies have long-term visions for adaptation and are professionally committed to developing the best adaptation plan for Negril. This professional outlook is often criticised by local people and communities, especially when such a plan does not reflect local views and preferences (Serju, 2014). To resolve this debate, this research uses John Friedmann's (1973) transactive planning model to connect expert and experiential knowledge. The success of this model lies in effective public participation – a method long discussed in planning literature (since the middle of the last century), even though its effectiveness is still debated (Fainstein, 2012).

Although the case study strategy facilitates obtaining the empirical evidence on climate change, building theoretical frameworks along with its operational strategies are justified through logical argumentation. ***Logical argumentation***, as a research strategy, underscores the understanding of phenomena and ideas through determining their coherent structure and relationships (Groat & Wang, 2002). Figure 1.6 illustrates the philosophical and research domain of this research, including their corresponding tactics. In particular, Chapter 2 uses a deductive approach to review literature; obtaining a detail methodological framework of this chapter defines the researchers' position and role in order to ensure neutrality. Additionally, Chapters 3, 4, and 5 use a reflexive (i.e., inductive-deductive) approach because the nature of investigation mostly belongs to interdisciplinary approaches, which facilitate making sense of levels of abstraction and technologies used in different disciplines.

In addition to logical argumentation, this thesis considers ***design projection*** – a reflexive research strategy common in design disciplines. Integrating theoretical predictions and empirical observation, this strategy encourages "individual creativity, imagination, and insight" (Swaffield & Deming, 2011). For example, Weller's (2008) projective design research includes seven future development possibilities for accommodating the increasing population of the city of Perth in Australia by 2050. Being both situational and synthetic, this strategy is more subjective than descriptive in nature. This thesis adopts this approach while transforming the empirical information and projecting future adaptation plans for Negril. With regard to ensuring neutrality, this research emphasizes the abstract urban morphological information presented either through thick abstract diagrams or through thick descriptions, as Groat and Wang advised.

Most importantly, all three strategies help the researcher meet the research goal of integrating concepts in the three fields: climate change adaptation, resilience, and urban planning and design. Abstracting and linking these interdisciplinary concepts and ways of operationalizing them through empirical evidence to reveal subjective reality dominate the process of rational foundation, thus constituting the theoretical framework for this research.

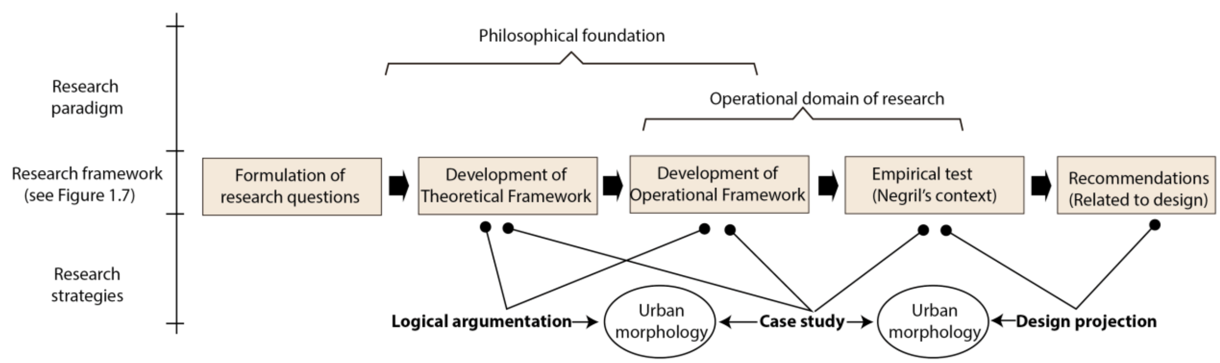


Figure 1.6 The (operational) domain of this research

Urban morphology: units of design

This study underscores urban design. One of the fundamental dimensions of urban design is urban morphology; the others include perceptual, social, visual, visual, functional, and temporal dimensions (Carmona, Heath, Tiesdell, & Oc, 2010). Urban morphology, a study of urban form, analyzes and reads cities through the lens of their physical form. Fundamentally, urban morphological research includes three principles in dealing with the structure of urban forms: form, resolution, and time (Moudon, 1997). Accordingly, these principles of urban form aid in understanding city development processes. Firstly, through the lens of form, urban form can be defined by three basic physical elements: building footprints and related open spaces, building blocks or lots, and street networks (Carmona, et al., 2010). Secondly, through the lens of resolution, urban form can be scaled at distinct levels of resolution, such as a neighbourhood or district. Lastly, through the lens of time, urban form can also be understood historically because elements that undergo continuous replacement and transformation indicate the temporal dimension of urban design.

The scope of urban morphology research includes three principal applications (Marshall & Caliskan, 2011):

i) as an explanatory or investigative technique to study the change in form and so clarify urban change
ii) as a diagnostic tool to study successful or unsuccessful kinds of urban fabric
iii) as a way of identifying exemplars, types or elements of urban form that could be used as "units of design[1]"

"Morphology is an abstract 'shadow' of physical reality...[and] indeed, design can be seen as a 'foreshadow' of a future reality" (Marshall & Caliskan, 2011, p.415). This potential of urban morphology research may perhaps become a tool for exploring the future design directions needed to deal with climatic uncertainty.

This tool enables researchers to understand individual (fundamental) components of Negril's urban form along with its design characteristics. This understanding justifies the researcher's epistemological position of investigating **how** we know the relationship between physical planning and urban design and climate change adaptation. The planning of Negril's coastal settlements, which represents a unique and linear morphological pattern regulated by tourism industry and local ecosystems, fails to incorporate appropriate adaptation responses (M. Wilson et al., 2014). Thus, this tool provides potential techniques to clarify the degree of vulnerability to climate change influenced by urban morphological components and their design features, thereby exploring adaptation interventions through planning and design.

Data collection, management, and analysis

In order to achieve neutrality and minimize the risk of possible research biases, diverse techniques are used to document, manage, and analyse data. First, this study employs the design charrette, a methodological approach, developed by Khirfan (in press) in linking adaptation and planning. Design charrettes, a tool of design projection research strategies, includes time-constrained and hands-on workshops and offers different design-based activities between professionals and locals to articulate a vision for building a sustainable community (Girling,

[1] By definition, urban morphology facilitates the study of the composite nature of urban form. Urban morphology, similar to "morpheme" in linguistics, includes the smallest meaningful and undividable units of urban form (Guney, 2008; Marshall & Caliskan, 2011).

2006; Swaffield & Deming, 2011). Two day-long design charrettes were organized in the Negril area to articulate local adaptation thinking into possible actions through physical planning and design. In total, 37 participants including planners, policy-makers, local activists, and locals, attended. Then, a questionnaire survey representing 151 respondents assessed the local adaptation preferences. Next, 19 in-depth interviews were conducted with the planning, design, and environmental professionals responsible for planning and development of the entire island. A GPS survey also considered several sections (west to east) along Long Bay; each section consisted of three observation points from south to north which were systematically separated based on high water mark, permanent buildings close to the sea, and the highway (Norman Manley Boulevard). Lastly, observation and transact walk analyses along with casual interaction with locals documented morphological characteristics. This observation entails the detailed description through documentation of the study area through observational site notes, such as those adopted by Friedman (2007) in his study of Senneville in Montreal. Among the secondary data, GIS maps were obtained from different agencies, including the Mona Geoinformatics Institute at University of West Indies, to gain information on existing built environments. Peer-reviewed and grey literature, government reports, and maps are a few other sources of secondary information. A number of techniques were used to document and manage this information, including layered maps, text scripts, field notes, spreadsheets, photographs. In addition, in data analysis, this research employed several qualitative techniques. For example, visual and graphical analysis dominated most of it and simple statistics verified interpretations of this research. Moreover, multiple sources of data and diverse techniques for their analyses ensured triangulation to achieve neutrality of this research design – in other words, trustworthiness in the naturalistic (interpretive/constructive) paradigm of this research.

1.7 The Research framework of this dissertation

The study includes three sequential steps as shown in Figure 1.7, corresponding to the research questions and the research paradigm chosen. The first step addresses the sub-questions and identifies research gaps and potential research agendas to connect climate change adaptation and urban design in relation to urban morphology. Eventually, it facilitates the development of theoretical frameworks of the following research design steps. Upon establishing the philosophical foundation and position of this researcher, these steps use different methodological approaches, including the design charrette, interviews, and direct participation, used to operationalize the conceptual framework. In addition to considering these primary sources of data collection, the steps consult a number of secondary sources to gather information. It also identifies several urban design attributes that have the potential to enhance the adaptive capacity of urban settlements and to set the qualitative and quantitative assessment criteria to measure adaptive capacity, particularly based on urban design measures. Using the results of these analyses, the last step develops urban design guidelines for the study area and generalizes them for application to other areas with similar climatic vulnerability and exposure to climate change.

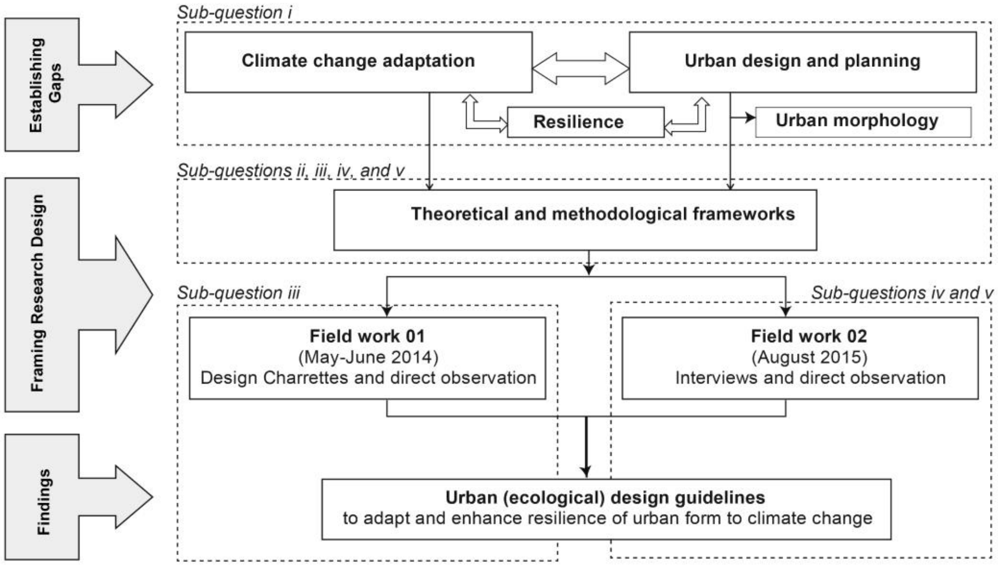


Figure 1.7 The research framework of this thesis

1.8 Structure of this dissertation

This dissertation follows a manuscript-based-format that consists of four stand-alone manuscripts prepared for peer-reviewed journals. Collectively, the purpose of these manuscripts is first, to achieve the overarching goal and to address sequentially the central research question and its sub components and then, to contribute to knowledge linking climate change adaptation to urban planning and design. Table 1.2 lists the manuscripts and their status. More specifically, Figure 1.8 highlights how each manuscript addresses the several research objectives of this research.

Table 1.2 *List of manuscripts included in this dissertation*

Manuscripts	Titles	Target Journals	Status
I	Climate Change Adaptation in the Urban Planning and Design Research: Missing Links and Research Agenda	Journal of Environmental Planning and Management	Accepted and in press
II	Community-based Adaptation through Ecological Design: Lessons from Negril, Jamaica	Journal of Urban Design	Published
III	Toward Developing a Multi-scale and Multi-dimensional Framework for Enhancing Resilience to Climate Change	Urban Climate	Under review
IV	Six Urban Design Measures for Climate Change Resilience: a Caribbean case study	Planning Theory & Practice	Ready for submission

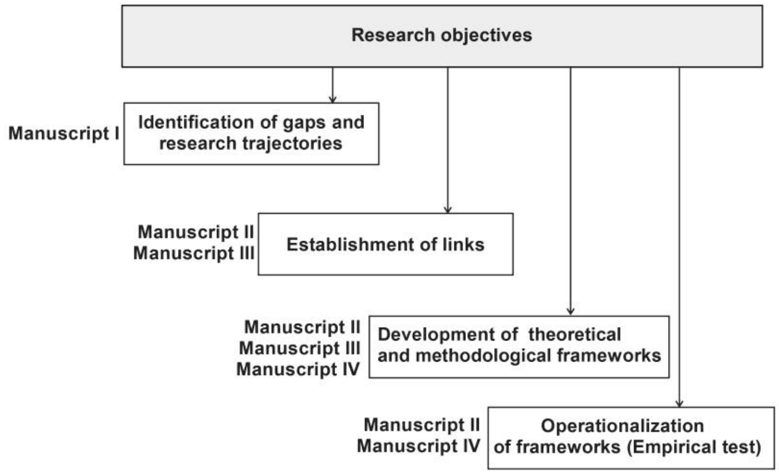


Figure 1.8 The manuscripts' roles in meeting the research objectives

1.9 Outline of this dissertation

Apart from this introduction chapter (i.e., Chapter 1), this thesis includes five other chapters. Each of the following four chapters (Chapter 2 to Chapter 5) sequentially presents one manuscript (I to IV respectively):

- Chapter 2 (Manuscript I) presents a literature review investigating the nature and extent of how the planning literature has addressed climate change adaptation since the early years of this century. This chapter identifies four shortcomings in the literature: the lack of interdisciplinary linkages, the absence of knowledge transfer, the presence of scale conflict, and the dearth of participatory research methods. It recommends a few trajectories for future research, and accordingly, provides rationales to validate this research.

- Chapter 3 (Manuscript II) considers the trajectories identify in Chapter 1 and pays attention to linking ecological design and ecosystem-based adaptation while synthesizing local and expert adaptation knowledge through empirical evidence in the study area. The chapter highlights design charrettes as a tool for participatory action research and prioritizes ecologically sensitive adaptation interventions.

- Chapter 4 (Manuscript III) establishes a theoretical framework to measure and enhance resilience to climate change while focusing on urban morphological components. Upon reviewing literature (primarily related to planning and design), the chapter establishes a number of resilience concepts that influence the shaping of urban form and that hold potential to adapt to climate change. Finally, it concludes with providing urban design guidelines to enhance resilience.

- Chapter 5 (Manuscript IV) reviews interdisciplinary literature, including adaptation, resilience and urban design and planning, and verifies the theoretical framework developed in Chapter 4. This chapter devises six urban design concepts to assess and enhance the resilience of an existing built environment. The framework is then operationalized in the context of Negril, using semi-structured interviews. This chapter reveals that Negril's planning adopts protective measures to maintain the prevailing patterns of built environment while overlooking the enhancement of the innate and transforming ability to cope with climate change and its resulting uncertainty.

Finally, Chapter 6 offers a synthesis of these manuscripts in relation to their rationales and coherence in addressing the research questions in order to meet the research goal. This chapter also discusses the research contribution to improving adaptation planning and practice, from both global and local perspectives, before presenting future research directions and offering concluding remarks.

Chapter 2 : Manuscript I

Climate Change Adaptation in the Urban Planning and Design Research: Missing Links and Research Agenda

[accepted and in press in *Journal of Environmental Planning and Management*]

Abstract

This article investigates the extent and the nature of how urban planning literature has addressed climate change adaptation. It presents a longitudinal study of 157 peer-reviewed articles published from 2000 to 2013 in the leading urban planning and design journals whose selection considered earlier empirical studies that ranked them. The findings reveal that the years 2006-07 represent a turning point, after which climate change studies appear more prominently and consistently in urban planning and design literature; however, the majority of these studies address climate change mitigation rather than adaptation. Most adaptation studies deal with governance, social learning, and vulnerability assessments, while paying little attention to physical planning and urban design interventions. This article identifies four gaps that pertain to the lack of interdisciplinary linkages, the absence of knowledge transfer, the presence of scale conflict, and the dearth of participatory research methods. It then advocates for the advancement of participatory and collaborative action research to meet the multifaceted challenges of climate change.

Keywords
Physical planning, urban design; climate change adaptation; mitigation

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2.1 The scope of this study

At the turn of the millennium, the Intergovernmental Panel on Climate Change (IPCC) (2001a) warned in its Third Assessment Report (TAR) that human settlements along with the energy and industry sectors will face the largest and most costly impacts resulting from the extreme weather events associated with climate change. IPCC's 4^{th} and more recent 5^{th} assessment reports follow up on TAR's findings, predictions, and recommendations for new research directions and, also, urge urban planning scholars to establish theoretical and empirical links between the science of climate change and urban planning and design.

The anthropogenic contribution to climate change is a widely accepted fact. According to the United Nations Framework Convention on Climate Change (UNFCCC) (1992, ar.3) climate change is "attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". This paper highlights the potential of the research and tools of urban planning and design to alter and mange human activities so as to mitigate and adapt to climate change. Mitigation refers to "an anthropogenic intervention [that seeks] to reduce the source or enhance the sinks of greenhouse gases" (IPCC, 2001b, p. 990), while adaptation means "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001b, p. 982). Indeed, the aforementioned TAR has highlighted several major barriers that hinder the adaptation of human settlements to climate change, including weak institutions, a lack of financial resources, and inadequate or inappropriate urban planning (IPCC, 2001b). This article expands on the distinctions between mitigation and adaptation, and reviews the discourse on adaptation in the urban planning and design literature in order to clarify its extent and nature and to offer future directions for research.

Specifically, this article addresses the following questions: i) to what extent do the leading urban planning journals include studies on climate change in general, and on climate change adaptation in particular? and ii) how has the urban planning literature addressed the connections between climate change adaptation and urban form? Through such investigation, this article underscores the links between climate change adaptation and physical planning and urban design by exploring the triad of theoretical, empirical, and policy-making and practice aspects. Firstly, theoretically, this article compares the extent of the urban planning research on climate change mitigation versus adaptation in order to identify directions for future research. Secondly, empirically, this article identifies the research designs and methods that have typically been deployed in the urban planning and design research on climate change adaptation. Lastly, from a policy-making and practice perspective, this article investigates how the research on climate change adaptation has contributed to the development of urban planning and design policies and practices.

In order to achieve its objectives, this article presents the outcomes of a longitudinal study that considered peer-reviewed urban planning and design articles that had been published since 2000 – a pivotal date that coincides with TAR's publication and its recommendations for urban planning and design research. This longitudinal study covered articles from 30 urban planning and design journals published between 2000 and 2013. The journals' selection is based on Goldstein and Maier's (Goldstein & Maier, 2010) and Salet and Boer's (Salet & Boer, 2011) studies that ranked urban planning and design journals and identified their scope and aims.

The following section introduces the basic concepts behind the science of climate change. It is followed by discussions on the turn toward climate change research and its links to environmental research in urban planning and design. A detailed discussion of the methodology adopted in the longitudinal study that led to this article then follows, followed by further discussion, and eventually, the conclusion.

2.2 Climate change: an emerging science

In 1979, the First World Climate Conference by the World Metrological Organization highlighted, among other topics, the necessity for nations across the world to predict and prevent potential man-made changes in climate that might impact the well-being of humanity (Zillman, 2009). In the wake of this conference, the World Climate Research Program was established to determine the predictability of climate and the effects of human activities on it (WCRP, 2012). This led the United Nations Environment Program (UNEP) and the World Metrological Organization to found, in 1988, the Intergovernmental Panel on Climate Change (IPCC) (Peake & Smith, 2009).The IPCC published its First Assessment Report in 1990 at the Second World Climate Conference. Like its predecessor, this conference highlighted the risks of climate change and led to the establishment of UNFCCC. Under UNFCCC's auspices, the 1997 Kyoto Protocol[2] sought to obligate – mostly industrialised – countries to reduce their greenhouse gas emissions (UNFCCC, 2013). The 1980s and 1990s also witnessed the endorsement of several reports and agreements, such as IPCC's First and Second Assessment reports (in 1990 and 1996 consecutively), the Kyoto Protocol, and Agenda 21[3]. Thus, during these decades, climate change was initiated as a scientific field that set new directions for researchers from various fields, while several climate change-related notions developed, including the aforementioned adaptation and mitigation as well as vulnerability, risk, and resilience (Box 1). The following discussion presents an overview of the subsequent development of climate change science, particularly adaptation.

[2] The Kyoto Protocol, adopted in Kyoto, Japan, in 1997 and entered into force in 2005, is an international agreement linked to the UNFCCC, that commits its parties to set binding to greenhouse gas (GHG) emission-reduction targets (UNFCCC, 1998).

[3] Agenda 21, adopted at the Earth Summit held in Rio de Janeiro, Brazil, in 1992, reflects a global consensus and political commitment at the highest level on development and environment cooperation. It addresses global environmental problems to accelerate sustainable development for the 21st century (United Nations, 1992).

Over the first decade of the 21st century, the emerging field of climate change adaptation has significantly advanced and attempted to address many interdisciplinary and cross-cutting themes. Nevertheless, Hunt and Watkiss (2011) noticed that the climate change literature failed to recognize “cross-spectral impacts and adaptation linkages” (p.40). Furthermore, Berrang-Ford et al. (2011) observed that adaptation studies consistently increased, and most addressed vulnerability assessments and natural systems while also including proactive adaptation – i.e., adaptation that occurs as a precautionary measure in anticipation of changes in climatic patterns (Figure 2.1a). Their study also revealed that the utility sector including, energy, water, and flood management, represented about 64% of the overall adaptation studies. In comparison, the sectors that could potentially link adaptation to physical planning and urban design, such as infrastructure and transportation (e.g., coastal engineering structures), represented 38% of the studies (Figure 2.1b). According to Ford et al. (2011, p. 330), about 90% of what they term “non-structural” are normative. In other words, these studies involve the development of management strategies, policies, and regulations in order to guide current and/or future adaptation plans and policies rather than structural (or physical) interventions, e.g., coastal protection and transportation. Berrang-Ford et al. (2011) also added that the majority of such studies include aspects like adaptive capacity, assessments of climate change vulnerability, conceptual frameworks, and general adaptation approaches rather than actual adaptation actions. These conceptual policies and mechanisms are often “insufficiently developed to have progressed substantively beyond the assessment and planning stages” (Berrang-Ford, et al., 2011, p. 27). To date, climate change studies have addressed the sectors primarily related to sea-level rise, extreme heat, health, and water resources, while the sectors associated with built infrastructure, energy, and transport remain less studied (Hunt & Watkiss, 2011). Reckien et al.’s (2014) recent study on climate change policy in 200 European urban areas revealed that 72% of such areas lack any adaptation plans and 35% lack a dedicated mitigation plan.

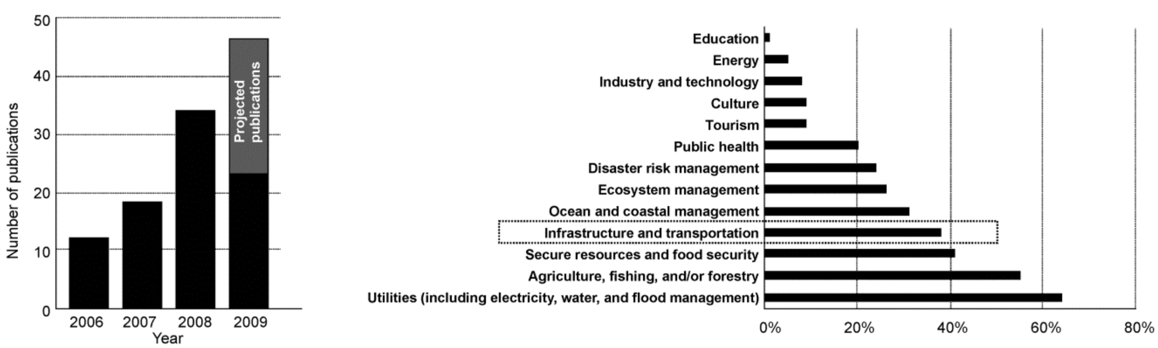

Figure 2.1. Consistency of adaptation studies (a) and Sectors involved in adaptation interventions (b) (adapted from Berrang-Ford, et al., 2011)

Lastly, Roggema et al.’s (2012) review identified the different foci of adaptation studies, including ones that tackle the fundamental definitions related to climate change as well as governance and institutional policies. Their study also revealed that the steadily growing body of literature on climate change adaptation has rarely included spatial planning, urban form, or urban design. Others have also established that the majority of adaptation studies thus far underscore isolated aspects of adaptation and rarely address the complex interactions between the bio-physical, economical, and environmental agents of an urban area (Hunt & Watkiss, 2011; Revi, et al., 2014). In fact, the climate change adaptation literature generally acknowledges this inadequacy and hence recommends better urban planning and design; underscores the quality of building, infrastructure, and services; and advocates for land use planning and management that would collectively enhance the resilience of urban areas (Revi, et al., 2014). Notably though, while resilience has been discussed in the socio-ecological literature since the 1970s, it remains a relatively new concept in urban planning discourse, particularly vis-à-vis climate change adaptation (Davoudi, et al., 2012; Stead, 2014).

Box 1.
Vulnerability is the degree to which a system is susceptible to climate change and its inability to cope with the adverse effects of climate change. A system's vulnerability can also be described in terms of "its exposure to the impacts of climate and its baseline sensitivity to those impacts" (Yohe et al., 2007, p. 814). Exposure and sensitivity are almost inseparable attributes of a system and are dependent on the climatic stimulus (B. Smit & Wandel, 2006). Exposure indicates the degree to which a system is exposed to the exigencies of climatic extremes or hazards, and thus, the exposure of any system varies widely according to its geographical location in relation to latitude, land mass, and climatic variability (Roaf, Crichton, & Nicol, 2005).

Risk, according to Crichton (2001), is a function of exposure (E), vulnerability (V), and hazard (H), whereby: Risk(R) = f(E x V x H). This concept of risk has been widely used in the urban planning discourse (Fedeski & Gwilliam, 2007; Roaf, et al., 2005; E. Wilson & Piper, 2010). Others like Rosenzweig et al.(2011), considered that risk is the intersection of three vectors: hazards, vulnerabilities, and adaptive capacity, whereby adaptive capacity (i.e., a system's coping ability), influenced by the system's exposure and sensitivity (B Smit et al., 2001).

Resilience refers to a system's ability to absorb disturbances while retaining the same basic structure and ways of functioning and simultaneously possessing the capacity to adapt to climate change (IPCC, 2007). Thus, increasing a system's resilience could improve its long-term coping ability so as to reduce risks and vulnerability from climate change. As resilience is considered the antithesis of vulnerability: "the more resilient, the less vulnerable" (Pelling, 2011, p. 42) and thus, resilience often reflects a concept analogous to adaptive capacity (Beatley, 2014).

2.3 A new millennium: a new turn toward climate change research in urban planning

TAR's publication in 2001 brought the likely impacts of climate change on urban centers to the forefront by describing three non-climatic scenarios that would nonetheless characterize the sensitivity of any given system – an urban system in this case – to climate change, namely: socio-economic; land use and land cover; and environmental. Firstly, the socio-economic scenario included governing structures at different scales, patterns of technological changes, and social values that serve to project greenhouse gas emissions more so than to assess a system's vulnerability or its adaptive capacity. As for the land-use-change and land-cover-change scenarios, they involved processes that were deemed important for estimating climate change and its impacts. Both types of change influence greenhouse gas emissions and carbon fluxes and thus strongly impact climatic processes, which in turn lead to change in the land cover. The conversion and modification of land cover may even influence the properties of eco-systems and their vulnerability to climate change (IPCC, 2001a). For example, Moglen and Kim (Moglen & Kim, 2007) explored the potential of change in both land use and land cover as a tool to measure imperviousness which is considered to be an effective predictor of environmental degradation. They accordingly recommended limits to imperviousness that range from 7% to 8% of any given area to cope with climatic uncertainty. Lastly, the environmental scenario referred to future environmental changes other than climatic, but which nevertheless might significantly contribute to a changing climate, such as atmospheric composition; marine pollution; and the availability, use, and quality of water (IPCC, 2001a).

While these three scenarios are important for urban planning and design, equally important were TAR's findings that led to projections such as higher maximum temperature (i.e., more hot days and increased heat waves) and lower minimum temperature (i.e., more cold days and increased cold waves). Such variations would yield health repercussion such as higher incidences of death and major illnesses, especially among the elderly and the urban poor. Moreover, sea-level rise, whose severity and risk vary regionally, is expected to increase over 8 mm/year between 2081-2100 although between 1901-2010 its rate was 1.7 mm/year (Pachauri et al., 2014). Combined with more intense precipitation, sea-level projections indicate an increase in floods and landslides, the frequency of tropical cyclones, and the intensity of wind – all of which would negatively impact human settlements (IPCC, 2001c).TAR's premonitory projections echoed earlier studies like that by Nicholls et al.(1999), who estimated a fivefold increase in the number of people (nearly 93 million) who will be displaced annually due to the flooding that would ensue from storm surges if a 38cm sea-level rise occurred between 1990 and 2080. In fact, research warned that even an entire implementation of the Kyoto Protocol would not be sufficient to decrease global warming. Specifically, the overall target of the Kyoto Protocol was to reduce the 1990 greenhouse gas emissions by 5.2% by 2012, as achieving this target may yield a six-year delay in global warming by the end of the twenty-first century (Peake & Smith, 2009).

The inevitable impacts of climate change warrant the imperativeness of climate change adaptation research to seek sustainable development. In fact, several studies underscored the significance of empirical research on adaptation, such as Burton et al.(1998) and Smit et al.'s (2001). Such studies highlighted the following conditions: 1) climate change and its impacts are unavoidable; 2) anticipatory and precautionary adaptation strategies are more effective and less costly than forced and last-minute emergency adaptation or retrofitting; 3) climate change may be more rapid and more pronounced than current estimates suggest; thus unexpected events are highly possible; 4) immediate benefits can be gained from better adaptation actions; 5) immediate benefits can also be gained by removing maladaptive policies and practices; and lastly, 6) climate change presents opportunities as well as threats, and therefore, climate change may yield future benefits (B Smit, et al., 2001, p. 890). Clearly, adaptation to climate change constitutes the common denominator among these six conditions. The literature on climate change adaptation has advanced further through the development of concepts such as maladaptation (Barnett & O'Neill, 2010), ecosystem-based adaptation (Doswald et al., 2014; Travers, Elrick, Kay, & Vestergaard, 2012) and community-based adaptation (Huq & Reid, 2007; Schipper, Ayers, Reid, Huq, & Rahman, 2014). However, how has the urban planning and design discipline responded to these conditions? Planning scholars often claim that the planning and design literature has not contributed much to addressing these climatic conditions (Pizarro, et al., 2006; Roggema, et al., 2012). Therefore, this paper investigates the extent to which the urban planning and design literature has addressed the topics abovementioned using a longitudinal study. The next section describes the methodology deployed for this investigation.

2.4 Methodology

To answer the above questions, this paper presents a longitudinal investigation of scholarly research on climate change in the urban planning and design literature. This study has adopted several criteria to determine the eligibility of a scholarly work. **Firstly**, only peer-reviewed planning and design journals whose articles are published only in the English language have been considered. **Secondly**, this longitudinal study has considered the year 2000, a turning point as the start of a new millennium, and since 2001 also coincided with the publication of IPCC's TAR with its aforementioned three scenarios that had direct implications for urban planning research. Thus, only journals already in publication by 2000 are considered, in order to detect recent trends and the emerging areas emphasized in the urban planning and design research vis-à-vis climate change and especially adaptation. This entailed excluding planning journals that were launched after 2000, like the Journal of Urbanism: International Research on Placemaking and Urban Sustainability (issued in 2008) and the International Journal of Urban Sustainable Development (issued in 2010). **Thirdly**, the ranking of the journal also determined its eligibility for inclusion in this study based on two articles that had listed and ranked the planning journals, namely: Goldstein and Maier's (2010) article titled "The Use and Valuation of Journals in Planning Scholarship: Peer Assessment versus Impact Factors" and the commentary on it by Salet and Boer (2011), which was titled "Commentary: Comparing the Use and Valuation of Journals between US and European Planning Scholars". Thus, these three criteria yielded 24 journals that we classify as group A (Table 2.1). **Fourthly**, six additional urban planning and design journals, named group B (Table 2.2) were considered because they have the potential to link planning scholarship to climate change. Selection of this group employed a combination of their scope and aims, and also, their ranking according to the SCImago Journal Rank (SJR indicator and its H Index) (see www.scimagojr.com). In other words, group B journals deal with urban form and the environment and their interface. According to Kevin Lynch (1981), urban form refers to "the physical environment" of a city that includes the spatial pattern of its permanent and inert physical objects such as hills, rivers, streets, buildings, utilities, and trees.

Collectively, based on the four criteria, 30 urban planning and design journals in total (in groups A and B) were eligible for inclusion in this study.

Table 2.1 *Group A journals and their aims and scope*

Name of planning and design journals	**Top 20 journals** (by Goldstein and Maier, 2010)	**Top 20 journals** (by Salet and Boer, 2011)	**Aims and scope** Planning theory/history	Housing, real estate, community development	Economic development	Transportation, infrastructure	Land use	Environmental	Design, other	**Considered for this study** (Group A)
Journal of the American Planning Association	1	11/12	+	-	-	+	+	+	+	√
Journal of Planning Education and Research	2	9	+	-	-	-	+	-	+	√
Urban Studies	3	1	-	+	+	+	-	-	-	√
Housing Policy Debate	4		-	+	-	-	-	-	-	√
Journal of Urban Affairs	5		-	+	+	-	-	-	-	√
Journal of Planning Literature	6		+	-	-	-	+	-	-	√
Economic Development Quarterly	7		-	-	+	-	-	-	-	√
Environment and Planning A	8	2	-	-	+	-	-	-	-	√
Urban Affairs Review	9		-	+	+	-	-	-	-	√
Environment and Planning B	10	7/8	-	-	-	-	-	+	+	√
International Journal of Urban and Regional Research	11	6	+	+	+	-	-	-	+	√
Journal of Environmental Planning and Management	12		-	-	-	-	+	+	-	√
Journal of Planning History	13		+	-	-	+	-	-	+	√
Journal of Urban Design	14	15	-	-	-	-	-	-	+	√
Landscape and Urban Planning	15		-	-	-	-	+	+	-	√
Regional Studies	16		-	-	+	-	-	-	-	√
Transportation Research	17		-	-	-	+	-	-	-	√
Planning Theory	18	7/8	+	-	-	-	-	-	-	√
Journal of Architectural and Planning Research	19		-	+	-	+	-	+	+	√
Planning Theory and Practice	20	11/12	+	-	-	-	-	-	-	√
European Planning Studies		3								√
Town Planning Review		5								√
disP *(in German, English, French, or Italian)		10								
Planning Practice and Research		4								√
Environment and Planning C		13								√
Raumforschung und Raumordnung * (in German)		14								

Note: The numbers from 1 to 20 show the ranking of the journals according to Goldstein and Maier, and Salet and Boer. The positive (+) and negative (-) marks signify the areas of specialization on which the journals focus more or less respectively according to Goldstein and Maier; the check mark (√) indicates the journals that included in this study; and the asterisk (*) indicates that the journals publish articles in languages other than English.

Table 2.2 *Group B journals and their aims and scope*

Name of journals (Group B)	Aims and scope	SJR*	H Index*
Building and Environment	Sustainable built environments	1.27	53
Environment and Urbanization	Human settlements and environment	1.02	24
Journal of Urban Planning and Development	Development and redevelopment of urban areas	0.58	17
Urban Morphology	Research and practice in built environment	0.22	10
Urban Design International	Urban design and management	0.3	9
Built Environment	Environmental planning and urban design	N/A	N/A

* obtained from the SCImago Journal Rank (www.scimagojr.com)

Once the eligible 30 journals were selected, the next step entailed determining the eligibility of the articles themselves. For this purpose, a three-stage approach was adopted. **In the first stage**, we reviewed the title, abstract, and keywords of all the articles published in these 30 journals between 2000 and 2013. This inductive process employed a thorough review of articles of every issue and volume of these journals that was conducted manually in order to select articles for this research instead of only using search engines like Google scholar and web of science. It is because, in the early days, key terms like "climate action" might have referred to mitigation; however, now they stand for both mitigation and adaptation (P. Robinson & Gore, 2015). In addition, articles focusing on sustainability and risk include several components which are closely associated with climate change (mitigation or adaptation); however, in some cases, they have never used the terms "climate change" (see, for example, Jepson & Edwards, 2010). Thus, to minimize possible errors and the chance of losing relevant articles, any article whose subject matter addressed, whether directly or indirectly, either climate change mitigation or adaptation was selected. This first stage yielded a total of 405 articles that addressed climate change – whether mitigation or adaptation – of which 83 were published only in 2013. **In the second stage**, we separated the articles into two groups: mitigation and adaptation studies. The mitigation studies totalled 248 and included those articles that investigated the sources of and/or the methods for reducing greenhouse gas emissions through urban planning and urban design policies and practices. For example, mitigation studies included those that addressed the reduction of automobile dependency, which would indirectly promote the reduction of greenhouse gas emissions. The mitigation articles also included those that dealt with smart growth and compact urban form such as studies on New Urbanism and Transit-Oriented Developments (TODs) (see for example: Jepson & Edwards, 2010; Yedla & Shrestha, 2003).The adaptation studies totalled 157 articles and included those that sought to adjust the built environment either with the objective of moderating the harm, or exploiting the potential benefits of climate change. They also included studies that focus on the approaches for addressing the direct and indirect consequences of natural disasters that are posed solely by climate change. Accordingly, this study has excluded articles on earthquakes, for example, and instead only considered the planning research on the different strategies to alleviate the impacts of climate change. It should be emphasized that an article was included in the adaptation group depending on its subject matter regardless of whether it had specifically mentioned the terms "climate change" or "adaptation", such as the articles by Waugh and Smith (2006), Bahrainy (2003), and Thompson (2012). Also, the adaptation group included a few studies that have discussed both adaptation and mitigation.

The third stage focused solely on the 157 adaptation articles that appeared in the 30 chosen journals. Based on their content, these articles were classified into groups that are discussed in detail in the next section. This classification was based on Richard Klein et al.'s (2001) four iterative steps for adaptation strategies, namely information development and awareness raising; planning and design; implementation; and monitoring and evaluation. **The fourth and last stage** involved identifying the links between the climate change adaptation articles that were published in the urban planning and design journals in particular, and climate change literature in general. This took place by investigating the extent to which the urban planning literature on adaptation had actually cited climate change literature that had appeared in climate change journals such as: Global Climate Change; Climatic Change; Natural Hazards; Disasters; and Mitigation and Adaptation Strategies for Global Change among others. It is imperative to underscore here that our count focused on the links between peer-reviewed journal articles and excluded other sources.

2.5 Climate change adaptation in the urban planning literature

The result of sorting the 405 climate change articles during the second stage reveal that there is an increasing trend in the publication of empirical research on climate change in the urban planning and design journals (Figure 2.2). Figure 2.2 also indicates a noticeable increase in adaptation studies since 2006, after hurricane Katrina hit New Orleans. This finding is consistent with the publication in 2007 of IPCC's Fourth Assessment Report, which received the Nobel Peace Prize that same year – significant factors that may have contributed to successfully establishing climate change as a research challenge in the planning discourse. In fact, since then many journals have published special issues on climate change, such as *Built Environment*'s 2009: "Climate Change, Flood Risk and Spatial Planning"; the *Journal of the American Planning Association's (JAPA)* 2010: "Planning for Climate Change: Assessing Progress and Challenges"; and *Environment and Planning C*'s 2013: "Novel multisector networks and entrepreneurship in urban climate governance". Most importantly, the number of articles published on mitigation consistently far exceeded those on adaptation.

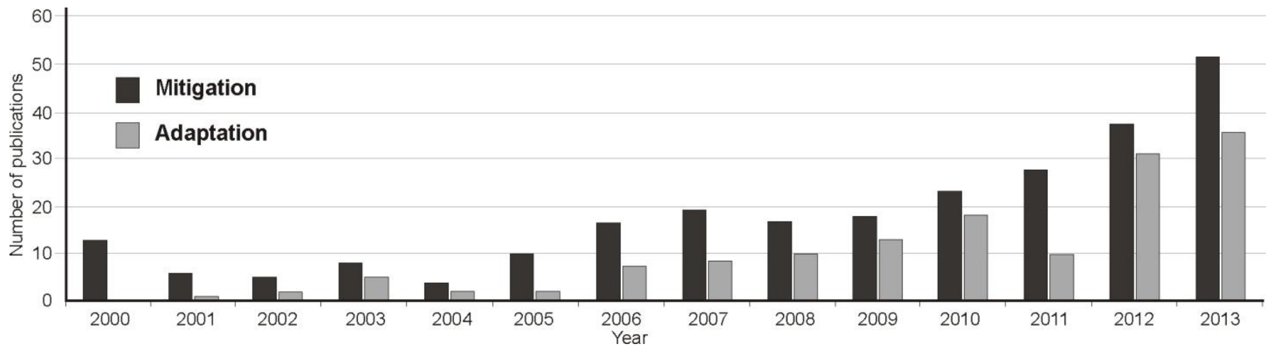

Figure 2.2 The number of articles on climate change mitigation and adaptation in the planning journals.

Next, the exhaustive review of the chosen articles on adaptation determined their distribution over the eight areas of focus (Figure 2.3). This finding reveals that governance and social learning studies constituted 34% of the 157 articles on adaptation, followed by risk assessments studies (16%). The articles on alleviation strategies, which included spatial planning and urban design, constituted only 15% of the adaptation studies. This finding comes despite the fact that the 1984 Ocho Rios conference and Burby et al.'s (1999) study both underscored land use planning as a powerful adaptation tool for reducing the negative impacts of climate change.

In order to situate the 157 articles within the existing frameworks of climate change science, this article has developed a conceptual framework that facilitates the classification of these studies. Table 2.3 describes this framework, which, in column 1, builds on Klein et al.'s four aforementioned iterative steps of adaptation strategies. Although initially developed for coastal zones, Klein et al.'s model can be adjusted for application to adaptation in general, given its abstract, non-contextual nature. We then juxtapose, in column 2, Klein's model against six factors that, according to TAR, determine the adaptive capacity of regions or communities, namely: information and skills; economic wealth; social and physical infrastructure; technology; equity; and institutions (IPCC, 2001b). Through this juxtaposition, we are able to establish the links between the iterative steps of adaptation and the factors of adaptive capacity.

This review facilitated the deduction of the main areas of focus in the current research on adaptation – a total of eight – that are listed in the third column of Table 2.3. They are grouped to correspond to the iterative steps and to the factors that impact adaptive capacity. These eight areas of focus are described in detail in Table 2.4.

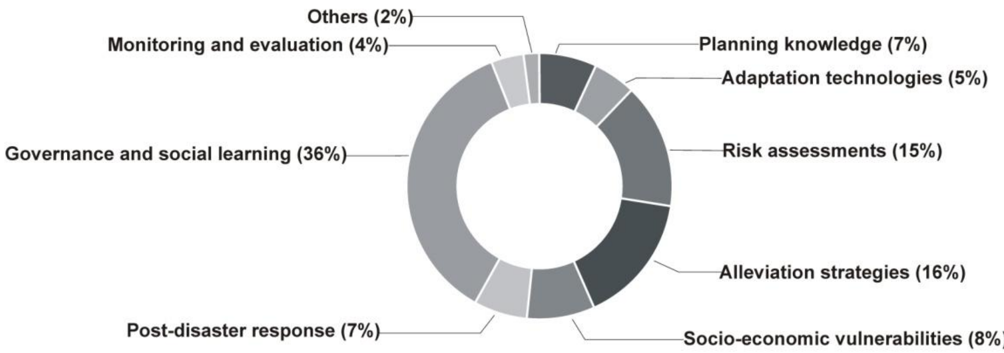

Figure 2.3. The distribution of the climate change adaptation articles included in this study, over the eight areas of focus

Table 2.3. *The conceptual framework showing the eight areas of focus for climate change adaptation in the urban planning and design literature*

The iterative steps of climate change adaptation strategies (after the Klein, et al., 2001)	The factors that influence the adaptive capacity (after the IPCC, 2001b)	The deducted eight areas of focus of climate change adaptation in the urban planning and design articles
1. Information development and awareness raising	1. Information and skills 2. Economic wealth 3-a. Social infrastructure	i) Risk assessments ii) Socio-economic vulnerability
2. Planning and design	3-b. Physical infrastructure 4. Technology 5. Equity	iii) Planning knowledge iv) Post-disaster response v) Alleviation strategies vi) Adaptation technologies
3.Implementation	6. Institutions	vii) Governance and social learning
4. Monitoring and evaluation		viii) Monitoring and evaluation

To shed further light on these climate adaptation articles, Table 2.4, in its four parts: a, b, c, and d, builds on the classifications in Table 2.3 and maps the research methods adopted in the empirical studies that led to these articles. Table 2.4 also lists the hazards that these articles identified and their primary sources of literature. Furthermore, it groups these findings under each one of the deducted eight areas of focus and, consequently, links them to Klein et al.'s (2001) four steps.

Tables 2.4 (a, b, c, and d). *The eight areas of climate change adaptation, their associated research methods, the hazards dealt with, and the articles' primary sources of literature –classified according to Klein et al.'s (2001) four steps*

Table 2.4-a *Step 1: Information development and awareness*

1. Information development & awareness raising				
Areas of adaptation	Description	Research methods	Hazards	Sources
Risk assessments	1) Different modeling, simulation, visualization framework to assess climatic risks 2) Land use, settlement patterns and buildings, and population distribution in disaster prone areas.	GIS analysis Land use modelling and simulation Indicator-based modelling Literature review	Heat stress Floods Hurricanes Sea-level rise	(De Sherbinin, Schiller, & Pulsipher, 2007; Fedeski & Gwilliam, 2007; Greiving, Fleischhauer, & Lückenkötter, 2006; Lindley, Handley, McEvoy, Peet, & Theuray, 2007; McGranahan, Balk, & Anderson, 2007)
Socio-economic vulnerabilities	1) Economic and social vulnerabilities ensuing from climate change 2) Urban poverty, economic loss, and international and local funding strategies vis-à-vis vulnerabilities 3) The costs of adaptation, migration, and vulnerable communities 4) Disaster preparedness and post-disaster response	Literature review Integrated assessment models (e.g., the Climate Framework for Uncertainty, Negotiation and Distribution)	Sea-level rise Floods Storms Coastal erosion	(Awuor, Orindi, & Adwera, 2008; Ayers, 2009; Black, Kniveton, & Schmidt-Verkerk, 2011; Hardoy & Pandiella, 2009; Narita, Tol, & Anthoff, 2010)

Table 2.4-b *Step 2: Physical planning and design*

2. **Planning and design**				
Areas of adaptation	Description	Research methods	Hazards	Sources
Planning knowledge	1) The gaps between urban planning and climate change research 2) Theoretical and methodological frameworks for climate change adaptation and/or mitigation; scales of adaptation planning; involving different stakeholders	Literature review	All climate change impacts	(Comfort, 2006; Davoudi, et al., 2012; de Wilde & Coley, 2012; Kates, Travis, & Wilbanks, 2012)
Post-disaster responses	1) Post-disaster financing and planning management; reconstruction and rebuilding; temporary housing; local government and the implementation of safety regulations 2) Integrated risk reduction approaches. Parallels between risk management and development planning; translating discourse into action. 3) Resilience strategies	Evaluation of policies/strategies for disaster management	Hurricanes Floods	(Bahrainy, 2003; Chamlee-wright & Storr, 2009; Hardoy & Pandiella, 2009; Olshansky, Johnson, & Topping, 2006; Talen, 2008; Waugh & Smith, 2006)
Alleviation strategies	1) Urban planning and design strategies to alleviate climatic impacts 2) Management of coastal zones; spatial distributions in disaster prone areas according risk's elements: hazards, exposure, and vulnerability 3) Surface water, land use, land cover, and building structures and materials	GIS Case study analysis Reviewing regulatory provisions and planning efforts Literature review	Floods Sea level rise	(S. D. Brody, Zahran, Grover, & Vedlitz, 2008; H. Campbell, 2006; Greiving & Fleischhauer, 2012; Howe & White, 2004; Sohn, 2006; White & Alarcon, 2009)
Adaptation technologies	1) Technological solutions; infrastructure 2) Urban drainage systems; storm water runoff management; flood reduction 3) Capacity of street detention storage; building downspout versus surface runoff.	Case study analysis Literature review Simulation and modelling	Floods Overheating	(Ashley et al., 2007; Raymond J Burby, Nelson, Parker, & Handmer, 2001; Gupta & Gregg, 2012; Lomas & Giridharan, 2012; Waters, Watt, Marsalek, & Anderson, 2003)

Table 2.4-c *Step 3: Implementation*

3. **Implementation**				
Areas of adaptation	Description	Research methods	Hazards	Sources
Governance and social learning	1) Governance and social learning tools; community-based adaptation. 2) Social learning forms: conceptual mapping of disasters through listing and ranking. 3) Social learning outcomes: local adaptation knowledge; alternative adaptation strategies; and social or technical skills 4) Community resilience, disaster management options, and community-institutions collaboration	Qualitative: Participatory methods Interviews Discourse analysis	All hazards (primarily flood)	(Burch, Schroeder, Rayner, & Wilson, 2013; Mukheibir & Ziervogel, 2007; Quay, 2010; Shackley & Deanwood, 2002; Tacoli, 2009)
		Quantitative: • Multi-criteria analysis • Questionnaires • Interviews	• All hazards	(Albert, Zimmermann, Knieling, & von Haaren, 2012; Amundsen, Berglund, & Westskogô, 2010; David R Godschalk, Brody, & Burby, 2003)
		Mixed-method: • Observation • Focus group • Interviews	• All hazards	(Albert, et al., 2012; Bedsworth & Hanak, 2010; Porter & Demeritt, 2012)

Table 2.4-d *Step 4: Monitoring and evaluation*

4. **Monitoring and evaluation**				
Areas of adaptation	Description	Research methods	Hazards	Sources
Monitoring and evaluation	1) Insights on existing strategies 2) Assessment and evaluation of existing adaptation actions and policies	Content analysis of documents Reviews of local policies and strategies	Floods Sea-level rise	(Cartwright et al., 2013; Evans-Cowley & Gough, 2008; Solecki, 2012; Vellinga, Marinova, & Van Loon-Steensma, 2009)

Furthermore, the findings reveal a dearth of empirical studies that address the neighbourhood and district scale of the urban fabric. Table 2.5 classifies the 154 (excluding three other articles) according to four scales: the scale of the individual building; the scale of the neighbourhood and district; the scale ranging from multiple neighbourhoods to the city; and lastly, the regional scale and beyond, including the territorial geographic and infrastructural networks. Table 2.5 reveals that most of the urban planning and design research on climate change adaptation had mostly addressed the larger scales of multiple neighbourhoods, the city, the region, and beyond. For example, 30 of the 37 articles on information development and awareness focused on the scale of multiple neighbourhoods, the city, the region, and beyond. Likewise, 39 of the 54 articles on physical planning and design have underscored these scales, in that most either addressed urban form through spatial planning tools such as land use modelling and spatial risk assessment frameworks (Lindley, et al., 2007; Mandarano, 2010; Muller & Yin, 2010), or addressed adaptation technologies like drainage systems (Ashley, et al., 2007). Eight of these 54 articles on physical planning and design addressed climate change adaptation strategies at the scale of an individual building, with a particular focus on architectural and engineering details of a specific project, including risk assessment (Beizaee, Lomas, & Firth, 2013; Huijbregts, Kramer, Martens, Van Schijndel, & Schellen, 2012; Nik, Sasic Kalagasidis, & Kjellström, 2012), green and resilient building practices (Gupta & Gregg, 2012; Pyke, McMahon, Larsen, Rajkovich, & Rohloff, 2012), and energy use and thermal comfort (Guan, 2012).

Only seven articles of the 54 on physical planning and design addressed the neighbourhood and district scale (e.g., Chamlee-wright & Storr, 2009; Lewis & Kelman, 2009; Neville & Coats, 2009). Likewise, at this same scale, only five of the 37 articles on information development and awareness addressed resilience and risk assessments (S. D. Brody, Gunn, Peacock, & Highfield, 2011; Van Zandt et al., 2012). These findings offer a clear indication of the need for further empirical and theoretical studies on climate change adaptation at the neighbourhood and district scales.

Table 2.5 *Distribution of climate change adaptation articles over various planning scales*

The steps of adaptation based on Klein et al.(2001)	Regional scale and beyond	More than one neighbourhood to the city scale	Neighbourhood and district scale	Building scale
1. Information development and awareness (n=37)	54%	49%	14%	11%
2. Physical planning and design (n=54)	35%	41%	13%	15%
3. Implementation (n=57)	54%	44%	18%	0%
4. Monitoring and evaluation (n=6)	83%	17%	0%	0%

2.6 Climate change resources: toward developing links

It is imperative for urban planning and design to cross the disciplinarily boundaries into the well-established climate change field – a task that requires the sharing of knowledge and resources and the adaptation of shared knowledge. If anything, acknowledging and citing climate change literature represent only one aspect of a genuine attempt to link the urban planning and design discipline to the climate change one. While the climate change literature is essentially not based in the urban planning discipline, it nevertheless includes several aspects that are relevant to urban planning and design, such as Rosenzweig et al.'s (2007) adaptation planning for infrastructure and Zahran et al.'s (2008) planning model for quantitative analysis of population distribution and density in disaster-prone areas. Therefore, this study includes the extent to which the urban planning and design literature has cited the climate change literature.

This part of the analysis also investigated trends. The most-cited climate change articles in the urban planning and design literature were those that discussed the definition and evaluation of adaptation and the interrelationships between the different concepts of adaptation and their applications (such as, W.N. Adger, Arnell, & Tompkins, 2005; Dessai, Lu, & Risbey, 2005; Füssel, 2007; Barry Smit, Burton, Klein, & Wandel, 2000; B. Smit & Wandel, 2006). Additionally, the findings, as summarized in Table 2.6, reveal that the information development and awareness articles in the urban planning and design literature witnessed the highest frequency of citing climate change literature. Interestingly, the physical planning and design witnessed the least instances of citation of the climate change literature. These findings are in line with other findings from studies, such as Roggema et al.'s (2012), who observed a lack of genuine attempts in the urban planning and design scholarship to cross the borders of other scientific areas particularly, climate change adaptation.

Table 2.6 *The average number of climate change articles cited in each planning article*

The steps of adaptation	**The average number of climate change articles that are cited by urban planning design articles**
1. Information development and awareness raising	3.76
2. Physical planning and design	1.63
3. Implementation	2.70
4. Monitoring and evaluation	1.67

2.7 Potential research limitations

This paper aims to present a state-of-the-art of adaptation research in planning discourse and to facilitate developing theoretical and empirical links between urban planning and design and the science of climate change, particularly adaptation. The goal is to identify future trajectories of planning and design scholarship; however, the methodology used here to select journals and articles, reduce, and shorten them, still encountered several challenges and yielded some shortcomings that, hopefully, will be addressed in subsequent studies. First, considering only planning and design journals may exclude relevant articles that are also available in venues other than the urban planning and urban design disciplines. For example, Climate Policy and Local Environment represent two of the renowned journals for climate change research and both have hosted planning related articles for years (see Betsill, 2001; Schmidt, Helme, Lee, & Houdashelt, 2008; E. Wilson, 2006).

Second, ranking systems or impact factors often prioritize journals that publish articles of diversified issues across the world, not those that only focus on issues of a particular area or region. Considering top ranked journals (both groups A and B) may exclude such scholarship available in geographically specific journals dealing with regional and local planning agendas. For example, E. Robinson et al's (2012) study on coastal settlements challenged by sea-level rise in a Caribbean city and P. Robinson and J. Gore's (2005) study on Canadian municipalities' response to reduce greenhouse gases are two excellent studies that are available in *Caribbean Journal of Earth Science* and in *Canadian Journal of Urban Research* respectively – two geographically-specific journals.

Third, this study's methodology considers peer-reviewed journal articles only. Consequently, a number of reports like UN-Habitat's (2011) *Global Report on Human Settlements* and several books like Harriet Bulkeley's (2013) *Cities and Climate Change, Critical Introductions to Urbanism and the City,* both of which highlight several planning and design agendas to facilitate climate change mitigation and/or adaptation have been excluded from this study. Nevertheless, this paper assumes that peer-reviewed articles represent the highest level of urban planning and design scholarship contributed mostly by planning scholars. That is why the methodology for this paper focused on the leading peer-reviewed planning journals.

In order to overcome these three challenges and the ensuing shortcomings, a future study would, instead of commencing with the highly ranked urban planning and design journals, track the venues that urban planning and design scholars use to disseminate their research on climate change. Such a study would analyze the relationship between these various venues and the mainstream urban planning venues, their rankings, and their impact factors. Such a paper would also compare the numbers of citations for the journal articles and compare these numbers to articles on climate change that have been published in the mainstream urban planning.

2.8 Conclusion and research agendas

Until the middle of the last decade, the planning and design literature rarely addressed adaptation, as Pizarro et al. (2006) noticed. Confirming their findings, this paper identifies 2006-07 as a turning point, after which climate change studies not only increased consistently but also became more prevalent in the literature (Figure 2.2). The increased number of climatic extreme events and their severity, particularly in the wake of New Orleans's Katrina in 2005, significantly raised awareness among the planning scholars toward climate change adaptation (for example, Campanella, 2006; Neville & Coats, 2009; Thompson, 2012). This review, however, reveals that much of the planning literature addressed climate change mitigation – i.e., decreasing greenhouse gas emissions – as opposed to adaptation – i.e., adjusting to climate change.

Furthermore, this paper notices that climate change adaptation studies in the planning literature follow two trends. Firstly, most focus on policies –albeit in various forms– by typically concluding with different sets of normative policy guidelines, or with several matrices to measure and/or to clarify the climate change vulnerability in a given context. As a result, adaptation studies in planning discourse hardly include adaptation actions. Berrang-Ford et al.'s (2011) review also reveals that overall adaptation research focuses more on climate change risk and vulnerability assessment, adaptive capacity, and/or conceptual approaches, not on adaptation actions. Similar to the mainstream climate change adaptation research, urban planning and design studies underscore local and regional governing systems, socio-economic vulnerabilities, and social awareness, together with learning to adapt to natural disasters at various scales (Figure 2.3). Secondly, while the planning literature investigates various aspects of planning and design interventions related to adaptation, including transportation, infrastructure, and land use, the physical planning and the design of built environments are less covered. In particular, there is a dearth of climate change adaptation studies that address urban design at the neighbourhood or district scales. This finding is in line with the IPCC's recent report, which also has revealed that adaptation knowledge vis-à-vis urban areas remains inadequate (Revi, et al., 2014). In general, adaptation scholarship frequently prioritizes locally-based actions, and thus place-based planning is often recommended for successful adaptation (Measham, et al., 2011). Such adaptation planning requires specific and implementable guidelines – adaptation actions – for designers, planners, and policy makers to apply them at the local level. One such practical initiative, for example, is Rotterdam's Sustainability Guide 2010 by Rotterdam Climate Initiative (Stead, 2014). This Guide includes several planning strategies for implementing climate change adaptation actions at local level, such as traffic management during evacuations, room for innovative water storage, and the use of green infrastructure.

Clearly, the discourse on climate change adaptation in the planning literature is more recent than that on mitigation; hence, it remains insufficient, particularly with respect to physical planning and urban design at the neighbourhood scale. Specifically, the analysis presented here leads to the identification of four gaps, together with the reasons behind them and the opportunities that they present for future research. These gaps pertain to the lack of interdisciplinary linkages, the absence of knowledge transfer, the presence of scale conflict, and the dearth of research methods.

To begin with, the lack of interdisciplinary linkages –conceptual and empirical– warrants innovative attempts to establish connections between the two fields, urban planning and design and climate change adaptation. Such links have been successfully established with regards to the underlying principles of climate change mitigation (as recommended by the Kyoto Protocol and Agenda 21) and sustainable development. A number of contemporary planning approaches (e.g., new urbanism) for sustainable development aim to reduce the ecological footprint, encourage mass transit, promote carbon neutral environment, and eventually, facilitate the reduction of GHG emissions, hence, contribute to climate change mitigation (Berke & Conroy, 2000). Along this line, Tang et al. (2010, p. 42) also added that jurisdictions for most local climatic actions exhibit "a serious consideration and commitment" for climate change mitigation not adaptation. Consequently, studies that operationalize different approaches of sustainable development and local climate actions abound in the planning literature and explain the surge in mitigation studies (Figure 2.2). For successful adaptation, approaches that integrate mitigation-focused action plans and adaptation-focused ones are highly recommended rather than stand-alone plans because of reducing the possible chance of maladaptation. Thus, local adaptation action plans could be a part of a comprehensive plan, such as a watershed or a transportation plan. Similar integrations have yet to be explored with regards to climate change adaptation. Parallels certainly exist between, on the one hand, urban planning and design concepts, such as urban green infrastructure and ecological design that enhance the resilience of urban areas and, on the other hand, the adaptation strategies found more recently in the climate change literature. The concept of resilience, long been discussed in socio-ecology, has emerged relatively recently in the planning discourse, but holds an enormous potential to link the planning scholarship and climate change adaptation (Davoudi, Brooks, & Mehmood, 2013; Davoudi, et al., 2012). The IPCC strongly advocates for ecosystem-based adaptations that rely on ecology and ecosystem services in order to increase a system's resilience and coping ability (i.e., its adaptive capacity) and thus function as long-term, no-regret, and proactive adaptations. Herein lies the opportunity for urban planning and design to identify the conceptual, empirical, and practical similarities with notions, such as ecosystem-based adaptations.

Secondly, the knowledge transfer gap is attributed to the dearth of climate change information at the community scale. Clearly, how climate change knowledge can be transferred through planning and design is more important than how planning knowledge is used by climate change science. It is essential to acknowledge that a knowledge transfer gap certainly exists: for instance, climatic models and projections are very complex and rather difficult to decipher. Thus, urban planners could potentially work collaboratively with climate change experts to convert projections and data into user-friendly media for planners and other end users. Yet, the point raised by Pizarro, et al. (2006) about ten years ago, still needs to be addressed: that is, planning holds the potential to reconcile the current format and scales (typically global) of climate change information and projections with a format more suitable for other sectors, including urban planning and design. Hunt and Watkiss (2011) observed that information about the impacts of extreme climatic events on cities and on the resulting uncertainty remains unavailable. Such uncertainty amplifies the risk of confusion between (past) evidence and (future) climatic projections for complex urban environments (Hallegatte, 2009). These information limitations restrict adaptation research in advancing from merely addressing isolated aspects to tackling the multiplicity and complexity of bio-physical interactions within urban areas. With the absence of such precise information, mitigation actions can be possibly executed at the local level through the universal planning models, such as compact urban form and TODs, one objective of which is to reduce GHG emissions. In fact, that is probably the reason why planners have primarily contributed to mitigation (more so than adaptation). In contrast climate scientists are primarily advocating adaptation in relation to the natural systems. Additionally, local climate and the characteristics of a local system influence adaptation actions that may vary spatially. So the availability and accessibility of climatic data for a particular area could make a significant difference in the approach and nature of adaptation action plans recommended for that particular area. Thus, along with the IPCC's recommendation, this paper suggests collaborative research and multi-disciplinary approaches to advance adaptation research that will combine scientific evidence of climate change and human-natural systems of climate change, and that will address the gaps existing not only in the planning literature (i.e., limited adaptation efforts), but also, in the climate change one (i.e., inadequate adaptation actions).

Thirdly, a scale conflict exists between the outputs provided by adaptation research (i.e., policy-based normative adaptation strategies), which generally occurs at the regional scale, and the inputs that a municipality requires for implementing adaptation planning at the local scale. This conflict is attributed to how adaptation decisions have been made, and also, by whom. Most recommendations and polices for climate change adaptation are to be implemented at the municipal scale, but a higher-level of governance (e.g., at the national scale) plays a key role in such adaptation decision-making (Ford, et al., 2011). This current paper also finds that most adaptation recommendations include governance as well as institutional policies and mechanisms for community awareness while overlooking adaptation actions through physical planning and urban design at the local scale. Perhaps that is why most European municipalities remain unable to approve adaptation plans (Reckien, et al., 2014).

Lastly, the dearth of research methods generates the fourth gap. Context is key for adaptation, hence, adaptation studies consistently recommend context-specific, participatory, and community-based tools for assessing vulnerability and identifying adaptation options. Nevertheless, many documented efforts on adaptation interventions in the planning literature maintain a top-down approach (Davoudi, et al., 2012). More specifically, this paper reveals limitations in the participatory component of adaptation in the planning literature, particularly with regard to the choice of stakeholders engaged in the planning processes. Participants are often limited to government bodies and institutional partners, while excluding other vulnerable stakeholder groups (e.g., Mukheibir & Ziervogel, 2007; Shackley & Deanwood, 2002). In addition, a very small number of planning studies involve participatory methods that seek to identify and acknowledge indigenous adaptation approaches in the planning process. Accordingly, there is an opportunity to identify and integrate indigenous adaptation actions through planning policies and implementations, particularly through green infrastructure at the local scale, by building on Steiner's (2014) suggestion to use case study analyses. Since altering human behaviour could potentially facilitate climate change mitigation, as Brody et al. (2012) examined, altering human actions toward increasing resilience and long term coping ability rather than resisting climatic risks could actually facilitate developing local adaptation plans.

Collectively, these gaps not only inhibit planners from establishing links between urban planning and climate change adaptation but also hinder the implementation of adaptation planning at the local scale. Collaboration, then, becomes essential for bridging the gaps between adaptation policies that are non-structural and those (i.e., structural/physical interventions) that a municipal institution requires. In order to address this shortcoming and also to explore the aforementioned potentials identified in the four gaps, the following research questions have emerged for future studies:

- How can climate change projection/information be better interpreted at the neighbourhood scale? And how may collaborative research among researchers from different fields achieve this?
- How can the participatory approaches of urban planning relate to the community-based approaches that are currently used in climate change adaptation research? How can each of these approaches benefit from the other?
- How can planners operationalize normative, non-structural (non-physical) adaptation studies through implementable interventions in areas that are vulnerable to climate change?
- Once implemented, how can urban planning and design develop methods to assess the progress (i.e., adaptive capacity and/or resilience) of the adaptation measures and interventions in any particular urban system?

These questions highlight the necessity to investigate potential connections between cross-cutting themes and scales not just for advancing adaptation research, but also, for complementing sustainable development while simultaneously balancing adaptation and mitigation. Although the urban planning and design scholars are increasingly aware of climate change adaptation, further integration of this topic is needed in the urban planning and design disciplines, given that the challenges of climate change on urban environments are multi-dimensional, multi-disciplinary, and multi-scale. While establishing the connections between the themes, a priority should also be set for implementing adaptations (i.e., adaptation actions) that are integrated with local development plans (including sustainable development plan for a community). Therefore, the planning literature must exploit all opportunities to address these challenges.

Chapter 3 : Manuscript II

Community-based Adaptation through Ecological Design: Lessons from Negril, Jamaica
[Published in *Journal of Urban Design*]

Abstract

This paper identifies the conceptual similarities between ecological designs and ecosystem-based adaptations to climate change. The former includes approaches grounded in expert knowledge, such as landscape ecological urbanism, while the latter is rooted in local experiential knowledge and relies on community-based adaptations. This paper bridges these expert and experiential knowledge forms through a transactive planning model by deploying design charrettes in the context of Negril, Jamaica. The findings reveal that local people are aware of ecosystems and prefer ecologically sensitive adaptation interventions. This study concludes with planning and design recommendations for climate change adaptation in Negril.

Keywords: Ecosystem-based adaptation, community-based adaptation, ecological design, landscape urbanism, design charrette.

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3.1 Introduction

Global sea levels are expected to rise between 0.45 m to 0.82 m by the end of the twenty-first century (Field et al., 2014). Even with a minimal sea-level rise of 0.5 m, up to 38% of existing beach areas will be lost in the Caribbean region alone (Mimura et al., 2007); hence, placing coastal settlements, livelihoods, and entire ecosystems at risk. Adaptations to these impacts occur at different spatial and temporal scales that range: from hard-engineered solutions to soft ecologically-based ones; from top-down scientific models to bottom-up approaches involving community participation; and from short- to long-term interventions. Large-scale hard interventions have been especially criticized for having indelible impacts on environments and ecosystems that would further reduce the resilience of coastal communities to climate change (Mycoo & Chadwick, 2012). In contrast, ecosystem-based adaptation (EbA), increasingly favoured as providing no-or low-regret adaptation options, capitalizes on natural resources to increase the resilience of human communities in adapting to climate change and simultaneously, advocates the sustainable delivery of ecosystem-related services (Chatenoux & Wolf, 2013). The links between EbA and urban design and planning, however, have been rare if not absent altogether notwithstanding the fact that all the urban design projects that adopt an ecological design approach share similar themes with EbA. Therefore, this paper explores the potential links between EbA and ecological design, particularly through landscape urbanism, which is a notion that considers landscape and green spaces as the fundamental units of (urban) design.

Accordingly, this paper identifies the conceptual links between landscape urbanism and EbA, namely, how they similarly advocate reversibility, biodegradability, and sensitivity to the environment and ecosystems. In recent years, the landscape urbanism discourse has paid more attention to the challenges posed by climate change and to the possible adaptation strategies through ecologically sensitive design. For example, a recent exhibition titled “Rising Currents” at the Museum of Modern Art (MoMA) displayed design proposals by five architectural teams who partook in an architects-in-residence program at P.S.1 Contemporary Art Center (MoMA, 2015). In particular, proposals, such as oyster-tecture[4], address sea-level rise, pollution, and the degraded coastal habitat along New York’s and New Jersey’s coastlines through “soft” infrastructure that prioritizes the ecology – an approach that is similar to EbA. Likewise, a multi-stage regional design competition, “Rebuild by Design”, which was organized by the US Housing and Urban Development (HUD) between 2013 and 2014 and funded by Rockfeller Foundation, addressed resilience for the regions affected by hurricane Sandy (HUD, 2015). The competition underscored five aspects, namely: resilience, climate change, ecosystems, the transformation of cities, and securing livelihoods. The winning proposals, e.g., by Big U, OMA, and SCAPE, encompassed several ecological design strategies, including integrating berms and

[4] Oyster-tecture, a proposal by Kate Orff (a landscape architect at SCAPE), acknowledges the complex biochemical and ecological process within urban ground around Brooklyn's Red Hook and Gowanus Canal. The project aims to nurture an oyster culture to deal with the issues of water quality, rising tides, and community-based development (see TED, 2010).

mashes to protect ocean surges, reef streets–live breakwaters to build ecological resilience, and improving green infrastructure measures to reduce risks from flash floods (Rebuild by Design, 2015). Interestingly, the operational guidelines of EbA, often refer to "soft" adaptation strategies, overlook the literature on urban design, landscape design, landscape ecological design, and urban planning. These guidelines do, however, emphasize public participation akin to the urban planning literature especially that most EbA projects entail community-based adaptation (CBA) – a process that capitalizes on the experiential knowledge of local communities in adapting to climate change. In contrast, the landscape urbanism literature remains mostly grounded in the expert knowledge of landscape architects and has yet to consider public participation that had been established in the urban planning literature since the 1960s.

This article builds on Friedmann's transactive planning model to construct a theoretical framework that combines the experiential knowledge from CBA and EbA, the expert knowledge from landscape ecological urbanism, and the participatory methods of urban planning in order to address climate change adaptation in vulnerable coastal communities. The proposed approach deploys the design charrette, a participatory tool, to operationalize this framework in Negril, Jamaica, a coastal area vulnerable to sea-level rise. In exploring these multi-disciplinary theoretical and empirical links between EbA, CBA, landscape ecological urbanism, and urban planning, this study builds on Frederick Steiner's (2014) recommendation for the development of an integrated approach to address climate change adaptation through design. In particular, this study addresses Steiner's (2014, p. 308) question: "how can concepts such as resilience and green infrastructure be advanced [to] design settlements to mitigate extreme weather events?"

The next sections introduce how CBA and EbA underscore tenets such as community participation, integration of local knowledge, and capitalization of ecosystems – tenets that are then juxtaposed against the discourse on public participation in the urban planning and design literature. A discussion highlighting the links between CBA and EbA on the one hand, and ecological design and landscape urbanism on the other hand, is followed by the theoretical and methodological frameworks. This article then discusses the study's findings and presents concluding remarks.

3.2 Community-based and Ecosystem-based Adaptation

3.2.1 Community-based Adaptation (CBA)

Community-based adaptation (CBA) is an approach based on human rights and represents a new field in development and climate change studies. CBA refers to "a community-led process, based on communities' priorities, needs, knowledge, and capacities", whose objective is to "empower people to plan for and cope with the impacts of climate change" (Reid et al., 2009, p. 13). CBA involves governance, power structures, changes, and uncertainty, while simultaneously considering issues of poverty, vulnerability, and the inequitable distribution of and access to resources. Two key factors dominate CBA: *who* comprises a community, and *where* this community is (Reid & Schipper, 2014). *Who* refers to anyone or any group of individuals affected by the impacts of climate change and, hence, is working with or without external interventions to cope with these impacts. As for *place*, its' scope determines the scale of a community and the extent of this community's vulnerability. CBA also identifies the adaptation priorities by relying on community-based and bottom-up tools. For example, the community-based vulnerability assessment (CBVA) developed by Smit and Wandel (2006) deploys the tools of CBA to identify and document the conditions and risks of communities, and any challenges related to adaptation approaches.

Emerging empirical research on CBA underscores aspects, including social capital and rising social awareness (K. M. Allen, 2006; Plush, 2009), livelihood options (Rashid & Khan, 2013; Wang, Brown, & Agrawal, 2013), and agriculture and food security (Bradshaw, Dolan, & Smit, 2004). Although the Intergovernmental Panel on Climate Change (IPCC) (2014) touts the benefits of deploying CBA for urban development and disaster risk reduction, especially in small islands, thus far the empirical studies based in CBA exclude ecological design and the planning of built environments from their debates. Several CBA studies simply allude to the incorporation of this approach in the design of human settlements. For example, Moser and Stein's (2011) study in Kenya and Nicaragua engaged local stakeholders through urban participatory climate change adaptation appraisals. These appraisals differentiated between asset-based vulnerability and the identification of operational adaptation strategies. In doing so, this study deployed several data-collection tools, including a transect walk, focus groups, and participatory mapping. Similarly, Gaillard and Maceda's (2009) study introduced three-dimensional participatory mapping, using physical models to assess a community's vulnerability. Both studies built on CBVA through developing visual tools. One of the few studies delving into the planning and design of built environments that are adaptive to climate change is Barron et al.'s (2012). This study modeled, visualized, and then evaluated potential flood impacts and adaptation options for the community of Delta in Vancouver's Metropolitan Area. The research team created "visioning packages", which consisted of two- and three-dimensional visualizations for different hydrological scenarios that presented the existing dike infrastructure breaching due to sea-level rise and storm surges as well as future adaptation strategies. Using qualitative and quantitative indicators this study asked citizen groups to assess the performance, policy implications, and social acceptability of the proposed strategies (Barron, et al., 2012). This study commendably incorporated CBA and public participation, but it overlooked the potential benefits of incorporating the ecosystem in the proposed strategies as they are laid out in ecosystem-based adaptation (EbA) and/or in ecological design approaches.

3.2.2 Ecosystem-based Adaptation (EbA)

The Secretariat of the Convention on Biological Diversity (2009) defines EbA as “the sustainable use of biodiversity and ecosystem services into an overall adaptation strategy [that] can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity”. EbA research and practice typically include: i) coastal defence through coastal vegetation maintenance and/or restoration ii) sustainable management of wetland floodplains, iii) natural conservation and restoration of vegetation and forests, and/or iv) healthy and diverse agro-forestry systems (Munroe et al., 2011). EbA ensures participatory decision-making and flexible management at multiple geographical scales and combines the best available science and local experiential knowledge of CBA (Andrade et al., 2011). Perhaps that is why over 60% of EbA projects employ CBA initiatives (Doswald, et al., 2014). Figure 3.1 summarizes the relationship between the different components of CBA and EbA. Like CBA, EbA is a relatively new concept, spearheaded by environmental and biological conservation experts who embrace multidisciplinary, participatory, and culturally appropriate approaches (Andrade, et al., 2011). Furthermore, EbA and CBA seem to be complementary: while EbA underscores reversibility and biodegradability simultaneously with increasing the resilience of ecosystems and humans, CBA identifies people and communities at risk and empowers them to take part in decision-making (Girot, Ehrhart, & Oglethorpe, 2012). Thus, EbA projects rely on local communities and ecosystems, and rank long-term, low-cost, and no-regret adaptation interventions. For example, an EbA project financed by the German Ministry for Economic Cooperation and Development proposed multidisciplinary and context-specific ecosystem-based approaches in the Caribbean region (Chatenoux & Wolf, 2013) that are in line with IPCC’s (2014) recommendations for small islands.

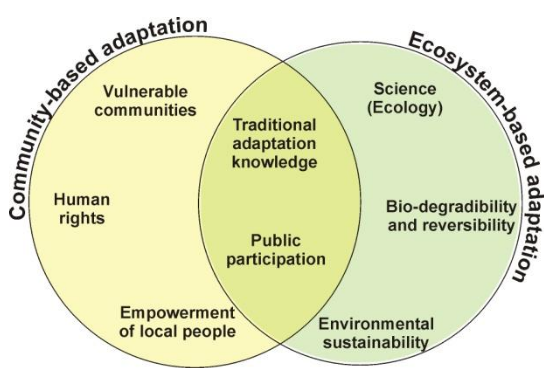


Figure 3.1. The relationship between CBA and EbA

Surely, EbA stands in stark contrast to hard engineering-based interventions that bear immediate and tangible outcomes, and which vary depending on the scale of the interventions. For example, large-scale interventions often involve irreversible engineered structures as protective measures that prevent nature from taking its course, such as seawalls, breakwaters, and concrete groynes.

Typically, these interventions entail a top-down decision-making process as opposed to EbA's inclusive and participatory one. Large-scale projects usually involve large-scale national and international contractors and/or foreign international donors, hence, rarely acknowledge local participation, let alone local technologies or skills (Wisner, Blaikie, Cannon, & Davis, 2004). Accordingly, they bear long-term impacts on ecosystems and on sustainable development (Girot, et al., 2012; Mycoo & Chadwick, 2012). Conversely, small-scale hard engineered interventions, including gabion baskets, soil nailing, ripraps, and surfaces covered with rocks or concrete blocks, are considered reversible. These small-scale interventions can be developed locally, permit natural ecosystem functions, and hold the potential to incorporate EbA approaches and thus may balance human and natural systems.

Moreover, EbA seems to parallel the approaches of ecological planning and design advocated by McHarg (1969) and Alexander (2002), which underscored the interconnection between nature, human-made interventions, and human beings. Certainly, the notions of designing in harmony are not new, and historically, humans have attempted to respond to environmental changes through the built environment. Design ideas, such as ecological fit (Ndubisi, 1997), going with the natural flow and more from less (Ellin, 2013), fluid exchanges between the human-made and natural interventions (Waldheim, 2006a), are but a few examples that highlight this interconnection. These notions deploy ecological standards to assess the degree of interweaving among environmental, cultural, and built systems. In particular, landscape urbanism that combines ecological and landscape design (Waldheim, 2006b) integrates McHarg's ecological advocacy and Corner's urban design vision (Steiner, 2011). Instead of focusing on urban form and function, landscape urbanism underscores the ecological process of landscape and green spaces as fundamental city development blocks that accommodate habitats, programs, and circulation both temporally and spatially (Waldheim, 2006a). Moreover, by advocating indeterminism and flexibility, landscape urbanism actually addresses uncertainty, whether climatic or non-climatic. This open-ended planning and design is also known as the generative process (Hakim, 2007) that incorporates the current needs while accommodating future changes and uncertainty. Clearly, the generative process of landscape urbanism signals theoretical links to EbA although ecological design and landscape urbanism have yet to directly acknowledge climate change adaptation, EbA, and CBA. Similarly, the climate change literature on adaptation, EbA and CBA fails to establish any links to any design disciplines. Lastly, and notwithstanding how landscape urbanism eliminates the isolation of the ecosystems from the human systems, it also overlooks the participatory component of design.

3.3 Participatory Planning and Design

3.3.1 Public Participation

The debates on participatory planning emerged in academic writings in 1960s among various reactions against rational comprehensive planning as an expert-based and goal-oriented approach (Filion, Shipley, & Te, 2007). For example, Davidoff's (1965, p. 332) advocacy planning underscored social justice whereby, in a bureaucratic society "great care must be taken that choices remain in the area of public view and participation". Advocacy planning also contributed to implementing the principles of social justice while challenging neutral objectivity in dealing with social problems (Hudson, Galloway, & Kaufman, 1979). In solving such problems, planners often rely on knowledge through consistency of observation, logic, and theoretical coherence (Friedmann, 1973, 1993). John Friedmann (1973) considered the planners' professional knowledge as "processed" and referred to it as "expert knowledge". He simultaneously emphasized the "personal" or "experiential knowledge" of the constituencies that the planners serve whereby such knowledge reflects these constituencies' experiences of problem solving. According to Friedmann, the experiential knowledge is richer in content than the expert knowledge as it reflects the daily life experiences, though it is less systematized and generalizable than the expert knowledge. In contrast to centered and comprehensive planning, Friedmann (1993) emphasized context-specific and situation-based planning and thus proposed transactive planning that combines both the expert and the experiential knowledge (Friedmann, 1973). This model underscores the mutual benefits of information exchange in terms of public interest (Filion, et al., 2007) and is often grounded in direct participation (Hudson 1979). Indeed, Fainstein (2012) asserts that good planning should simultaneously serve public interests and be guided by experts.

Therefore, the bridging of the two types of knowledge surely advances the planning process and increases its probability of achieving its objectives. The design charrette is one of the tools for bridging the experiential and the expert knowledge. A participatory tool that is borrowed from the design disciplines; the charrette holds the potential to operationalize the transactive planning model by providing a venue for combining the experts' professional knowledge and the locals' experiential knowledge.

3.3.2 Design Charrettes

Design charrettes consist of intensive and time-constrained participatory design activities. Design experts typically serve as facilitators and work with participants representing the various sub-communities, to collectively propose a vision for the community at hand (Girling, 2006). Design charrettes underscore both process and outcome, hence, incorporate three chronological stages: idea generation, decision making, and problem solving (Sanoff, 2000). Each stage involves a series of interactive discussions (dialogue) and design (or drawing) activities. The planning experts' role becomes that of "skilled counsellors", as in collaborative planning, so as to ensure that the process works "with rather than for" the communities (D. R. Godschalk & Mills, 1966, p. 86).

Therefore, this study considers the design charrette as a method of community-based planning and design that provides a common platform for mediating and negotiating between Friedmann's (1993) experiential and expert knowledge. Furthermore, and akin to Godschalk and Mill's (1966) collaborative planning, the design charrette empowers the local communities to present their needs, discuss their interests, and identify their future choices for climate change adaptation. This study maintains that the design charrette simulates and actualizes the "mutual self-discovery" of transactive planning through dialogue and design activities, thereby expanding and discovering participant knowledge (Friedmann, 1973).

Many recommend diverse expertise and backgrounds among participants of environment-oriented charrettes in particular, so as to ensure outcomes that better address the interdisciplinary challenges at hand (Sutton & Kemp, 2006). This approach resonates especially with issues related to climate change adaptation. Furthermore, through empowering communities, the process of mutual self-discovery can be associated with CBA and EbA to assist communities explore various adaptation strategies and identify preferred ones. Figure 3.2 reveals how participation, the key tenet of this process, establishes the conceptual link between the design charrette, EbA, and CBA, and how design charrettes can perform as a tool of transactive planning vis-à-vis climate change adaptation. Thus, design charrettes hold the potential to incorporate transactive and collaborative planning, and to integrate expert knowledge and local experience, while maintaining the significance of the planners' role.

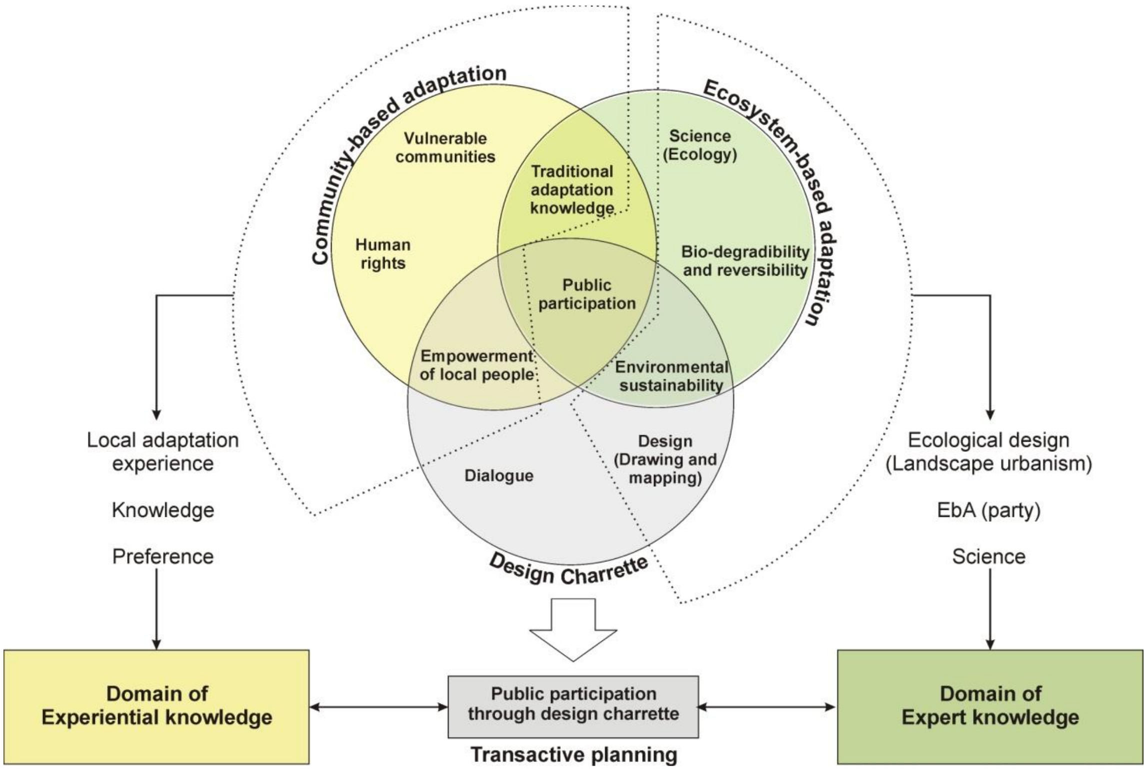


Figure 3.2 The design charrette as a transactive model and its links to EbA and CBA

3.4 The Theoretical and Conceptual Frameworks

Ecological design theories underscore the interventions that integrate environmental and human systems. Such integration theoretically promotes environmental sustainability while simultaneously enabling a system (primarily an environmental system) to cope with environmental change and uncertainty. Similarly, EbA combines science and local experience and incorporates ecology and climate change to identify local natural species–humans excluded–that could potentially adapt to particular climatic impacts of any given area. Based on this scientific foundation, EbA prioritizes small-scale engineering interventions while simultaneously advocating no-regret and reversible strategies that are sensible to the environment and that generate co-benefits. While these principles are in line with ecological design strategies, including landscape urbanism, EbA differs by incorporating local experience, or Friedmann's (1993) experiential knowledge, as an integral component of human systems. Therefore, EbA deploys CBA to identify local expert knowledge and local experiential knowledge that collectively demonstrates vulnerabilities and strengths of local ecosystems, as well as local adaptation experiences and preferences. Accordingly, EbA represents a departure from landscape urbanism's reliance solely on what Friedmann identified as the realm of experts' knowledge–their opinions and on science–to determine the best design options. Furthermore, while landscape urbanism's interventions rely on spatially grounded designs, EbA's interventions can be framed more as courses of action that can potentially integrate spatially

grounded designs. Both approaches underscore similar theoretical/conceptual principles and strategies for enhancing an environment's ability to cope with uncertainty.
Building on these theoretical links, this research utilizes design charrettes with local experts and local communities as a spatially grounded application of CBA. As a participatory tool that offers a platform for dialogue and debate, the design charrette empowers local communities to voice their opinions and identify their choices (Arnstein, 1969), and thus complies with the key tenets of CBA. Simultaneously, the tool conforms to Friedmann's transactive planning model by providing a venue that combines both expert and experiential knowledge (Figure 3.2).

The next section discusses how design charrettes were deployed in this research to operationalize the transactive model while combining EbA and CBA with ecological design.

3.5 The Research Method

To integrate expert and experiential knowledge while ensuring public participation, this study adopted a participatory action research (PAR) approach. PAR ensures active participation of the study community throughout the research process and to pursue solutions to concrete problems (Whyte, Greenwood, & Lazes, 1991). In doing so, this study adopted case study research design to investigate the local communities' awareness of Negril's vulnerability to climate change, and their knowledge of adaptation. A contemporary case study, where researchers have little control over events, provides a distinct advantage for collecting and analyzing empirical evidence (Yin, 1989). In investigating Negril, the research questions–"what" climatic risks occur and "how" the community adapts to the risks–lent PAR malleably to range from an explorative investigation to an explanatory (or descriptive) one.

This research project constituted three major phases: pre-fieldwork, fieldwork, and post-fieldwork. The pre-fieldwork phase, between January and May 2014, concentrated on collecting secondary data, including maps, peer-reviewed publications, newspaper articles, and government reports, and establishing contacts with local institutions and agencies including the University of the West Indies (UWI), Mona Campus; Negril Area Environmental Protection in Negril, Jamaica; and CaribSave, a Caribbean regional not-for-profit organisation. In addition to secondary data sources, these institutions provided local networking and resources, including three graduate students from UWI who partook in the fieldwork. These secondary data informed the design of the subsequent fieldwork phase, which took place in Negril between 29 May and 08 June, 2014. The fieldwork facilitated primary data collection through design charrettes, survey questionnaires, GPS, and field observations.

Firstly, two day-long design charrettes were held in Negril, the first in a local conference hall, with planners, policy-makers, and local activists, who collectively influence policy formation and who shared their "expert knowledge". Of these experts, 17 of 39 were invited through email, phone, and CaribSave to participate in the first charrette. The second was held three days later in a public community center, with members of various local communities invited through posters, leaflets, personal communication, and CaribSave. Twenty local people, including housewives, musicians, and fishermen, participated. Each charrette's focus and invitation methods differed, meaning no participant overlap.

According to Lennertz et al. (2008), charrettes consist of pre-charrette, charrette, and post-charrette events (Figure 3.3). Here, the pre-charrette included groundwork, preparation, and charrette introduction–including charrette objectives, study areas and maps, and participant roles–followed by separating participants into three to four six-to-eight member groups reflecting diverse backgrounds. The researchers shared no specific evidence collected pre-fieldwork with participants, to ensure bias-free discussion. Ice-breaking activities, such as pointing out participants' homes on maps, and sketching and sharing how they experience Negril, helped familiarized everyone with the project and one another, thus, ensuring their engagement and effective contribution. The second phase represented the major exercise for stimulating mutual self-discovery of Friedmann's transactive model to gather, cross-reference, and share information about CBA and EbA. Three to four researchers facilitated each group's discussion, including at least one from UWI, whose presence demonstrated sensitivity toward local socio-cultural values, establishing rapport with locals and constructive dialogue. To ensure internal validity, each group followed the same structure, deployed the same tools, and was guided by the same topics: the major threats posed by climate change, local coping strategies, and possible adaptive strategies. Post-charrette event included managing and synthesising information and disseminating results to participants.

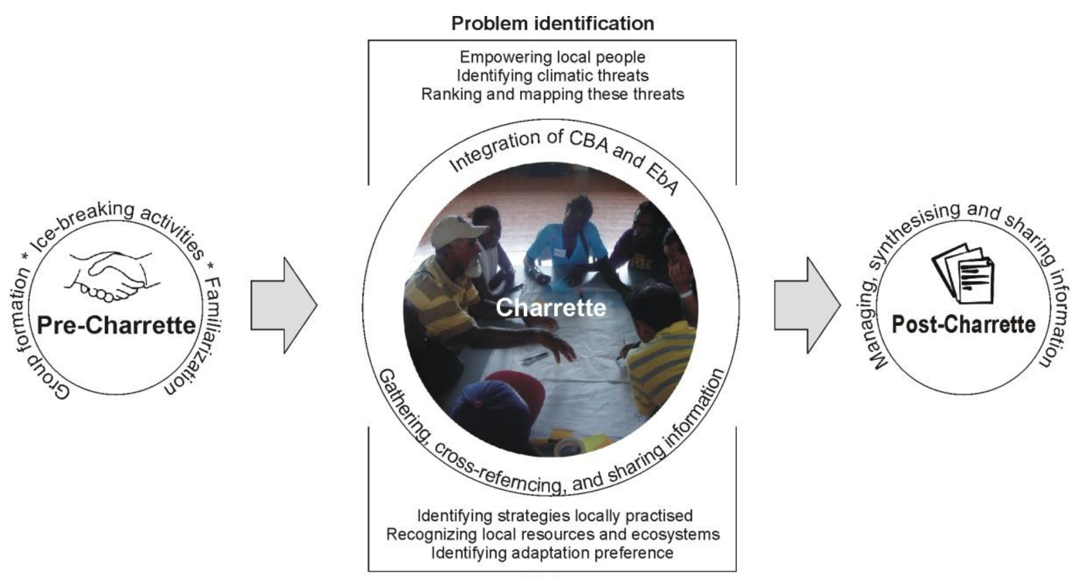


Figure 3.3 The design charrette process and its application in this study

Secondly, questionnaires surveyed local inhabitants' and international tourists' adaptation preferences for Negril's future planning and design. Questions were based on the IPCC's (Dronkers et al., 1990) three basic coastal adaptation strategies: retreat, accommodation, and protection[5]. Respondents were provided with two design options for each of the latter two–one hard engineering-based and the other soft ecosystem-based (see Appendix A). Retreat had one choice: coastal set-back. Thus, respondents were offered five options (i.e., retreat, accommodation-hard and soft, and protection-hard and soft) and asked to rank their preferences. In total, 151 questionnaires were conducted in person (i.e., N=151), 97 with locals and 54 with tourists, at different times and locations, including the downtown, streets, beaches, villages, and the charrette venues. Overall, respondents were generous, providing a wealth of qualitative comments about adaptation strategies.

Thirdly, devices, including GPS and measuring tapes, were used to collect data for 19 sections along Long Bay (from north to south), identified in the literature as Negril's most vulnerable area. Long Bay is generally low-lying, but its elevation slightly varies making some parts, including buildings, more vulnerable to sea-level rise, flood-surge, and flash flood. Thus, for each section, several data points (from west to east), such as the high-water mark, building edges, and the highway, were set to measure their distances from the high-water mark and elevations relative to their mark. To avoid instrument errors, three different GPS devices were simultaneously used for each data point.

Lastly, photography documented direct observations of the landscapes, buildings, infrastructure, and ecosystems of Negril area. This research entailed dividing the study area into segments, walking along each segment, and photo-documenting it while taking detailed notes along the way.

3.5.1 Data Management and Analysis

The design charrettes yielded the study's largest and most significant data which were organized by several data collection and management strategies, including layered maps and information, flip charts, post-it notes, and colour coding. First, each group used a standard base map, which was layered and topped with sequentially numbered trace-paper sheets as required. Colour coding was kept consistent along all media. For example, red consistently represented major climatic threats, whether on a map, chart, or post-it note. Immediately after each charrette, the visual data were transcribed into diagrams using relevant software (e.g., Adobe Illustrator, ArcGIS, and AutoCAD), while the textual data from the flip charts, post-it notes and discussion notes were transcribed into text. To transcribe the visual data and support data analysis, a uniform and simplified graphical language was used to standardize charrette outcomes. Significant amounts and different types of qualitative charrette data from each layer were then

[5] *Retreat* involves no effort to protect the land from the sea. The coastal zone is abandoned and ecosystems shift landward. *Accommodation* implies that people continue to use the land at risk but do not attempt to prevent the land from being flooded. *Protection* involves hard structures such as sea walls and dikes, as well as soft solutions such as dunes and vegetation, to protect the land from the sea so that existing land uses can continue (Dronkers, et al., 1990, p. iv).

analysed using visual transcriptions, layered maps, and symbols portraying vulnerabilities and solutions. Lastly, the data obtained through the survey questionnaires and the GPS surveys were organized into spreadsheets. Simple statistical methods were used to analyse the survey data to compare preferences among different adaptation options and between locals and tourists. GPS data were processed through GIS to obtain and analyse the different section elevations.

3.6 Negril, the Case Study

This study's participatory approach investigates Negril's climatic risks and the local adaptation responses – an approach that renders this investigation an exploratory case study with an explanatory component to it (Yin, 1989, 2011). Among the most popular Caribbean tourism destinations, Negril, located on Jamaica north-west coast, has been designated the Negril Environmental Protection Area and Marine Park. Negril is Jamaica's third largest tourist resort after Ocho Rios and Montego Bay, but generates more income than either of them (Otuokon, 2001). Jamaica's economy relies heavily on tourism, and Negril's tourism industry alone contributes approximately 5.5% to the national GDP (UNEP, 2010b). Nevertheless, like other Caribbean coastal-regions, Negril is at risk, particularly to beach erosion. Estimates forecast that only one meter of sea-level rise would fully or partially damage 29% of Caribbean coastal resort developments of which nearly 55% are under threat of beach erosion (Scott, Simpson, & Sim, 2012).

These estimates are troubling, especially given that over 50% of the Caribbean's population resides within 1.5 km from the shoreline (Mimura, et al., 2007) and nearly 82% of Jamaica's population in particular resides in coastal settlements (Ishemo, 2009). Thus, Negril's coastal communities and tourism infrastructure are highly vulnerable to sea-level rise and any associated impacts.

3.7 Negril's Vulnerability and Adaptation Options

Negril's most dense and vulnerable built-up area is Long Bay, situated on a narrow strip along a seven mile beach, and defined by the sea and the great morass (Figure 3.4). This morass covers over 5,500 acres and accounts for 20% of Jamaican wetlands. It is a major resource of herbaceous marchlands, swamp, mangrove, and other lowland forest. Additionally, it protects a number of species and local ecosystems (Town and Country Planning Development Order, 2013). The built environments, the morass, and the entire ecosystem are highly exposed to coastal inundation and sea-level rise. This study pays particular attention to Long Bay and considers the entire ecosystem of Negril. Using primary data, the following sections discuss the different climatic threats and preferred adaptation practices for Negril, before concluding with design and policy recommendations.

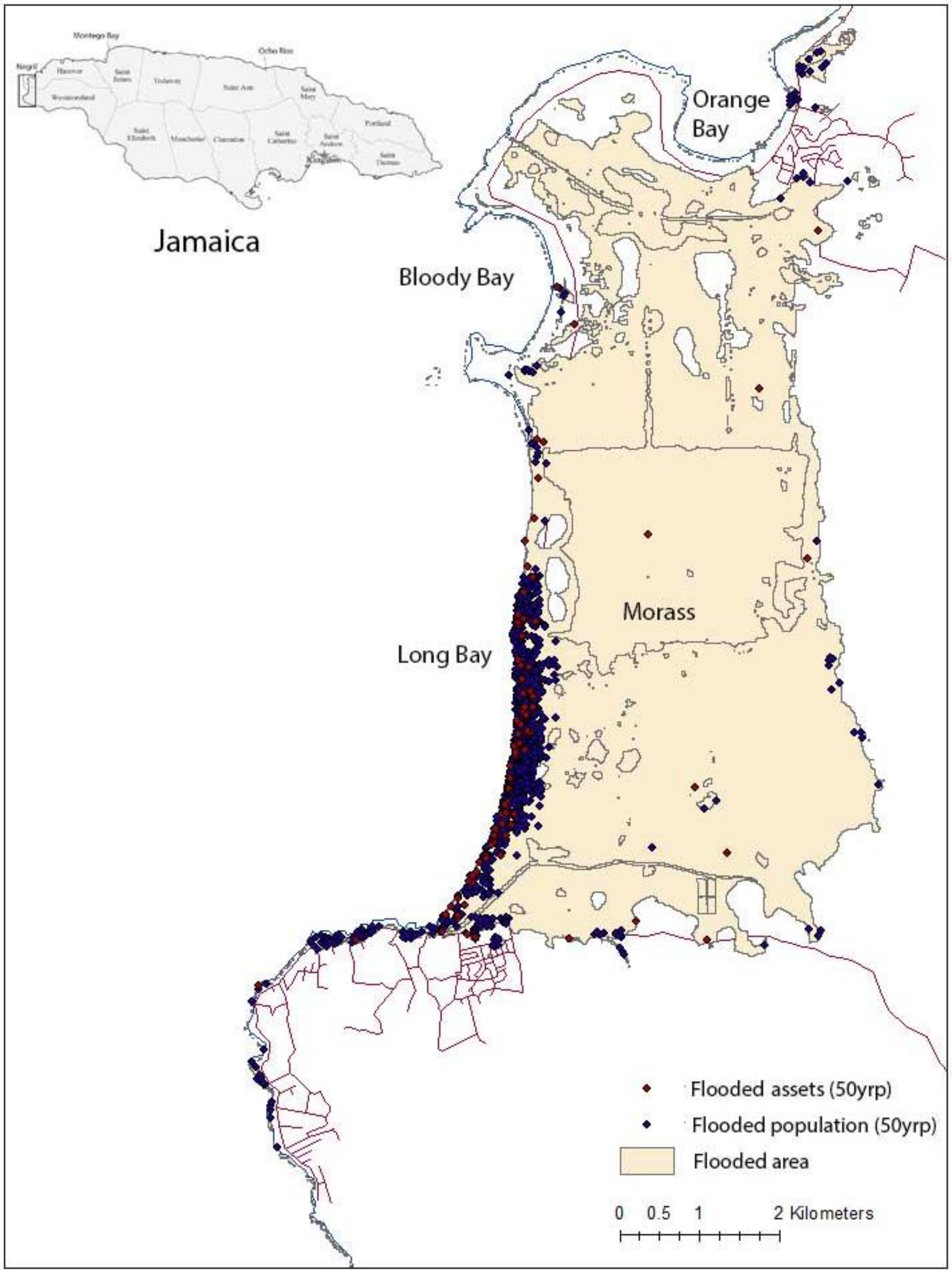
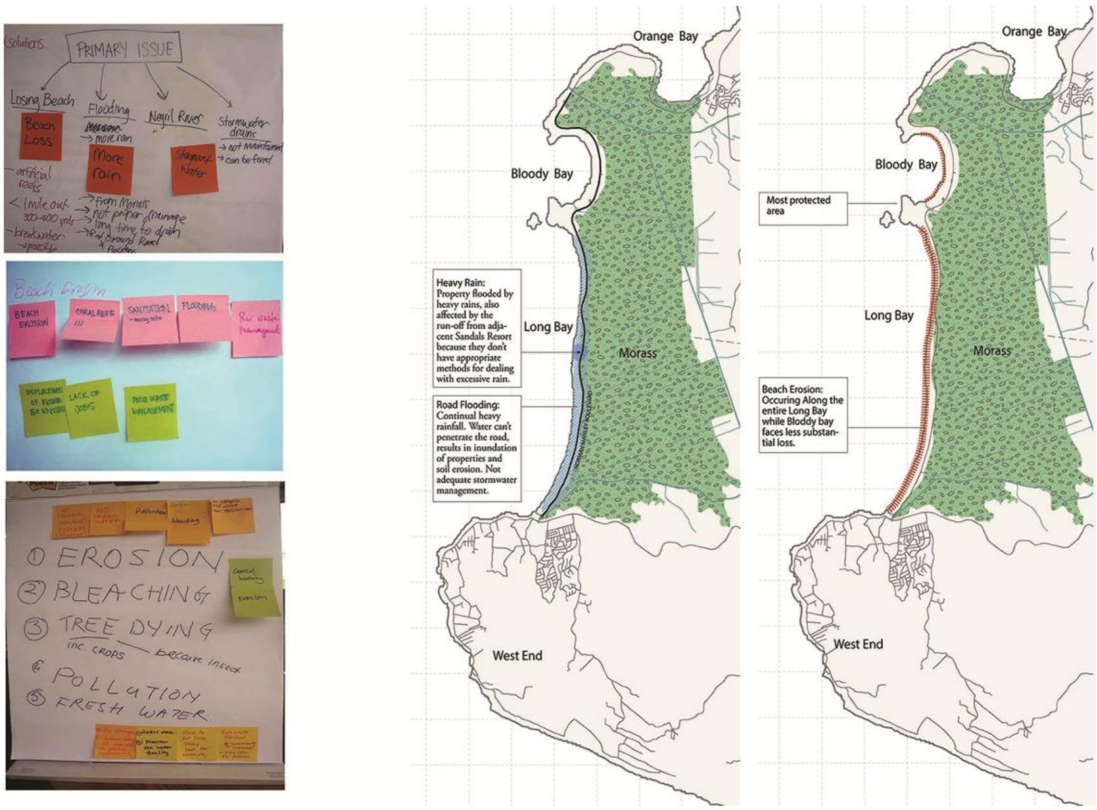


Figure 3.4 Long Bay and its linear pattern of coastal development (Data source: RiVAMP)

3.7.1 Threats to Negril

Beach erosion is considered a natural phenomenon; however, the charrette discussions revealed that Negril's sand production is low, partially because of damaged ecosystems, particularly seagrass. These conditions help identify beach erosion as a major threat (Figure 3.5 a). Over the past 30 years, the average rate of erosion has been one to two meters per year (Veira, 2014). According to Robinson, et al. (2012), if this rate continues, and combines with anticipated sea-level rise, 6 to 10 m beach erosion will occur by 2030, and 12 to 21 m by 2050.



a) Identification of threats b) Mapping beach erosion

Figure 3.5 Beach erosion, the key threat to Long Bay

Long Bay, a low lying region, has been experiencing relatively higher rates of erosion than neighbouring areas. Many charrette participants identified the middle to north of Long Bay as more vulnerable; however, others considered the entire area vulnerable (Figure 3. 5 b). GPS data also revealed that vulnerability varies spatially across Long Bay due to differences in elevation and slope. Accordingly, four zones (A, B, C, and D) were identified along Long Bay (Figure 3.6). Zone A represents scenarios when the highway, Norman Manley Boulevard, lies at the same or lower elevation than the current high-water mark (the point of reference). B represents where the highway lies 0 to 2.5 m higher than the point. Similarly, C and D represent scenarios where the highway is positioned at least 2.5 to 5 m, and over 5 m, respectively, above the reference point. To assess and compare the vulnerability of these zones, this research juxtaposes these scenarios with 2100 estimations of sea-level rise and storm surges, such as IPCC's (Mimura, et al., 2007), Jevrejeva et al.'s (2010), and Vermeer and Rahmstorf's (2009), as well as recent experiences of local people. Findings reveal that areas in zone A will be submerged with even 0.58 cm sea-level rise, while D is relatively safe compared to others (Figure 3.7). Northern parts of Long Bay (zone A, the area near the hotel, Beaches) are particularly vulnerable, and include identified hot-spots that have historically lost beach cover and are inundation-prone when direct rainfall combines with sea-level changes (E. Robinson, et al., 2012; M. Wilson, et al., 2014).

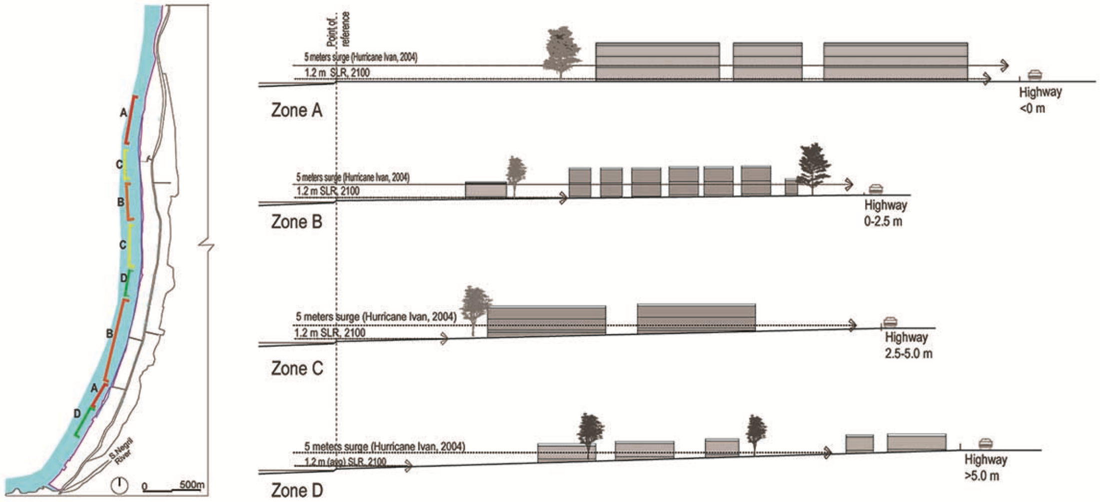


Figure 3.6 The four vulnerable zones at Long Bay

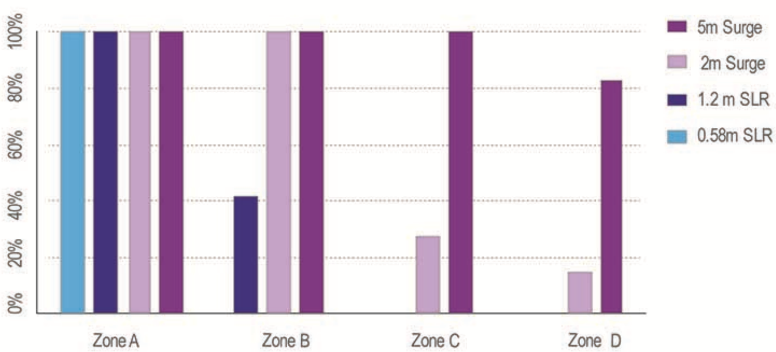


Figure 3.7 The degree of vulnerability at different zones

In addition to beach erosion, the charrette exercises identified degradation of reefs, seagrass, and mangroves; water scarcity in dry seasons; poor waste management, and flash flooding and runoff as secondary threats. During charrettes, local people shared their experiences of extreme flash flooding due to 2010’s heavy rain that inundated the entire Negril area for 10 days. Local professionals and environmentalists blamed anthropogenic actions, such as water pollution and poor waste management, which are indirectly affecting coral reefs, seagrass, and ecosystems. For instance damage to coral reefs increases wave energy and beach erosion. Charrette participants also agreed with what the Negril Area Environmental Protection Trust (2010) concluded– the morass is slowly drying out, resulting in the loss of its basic functions, including flood alleviation, and filtering of nutrients and chemicals. Furthermore the overuse of resources, illegal farming in the morass, and deforestation are also increasing vulnerability of Negril's ecosystems.

Observation and GPS data revealed that buildings along Long Bay are also exposed to climate change because of their proximity to the sea. For example, the hotel Lazy Day's permanent structures are located only 10 m from the high-water mark, far short of the 45.75 m legal minimum coastal setback. Apart from setback regulations, many buildings in Long Bay rarely follow the standards for flood and surge prone areas set by the Office of Disaster Preparedness and Emergency Management, Jamaica (ODPEM, 2015). Typical coastal settlements in the Caribbean, including Jamaica, hardly follow planning and land use guidelines (Ishemo, 2009; Lewsey, et al., 2004). Overall lack of awareness of the implementation of planning guidelines elevates vulnerability.

3.7.2 Local Adaptation Strategies and Preference

The design charrettes and observation revealed that Negril has adopted various proactive adaptation strategies, ranging from individual to regional projects, to reduce beach erosion. Examples at the project scale include coral reef restoration (by Sandals Resorts), the use of sand bags and gabion baskets (by Hotel Lazy Days), and increasing vegetation such as coconut trees (by Charela Inn Hotel) (Figure 3.8). At the community scale, Orange Bay, a fishing village that has experienced over 12 m erosion in recent decades, has been restoring mangroves to reduce impact through CBA (Figure 3.9).

An example of a regional scale project includes a proposal for off-shore submerged breakwaters, 3600 m in length, a highly engineered and top-down planned adaptation strategy for Long Bay. Mondon and Warner's (2012) study confirmed how effectively the breakwaters would imitate nature in reducing erosion. The project exemplifies a centralized planning initiative that will be near-impossible to revise once implemented. Participants, particularly in the first charrette, raised strong opposition to the proposal due to its irreversibility and potential impacts on Negril's environment, marine ecosystems, and tourism development. Local media, such as Serju (2014), also reported this perspective; however, the Government is still pressing for approving and implementing the project (Saunders, 2015). At the same scale, for managing inland flood and storm water, soft infrastructural measures, including vegetated ditches and drains, are employed along the highway. The existing ditches mostly along southern Long Bay have adequate depth and width; however, in the vulnerable north and middle sections, ditch continuity and uniformity are often disrupted. Improving eco-infrastructure integrated with new and existing ditches is important to reduce the vulnerability of these sections to heavy rain and flood.

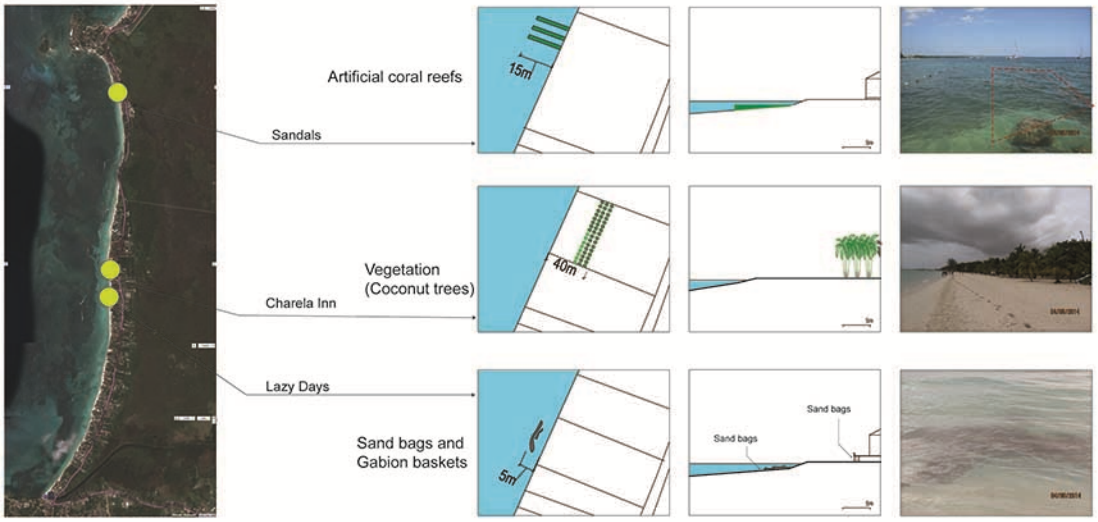


Figure 3.8 Local adaptation strategies along Long Bay

Figure 3.9 Mangrove restoration, a CBA approach in Orange Bay

Survey questionnaire results reflect an overall preference for soft adaptation strategies (Figure 3.10 a & b). Specifically, for Long Bay, locals preferred soft protection and retreat strategies, while tourists preferred soft accommodation and retreat strategies. Referring to soft interventions by neighbouring countries like Cuba, charrette participants discussed beach nourishment because it would provide additional room to adjust current setback deficiencies. In fact, there is insufficient room for future development on either side of the highway; however, about 77% of locals and 44% of tourists still prefer retreat as a feasible option for Long Bay. Additionally, respondents' qualitative comments and charrette discussions reveal that it is too late for retreat; however, increasing density of development away from the coast as much as possible could work. In fact, this proposal for densification and intensification along Long Bay is similar to Robinson et al.'s (2012) suggestion. Participants strongly opposed large-scale hard engineering and centralized interventions, due to their possible negative impacts on local ecosystems, as discussed by Mycoo and Chadwick (2012) in Barbados. Conversely, locals preferred decentralized systems that are easy to build and maintain, and use local resources, thus integrating CBA and EbA. For example, the resort, Rock House uses solar panels as an alternative and decentralized energy source that can still run if the central system fails. Rainwater harvesting at the household level, as one charrette participant already practices, can also meet water demands in dry seasons, bypassing the central supply.

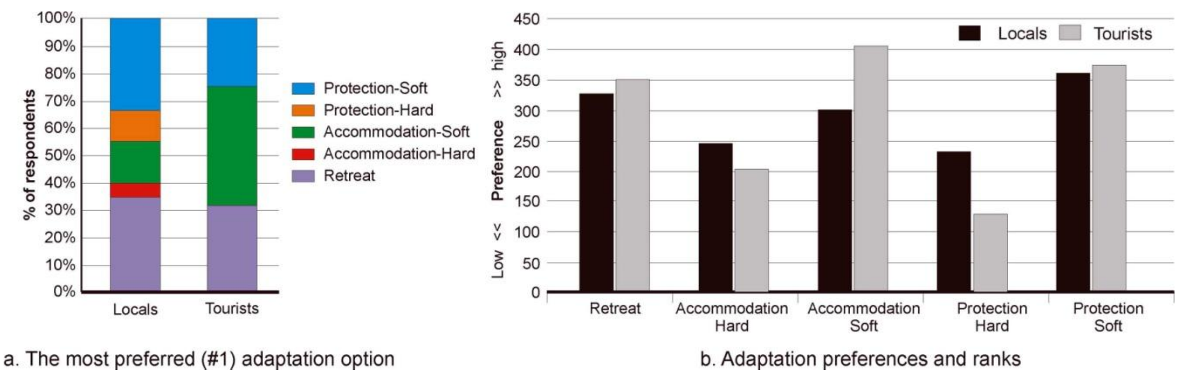


Figure 3.10 The adaptation preferences of the locals and the tourists in Negril

This empirical evidence exhibits preferences for soft adaptation or EbA interventions including small-scale engineering interventions whether through government, CBA, or individual attempts, due to their reversibility and their minimal environmental impact. Both locals and tourists are sensitive to the need to preserve the environment and the local ecosystems while enhancing tourism development and the local economy. As beach-tourism is becoming increasingly challenging due to sea-level rise, charrette discussions highlighted alternative tourism (eco-tourism) to support local livelihood. For example, Negril's Royal Palm Reserve Park and the morass itself used to serve tourists for many years but the lack of integrated planning and infrastructure currently hinders alternative exploration. Figure 3.11 shows an abandoned tourist center in the morass. The Town and Country Planning Provisional Order (2013) for Negril also promotes eco-tourism and man-made historic features while restricting further development on the protected morass and maintaining healthy environment and ecosystems. However, the Order omits local adaptation strategies, particularly EbA, now in practice.

Figure 3.11 An abandoned tourist center in the Great Morass near Royal Palm Reserve Park

3.7.3 Possibilities and Opportunities

The findings parallel arguments posed by ecological design (e.g., landscape urbanism), EbA and CBA, while ensuring effective public participation through the transactive planning tool, design charrettes. Based on these findings, the following recommendations are intended to inform future planning and design for Negril's built environments in the age of climate change.

1. *Integrated coastal adaptations strategies* are essential to reduce Long Bay's beach erosion. These strategies seek to enhance natural adaptive capacity by rejuvenating marine ecosystems through long-term EbA. Restoration of coral reefs, mangroves, and sea grass might be prioritized. Set-back regulations, beach nourishment, and/or combined with low-impact hard protection measures can be considered.

2. *Situation-specific land use planning* could minimize secondary threats, such as water pollution, that severely impact Long Bay when combined with climate change. Specifically, land use planning could control anthropogenic activities along the South Negril River (e.g., repairing of fishing boats) and around the morass (e.g., illegal farming) to reduce run-off pollutants, such as oil and fertilizers/chemicals, that ultimately impact marine ecosystems.

3. *Bio-degradable and reversible adaptations* are locally preferable and are advocated by landscape urbanism and EbA. Reversible and adaptable strategies promote efficient resources use–an important consideration given the uncertainty of climatic data.

4. *Landscape as eco-infrastructure* can preserve ecosystems and thus, facilitate EbA. Negril's physical infrastructure, for example, could incorporate new ditch or bioswale designs, according to the different vulnerable zones (Figure 3.6), along the highway integrated with existing ditches to reduce surface runoff and pollutants from entering the sea.

5. *Decentralized systems* can reduce climatic impacts during emergencies. These systems might include cluster-based and modular systems of built environment and infrastructure design, for example, the decentralized power system by Rock House.

6. *Eco-tourism* could provide economic activities additional to existing beach tourism. Negril hosts protected wetlands and marine parks and is in a good position to promote eco-tourism, as the Town and Country Planning Order for Negril has advocated.

3.8 Conclusion

Unplanned interventions and climate change are affecting the interconnection between environmental and human systems at different scales. Locals and tourists are aware of this interconnection and socio-culture values that distinguish Negril as unique and distinct from neighbouring tourism destinations (e.g., Cancun's high-rise resort development). Every area is unique in terms of its exposures to climate change and indigenous adaptation strategies using local experiences and ecosystems. The major objectives of EbA and CBA are to offer adaptation interventions that are culturally and environmentally appropriate. Additionally, landscape urbanism holds the potential to promote context-specific design but does not necessarily incorporate experiential knowledge. Including EbA incorporates human experience in landscape urbanism while advancing proactive adaptation though ecological design.

The planning and design of costal developments and infrastructure in small island developing states like Jamaica should utilize local resources in ways that are reversible and sensitive to local ecosystems and that can pre-emptively adapt to climatic change. This proactive adaptation requires an integration of inputs from different professionals–planners, environmentalists, and climate change experts–and the nuanced knowledge and experience of locals. A design charrette, as a transactive planning model, incorporates local experiential knowledge though bridging EbA and CBA. Thus, the model can be applied to identify and recognize locally appropriate and preferred responses (particularly, design responses) to climate change. Although the recommendations made here are site-and context-specific, their underlying concepts, including reversibility, modularity, and eco-infrastructure, can be applied to other coastal areas, once the input of local communities is obtained. The model can be further used to effectively apply the concepts to a particular context, not only allowing stakeholders' such input and defining the ecological design strategies, but also helping policy makers govern them. Synthesis of expert and experiential knowledge is essential to integrating CBA, EbA, and ecological design while advancing landscape urbanism to link to climate change adaptation. The design charrette is a worthy tool in achieving these objectives.

Chapter 4 : Manuscript III

A Multi-scale and Multi-dimensional Framework for Enhancing the Resilience of Urban Form to Climate Change

[under review in *Urban Climate*]

Abstract

Both the planning and climate change literature highlight the concept of resilience to facilitate long-term adaptation strategies. Decades before the onset of climate change science, the concept evolved in the urban planning and design literature to deal with uncertainty albeit using various notions analogous to resilience. This paper argues that these concepts, including their underlying theories, hold the potential for application in the context of climate change adaptation; however, they yet remain isolated from the mainstream resilience and climate change discourses. Upon reviewing such concepts that have been cultivated in the planning and design literature since the latter half of the 20th century, this paper proposes a theoretical framework for urban design to better understand the links among the climate change adaptation, resilience, and urban form. This paper uses urban morphology, a study of urban form representing its physical, spatial, and functional characteristics and its changes over time, to establish these links. Finally, the framework includes a set of urban design variables that could potentially influence the resilience of urban form hence are proposed to measure its resilience to climate change.

Keywords: Climate change adaptation, resilience, and urban form and design.

4.1 Introduction

Resilience is a socio-ecological concept that determines “the persistence of relationships within a system and is a measure of the ability of the system to absorb changes of state variables, driving variables, and parameters, and still persist” (C.S. Holling, 1973, p. 17). Accordingly, a resilient system underscores non-linear dynamics, thresholds, uncertainty, surprise, and most important, holds the potential “to create opportunities for doing new things, for innovation, and for development” while responding to shocks such as those caused by climate change (Folke, 2006, p. 253). Hence, in the field of climate change, operationalizing resilience might be a possible way to capitalize on the beneficial opportunities of climate change adaptation actions–hitherto an unexplored area of adaptation research. Nevertheless, thus far, scholarship that underscores the relationship between adaptation/adaptive capacity and resilience remains limited (McEvoy, Fünfgeld, & Bosomworth, 2013; B. Smit & Wandel, 2006). In other words, the resilience knowledge domain is weakly linked to the adaptation and to the vulnerability domains (Janssen, Schoon, Ke, & Börner, 2006). In the planning literature, the emergence of resilience in relation to climate change adaptation is recent, and many consider resilience as a bridging concept between urban planning and adaptation (Davoudi, et al., 2012). Particularly, in the realm of urban design, resilience potentially allows the built environments to be transformed incrementally so as to adapt to and cope with natural disasters and their resulting uncertainty (Lennon, et al., 2014; León & March, 2014).

The concept now known as resilience is analogous to several key ideas, such as alternative stable states, transformability, adaptability, and flexibility, and opposed to rigidity, stability, and permanency, in many disciplines (Beatley, 2009; Davoudi, et al., 2012; Gunderson & Holling, 2002; B. Smit & Wandel, 2006). This paper argues that resilience, along with these analogous notions, evolved in the planning and design literature decades ago independently of climate change scholarship to deal with uncertainty – albeit uncertainty that is not necessarily posed by climate change, but by socio-economic and cultural changes, technological up-grading, and personal preference. Evidence existed even in the early 20th century, for example, Le Corbusier’s Maisons Domino in 1914 (Priemus, 1993), but mostly since the post-modern period. Depending on the scale of the shocks, a complex urban system may derail toward an unknown trajectory (Grinberger & Felsenstein, 2014).While exploring the potential opportunity of such an urban system, these notions promote the innate ability of built environments in terms of their design for transforming incrementally as they respond to shocks, disturbances, and unknown future circumstances – whether or not posed by climate change. However, the ideas and their potentials have to date been isolated from the mainstream resilience and climate change discourse. Thus, this paper highlights the design concepts along with their underlying theories that shape urban form and that simultaneously enhance its resilience to climate change and decrease its resulting uncertainty.

To date, and in order to address the increasing impacts of climatic change and uncertainty, the planning and design of new urban developments often rely on climatic scenarios that have been projected by various climate models. In doing so, two key problems manifest: the disjunction between what these models render and what decision-makers require, including precise projections of the magnitude and the frequency of extreme events, and also the uncertainty associated with climate change models because of approximations, inadequacies, or errors (Collins et al., 2012; Hallegatte, 2009). While ongoing improvements in climate modelling and associated downscaling techniques hold the potential to address the former, the second remains more challenging. A real risk of confusion between past evidence and predictive model outputs is amplified by climatic uncertainty. Thus, the ambiguity of existing information along with its multiplicity of meanings to understand a situation falls in the realm of uncertainty (Grote, 2009). The degree of this uncertainty is further intensified when combined with the impacts of climate change and with the complex interactions within an urban area between its bio-physical agents (e.g., local geomorphology, climate, and natural disturbance) and human agents (e.g., individual choices and actions) (Alberti et al., 2003). Additionally, the Intergovernmental Panel on Climate Change's (IPCC) 5th assessment report on urban areas revealed that inadequate knowledge about the vulnerability, uncertainty, and adaptive capacity of urban built environments to climate change hinders developing the appropriate adaptation responses needed, whether in terms of new or retrofitted systems (Revi, et al., 2014). In the age of climatic uncertainty, resilience also highlights flexibility and transformability of city infrastructure to cope with the unknown future.

The IPCC's expert recommendations call for incremental and transformative preparedness would provide opportunities for urban adaptation and may also reveal trajectories toward sustainable and resilient development (Revi, et al., 2014). However, when implementing such a new concept through urban design, Costa, et al. (2014) identify two distinct challenges that cities face: the first relates to achieving incremental preparedness of the existing urban landscape while the second refers to having limited opportunities to adding new urban forms and to adapting the existing ones. Thus, questions arise with regards to how well our city forms are prepared or are resilient to withstand the impacts of climate change and to be changed incrementally toward an unknown trajectory. More specifically, how does the design of urban form influence this resilience and accordingly, what are the design variables that enable us to measure and/or assess this transformative capacity and resilience of urban form? And last, how do we deploy these variables to achieve such purposes?

To explore these potentials and to investigate the aforementioned questions, this paper first discusses resilience, its various analogous concepts, and its theoretical underpinning cultivated in the urban planning and design literature since the post-modern period (i.e., the late 20th century). Then, it discerns the concepts that lead to devising a theoretical framework for resilient urban form at the neighbourhood scale according to which a conceptual framework identifies the associated (urban) design variables and measures. In doing so, this paper deploys urban morphological research that consists of the town plan, the three-dimensional built form, and the patterns of land use whereby the town plan itself is composed of the street network, the blocks and parcels, and the building footprints. Urban morphology, as a unit of (urban) design[6], provides an essential foundation to understand the structures and complexity of built environments as well as to create, transform, and manage urban forms over time (Kropf, 2011; Marshall & Caliskan, 2011). Thus, such a study of transformability offers a wider scope of resilience and its applicability at the community level so as to establish the links between the design of urban form and its potential to deal with uncertainty relative to climate change. The contribution of urban planning and design literature to the scholarship on adaptation to climate change scholarship has, so far, been limited. The proposed framework and its operational variables enable researchers, policy makers, and design professionals to measure and/or assess the resilience of existing urban forms and, by consequence, facilitate either the incorporation of new or the retrofitting of existing urban forms in the process of adapting to climate change.

The following sections first present an overview of the resilience concept and then highlight its links to climate change adaptation and adaptive capacity in relation to the urban planning and design. Then, the paper discusses the different concepts of resilience in the urban planning and design literature since its emergence in the 1970s before offering the theoretical framework and the ensuing design variables that influence the resilience of urban form.

4.2 Understanding resilience and its link to planning and design

4.2.1 Resilience and its contemporary discourse

C.S. Holling's (1973) seminal work *Resilience and Stability of Ecological Systems* is often considered to be the beginning of the concept of resilience and its application to the natural and social systems. Our review of the literature on resilience yields several observations. First, there are three types of resilience identified in the literature – engineering, ecological, and evolutionary resilience, and second, these types are concerned with both the time and the process of absorbing shocks. The following discussion, along with Table 4.1, underscores their characteristics and differences.

In general, resilience highlights a system's ability for self-organization, renewal and development. The climate change literature defines resilience as "the ability of a social or ecological system to absorb disturbance while retaining the same basic structure and ways of functioning, the capacity for self organization and the capacity to adapt to stress and change" (IPCC, 2007, p. 880). The underpinning notion of the IPCC's definition focuses on resistance to disturbance and the system's innate property of bouncing back to a state before external stress.

[6] By definition, urban morphology facilitates the study of the composite nature of urban form. Urban morphology, similar to "morpheme" in linguistics, includes the smallest meaningful and undividable units of a form-composition (Guney, 2008; Marshall & Caliskan, 2011).

This definition is similar to what Holling (1973; 1996) calls *engineering resilience*, often claimed as “bounce-back”, which highlights a system’s ability to return to equilibrium or a steady-state after a disturbance. Thus, this form of resilience includes planned approaches that enable a system to return back to its previous state while dealing with a disturbance. In contrast, the *ecological resilience* of a system highlights the innate potential to self-organize, learn, and adapt while simultaneously absorbing disturbance and undergoing change (W Neil Adger et al., 2011; Turner, 2010). Additionally, ecological resilience still facilitates retaining the same function, structure, and identity of the system (C.S. Holling, 1996; Walker, Holling, Carpenter, & Kinzig, 2004, p. 33). For resilience to evolve from an innate and inherent quality into an intentional and planned practice, Wu and Wu (2013) argue that it hinges on addressing ecological rather than engineering resilience. Manyena, et al. (2011) call this form of resilience “bounce-forward” that advocates the transformative changes led by affected communities, after a disaster for example, and that believes in multiple equilibria of a system.

The third type, *evolutionary resilience*, challenges all ideas of equilibrium and accedes that the nature of a system might change over time with or without external disturbance (Davoudi, et al., 2013; Davoudi, et al., 2012). It focuses on Folke’s (2006) evolutionally perspective of a socio-ecological system, and multiple and ever-changing processes rather than on a single state, thus we dub it “transform-forward” (Table 4.1). Thus, Folke (2006, pp. 253-254) highlighted the ability for transform and for “renewal, re-organization and development”. The idea has a strong foundation in ecological resilience, as they both assume the existence of multiple stable states–“basins of attraction, multiple equilibria, or regimes” (Wu & Wu, 2013, p. 214).

Table 4.1 *Types of resilience and their characteristics*

Resilience types	**Purpose/objectives**	**Focus**	**Responding to**
Engineering resilience (bounce-back)	Maintains efficiency of function	Efficiency, consistency, predictability	External disturbances
Ecological resilience (bounce-forward)	Maintains existence of function	Persistence, change, and unpredictability	Internal and external disturbances
Evolutionary resilience (transform-forward)	Maintains the ability to change	Persistence, adaptability, and transformability	With or without any disturbance

The IPCC (Revi, et al., 2014) and Lennon, et al.,(2014) also highlight the ability of incremental transformation, similar to evolutionary resilience, that portrays significance in meeting the climatic uncertainty and complexity in urban areas. Moreover, the recent discourse of resilience addresses the holistic ability of a system to cope with disturbance, uncertainty, and ever-changing processes of a society, whether or not challenged by external stresses or climate change. Patron (2006, p. 8) uses resilience as a measure of “how well people and societies can adapt to a changed reality and capitalise on the new possibilities offered;” the latter is consistent with the IPCC’s definition of adaptation. Thus, resilience is more concerned with the “time” required for, and the “process” of, reorganizing a system to settle and function as desired, not necessarily as before, and to cope with ongoing changes while exploiting new opportunities. This current paper considers Patron's measure and different concepts of resilience discussed in design and planning literature to propose the framework that can assess the ability of this ever-changing transformative process of urban form through design.

4.2.2 Adaptive capacity and resilience

The term adaptation, which originated in the natural sciences, particularly within evolutionary biology, refers to the genetic or behavioural characteristics of organisms by which they cope with environmental changes and uncertainty over time to survive and reproduce (B. Smit & Wandel, 2006, p. 283). The climate change literature defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits opportunities" (IPCC, 2001b, p. 365). Although discussions on climate change adaptation emerged in the planning discourse less than a decade ago, several similar concepts, such as adaptability and flexibility, have existed in the planning and design literature for decades. Based on our understanding of the scholarly writings (e.g.,Friedman, 2002; N.J. Habraken, Boekholt, Dinjens, & Thijssen, 1981; Leupen, 2006), we define adaptation in urban planning and design as the inherent physical characteristics of a system (e.g., a building and infrastructure) guided by this system's physical planning and design by which it copes with changes and uncertainty over time. This coping mechanism allows the system to incrementally transform to address climatic or non-climatic changes (but mostly non-climatic). Thus, adaptation in the urban planning and design literature focuses more on survival mechanisms as a pre-emptive approach to coping with an unknown future, akin to adaptation in the natural sciences, while optimizing the use of resources. Adaptation to climate change is well established and one of the key concepts reviewed by the IPCC. While adaptation has been considered at various scales, adaptation scholarship frequently priorities locally-based action: local and place-based planning play a significant role in achieving successful adaptation (R. Klein, et al., 2007; Measham, et al., 2011).

In the human dimensions of the climate change scholarship, adaptation is intimately associated with adaptive capacity and vulnerability. Adaptive capacity refers to a system's (e.g., a community) ability to adapt to the impacts of climate change, and the latter means a system's susceptibility to cope with the impacts of climate change. The IPCC (2007, p. 6) refers it to "a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system". In any given area, improving a system's adaptive capacity can reduce its exposure to climate change, thereby reducing this system's vulnerability and improving its ability for coping with uncertainty – in other words, the system's resilience. In fact, there are commonalities between the research on vulnerability and resilience, such as stresses and shocks that are experienced by socio-ecological systems (W. N. Adger, 2006). Adaptive capacity is often a key feature of resilience (Beatley, 2014). Thus, adaptive capacity and resilience are frequently interpreted as antidotes to vulnerability, that is, "the more resilient [a system is], the less vulnerable" (Beatley, 2014; Pelling, 2011, p. 42). A system's resilience certainly helps build a system's adaptive capacity or vice versa, even though the relationship between adaptive capacity and resilience remains rather ambiguous (Folke, 2006). Janssen, et al. (2006) attributes this ambiguity to the lack of cross disciplinary attempts, particularly between resilience and adaptation. For example, the scholarship on resilience is dominated by scholars who are primarily concerned with the integrated dynamics of human-nature systems but from a social-ecological perspective. The scholarship of vulnerability and adaptation often overlaps and deals with similar dynamics focusing more on human-induced climatic change. The fact that scholars frequently cite the work of other scholars from within their own domains yields a dearth in theoretical, conceptual, or empirical cross pollination that integrate the resilience and the adaptation bodies of scholarship (Janssen, et al., 2006).

In other words, adaptive capacity, which is dominated by the climate change literature, particularly the knowledge domain of adaptation and vulnerabilities highlighting the human dimension of climate change, focuses on the stresses and uncertainty posed only by climate change. However, resilience considers a system's vulnerability and adaptation to climate change as temporary impacts on this system, hence becomes part of this system's entire transformative process, whether natural or anthropogenic. The human dimension of adaptation represents mechanisms as well as human interventions and could only be considered under the big umbrella of resilience frameworks of human-nature systems. Thus, an adaptive system is not necessarily always resilient, but a resilient system can always be adaptive.

4.2.3 Resilience, an approach of anticipatory adaptation planning

Climate change adaptation requires knowledge about who adapts, what are they adapting to, and how. The recent experiences of extreme climatic events have resulted in a rethinking of adaptation planning to respond to these increasing climatic events –when and where these might occur– and their impacts, and to better anticipate long-term preparedness. This shift from responding to the impacts toward anticipating and planning for future change –often complicated by uncertainty– influences and challenges the decision-making surrounding adaptation (McEvoy, et al., 2013). Hence, such responses to planning for built-in preparedness prioritize anticipatory (or proactive) adaptation, which includes pre-emptive actions and preparedness before the initial impacts of climate change appear. In contrast to reactive adaptation, which occurs after the impacts of climate change manifest, anticipatory adaptation is particularly important for achieving long-term sustainable development and in dealing with uncertainty because it involves less cost and fewer resources than last-minute emergency or retrofitting responses (B Smit, et al., 2001). For example, if no adaptation actions are taken proactively, the total amount of losses in metropolitan Boston from flooding would exceed USD 57 billion by 2100, of which USD 26 billion would be attributed to climate change (Hunt & Watkiss, 2011). In this particular case, it is estimated that anticipatory adaptation would reduce the amount by 80%. In their review of the adaptation scholarship, Berrang Ford, et al., (2011) note that about 78% of peer reviewed papers on adaptation at the time of their analysis focused on planned and/or anticipatory adaptation. Certainly, resilience holds the potential to facilitate such preparedness. Thus, resilience is “anticipatory, conscious, and intentional in its outlook–while much cannot be known about future events, much can, and planning ahead becomes a key aspect of resilience” (Beatley, 2014, p. 127).

4.3 Resilience in the planning and urban design literature: a review

Although planning is often “condemned to apply yesterday’s problem” (Taylor, 2009, p. 150), a resilient system focuses on planning and preparedness and anticipates dealing with future problems. In the planning literature, the concept of resilience is used frequently to refer to the themes of flexibility, adaptability, and durability (Beatley, 2009). Since the beginning of postmodern urbanism, resilience has been discussed in the urban planning and design literature–albeit in various forms and scales–to deal with an unknown future. Figure 4.1 summarizes our findings of the review of the urban planning and urban design literature on resilience since the 1960s. Depicted as a timeline, the illustration traces the different concepts of resilience that have been linked–whether directly or indirectly–to the design of urban form. Upon reviewing these concepts, this paper explores their potential to enhance resilience to climate change and its resulting uncertainty, and how they can be achieved through urban design, particularly, the morphological dimension of urban design at the community level. The literature review and its analysis led to proposing a theoretical framework that considers this potential whereby we deploy urban morphology to operationalize it. Accordingly, the following sections discuss the concepts and identify the possible urban morphological variables that hold the potential to enhance resilience to climate change and its resulting uncertainty.

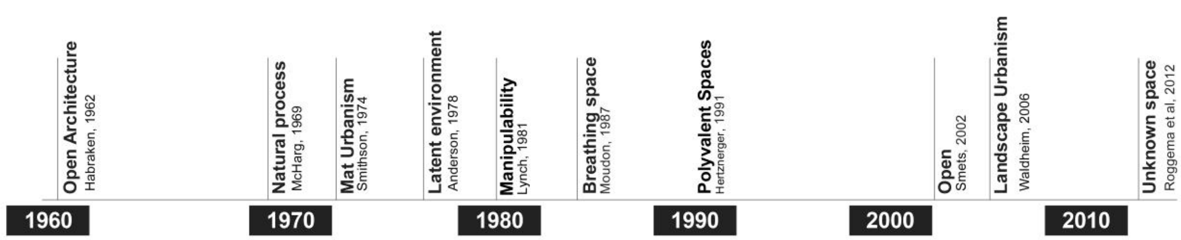


Figure 4.1 Resilience in the urban planning and design literature

4.3.1 Flexibility and adaptability

Against the prevailing rigidity of modernism, the concept of “open architecture” was introduced to Northern Europe by Dutch architects Herman Hertzberger and Nikolaas Habraken (Ellin, 1999). The concept advocated the provision of providing open or half-determined structures for a dwelling that its users would finish. Habraken’s (1972) book titled *Supports, an Alternative to*

Mass Housing, first published in Dutch in 1962, proposed two basic components of construction and design of a residential building, namely support (i.e., base building) and infill (i.e., interior fit-out) in order to allow the participatory role of its users in the design process. The support and the infill are also called the “hard” and “soft” components of design respectively (Schneider & Till, 2007). The concept aimed to increase the resilience, as a built-in design principle, in order to incorporate varieties of design options, for example different layouts, to meet future uncertainty because of changes of socio-economic and cultural states (such as individual and cultural preferences) and for technological advancement over time (N.J. Habraken, et al., 1981). The users would add to the original structures and adjust them based on emerging needs that are not necessarily predictable, thus allowing room for catering to uncertainty in the future. The 1960s were known for attempts to achieve flexibility by offering purposely unfinished designs to meet uncertainty (Sarkis, 2001). Later, Avi Friedman (2002), in his book titled *Adaptable House,* adopted a similar concept that increased resilience by offering enormous design options for end-users so that they could choose and change the design according to their budget and individual preferences. Friedman’s “Grow Home” in Montreal allows its owners to expand and change their home over time based on the space needed and finances available. Kevin Lynch’s (1981) *manipulability* underscores the ability to change in terms of physical form and its uses, similar to the adaptability of open architecture, which is intended to allow all possible future functions. Unlike open architecture, manipulability focuses on maintaining functions for the predicable near future. Open buildings (Kendall & Teicher, 2000) and flexible houses (Schneider & Till, 2007) are a few contemporary movements of the open architecture. Open architecture focuses more on providing resilience primarily at the building scale to respond to steady socio-economic and technological changes in order to augment the design process rather than the end product of the built environments. However, the concept hardly ever takes external environmental stresses posed by climate change into account.

Based on this open architecture, an entire urban system can be classified into various hierarchical levels, from determined, hard, or long-term (e.g., major streets) to relatively half-or undetermined and short-term components (e.g., individual plots and their uses) (N.J. Habraken, 2002). These levels of hierarchy can help understand the decision-making time horizons of adaptation planning (Costa, et al., 2014; Hallegatte, 2009), which determine how the life-spans of the different components of an urban form, especially its morphology, can be adjusted in accordance with the emerging climatic impacts and uncertainty. For example, when building or retrofitting a structure in a hazard-prone area, it might be rational to consider designing the structure to have a short lifetime, based on the extent of risk, instead of aiming for a long-term structure.

4.3.2 Incorporating ecological design and planning

Ignoring the natural and ecological processes is to exclude life-threatening natural hazards including pervasive environmental degradation (McHarg, 1997). Ecological design includes the forms and the processes of change, and directs and manages human actions to incorporate these processes of change in tune with the ecological processes. For example, akin to open architecture, "mat urbanism" by Smithson (1974) underscores a systemic process of planning the environment to improve resilience. Instead of a static architectural composition and rigid urbanism, mat urbanism suggests a generative installation in reference to the transformative processes of urban forms that are respectful of the local nature and climate, and that are open to change: "mat building is a process, a growing structure of additive elements characterized by a delicate interplay between variations and repetitions of forms" (Forés, 2006.). Such generative installation is somewhat similar to Besim Hakim's (2007) generative process of urban transformation, even though the latter does not necessarily consider eco-design or ecosystems. The mat allows indeterminacy in size and shape, flexibility in building and land use, and mixed programs. It thus tends to provide flexibility in planning and design and so offers a range of functions over time. Smithson argued that "the [mat] systems will have more than the usual three dimensions...they will include a time dimension" (Smithson, 1974). Studying the different hierarchies of urban tissues, the mat offers a critical shift from architectural scale to urbanism and proposes a new organizational principle based on a "stem" or "cluster". The stem, a treelike network, similar to street-networks, implies the hierarchy of transportation systems and tends to spread out, dispersing density, hence, it seems that the stems unintentionally endorse the concept of contemporary urban sprawl. Beyond considering the landscape as a formal model, the mat also considers it as a model for process (S. Allen, 2001). Internally, the mat proposes a loose scaffolding base or a porous interconnectivity in which transitional spaces/nodes are connected; however, externally, they are loosely bound (S. Allen, 2001).

Similarly, landscape urbanism that considers the landscape as the fundamental building block for city design promotes organising urban forms around cultural and natural processes (Steiner, 2011). During the postmodern period, popular European city-making principles, both in theory and in practice, became questionable because of their rigid notions and prejudices that often presented culture without context. In contrast, the indeterminacy and instability of contemporary cities have influenced the emergence of landscape urbanism (Waldheim, 2006a). Landscape urbanism considers the landscape first, as a lens to portray the contemporary process of urbanism and second, a medium that is uniquely suited to the open-endedness, indeterminacy, and change demanded by contemporary urban complexities and imposed by temporal uncertainties. For example, James Corner's scheme for the Singapore Garden Bay project shows varieties of organizational structure in terms of materials, texture, space configuration, and scale (Czerniak, 2007). The design scheme facilitates a multi-functional landscape for all needs, some functions of which are clearly marked and defined while the rest are left for exploring unknown uses. Corner's project suggests infinite exchange ability to bounce forward, similar to evolutionary resilience, based on the users' choices, the specific conditions of the site, the cost, and the project's lifespan. Although theoretically the project focuses on ecological, environmental, and long-term sustainability, its spaces equally hold the potential to withstand climatic uncertainty, particularly the impacts of natural disasters like floods and windstorms. Both mat and landscape urbanism have strong foundations built on ecological processes and used to guide urban forms. In other words, they integrate natural processes and human technologies and so promote green infrastructure, which holds potential to enhance the resilience of urban forms while “preserving and enhancing diversity within ecosystems in terms of habitats, species and genes" (Tzoulas, et al., 2007, p. 170). Green infrastructure highlights hydrological functions of urban landscape to manage storm water and reduce additional needs for gray infrastructure (UNEPA, 2015). Moreover, all these approaches are influenced by Ian McHarg’s (1969) advocacy for adaptive, flexible, resilient, and responsive designs in which the individual form and the function seem to be invisible and fused with natural processes.

4.3.3 Toward heterogeneity

The heterogeneity of a system facilitates spreading risks across geographical areas, across time, and across multiple systems and thus, can potentially increase the system’s resilience. In contrast to homogeneity, the concept of heterogeneity promotes hierarchy and multiple stable states, which are essential components of ecological resilience. The concept also contributes to understanding urban forms and their design processes as a part of entire socio-ecological systems (Wu & Wu, 2013). Characteristically, urban systems are heterogeneous in terms of urban density, vegetation, types of infrastructures, and different socio-economic; and cultural activities over time compose this heterogeneity (Cadenasso, 2013). Thus, the heterogeneity of an urban system can be understood in many ways: in terms of its lifespan (Auld, 2008; Fernandez, 2002), its program (e.g., land uses and activities) (Czerniak, 2007), and its land cover (i.e., spatial) (Cadenasso, 2013; Cadenasso, Pickett, McGrath, & Marshall, 2013). For example, mat urbanism tends to provide flexibility to deal with rapid urbanisation, by facilitating the heterogeneity of functions repeatedly subjected to revision and adaptation (Forés, 2006.). Also, in order to understand temporal heterogeneity at the city scale, Auld (2008) categorises a city’s entire infrastructure according to its different life-times, for example, 60-100 years for residential, 50-100 years for commercial, and 20-30 year for roads, based on their life-times in terms of their susceptibility to climate change. Further, at the building scale, Fernandez’s (2002) proposition of temporal heterogeneity classifies and separates the different parts of a building’s designed elements into different life-spans ranging from 10 to 100 years in accordance with short-and long-term climatic vulnerability. This temporal heterogeneity, also known as decision-making time horizons (Hallegatte, 2009), can guide the potential retrofitting phases as part of a long-term adaptation planning because adaptation actions are akin to a progressive marathon rather than explosive sprints (Costa, et al., 2014). A system’s heterogeneity can further be operationalized through modularity (Ahern, 2011). For designers, modularity often refers to employing or involving “a module or modules as the basis of design or construction”, for example modular housing units (Waguespack, 2010, p. 32). Thus, modularity, as a pre-emptive design approach, enhances resilience and ensures that if a part of the system fails, it does not necessarily affect the other parts and thus modularity reduces the impacts of climate change. Lister (2007) used the analogy of “safe-to-fail” in order to understand heterogeneous and modular systems, which represents a paradigm shift from the conventional mentality of "fail-safe", in other words, a shift from engineering resilience.

4.3.4 Latent potential

Anderson's (1978) proposition of "latent environment" represents the onset of understanding the degree of resilience within a physical environment, such as a street or a park. This environment is a result of many potential actions and interpretations by its users. According to Anderson, a physical environment consists of three major domains of potential: exploited potential, recognized but unexploited potential, and unrealized potential (Anderson, 1978) (Figure 4.2). The degree of resilience or latency of the environment varies based on the latter two potentials, both of which, in fact, seem analogous to the concept "open architecture" at a larger scale albeit without necessarily changing the physical state of a system. More specifically, open architecture places the emphasis on promoting and preserving the bounce forward idea, while latent spaces underscore the tendency to bounce back to the original state of a system. Latency, which depends on different perceptions of using a space, allows people and communities to recognize the space according to societal changes over time, without any particular physical change (Anderson, 1978). In the context of climate change adaptation, the latent spaces hold great potential because they offer indeterminacy, similar to landscape urbanism, but in a more guided way. For example, these spaces can be used temporarily to store storm water runoff and/or to function as bioswales if required.

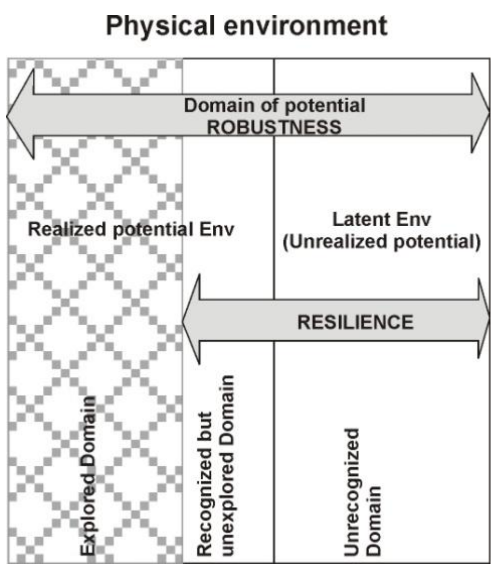


Figure 4.2 Physical environment and resilience (adapted from Anderson, 1978)

Anne Vernez Moudon (1986) finds similar spaces at the neighbourhood level that were created from the accidental intersection of irregular street grids in San Francisco and that allowed the communities to manipulate and personalize their uses. She called them "breathing spaces" for the community, even though these spaces were not intentionally programmed. Such community spaces might facilitate the recovery actions immediately after climatic and non-climatic hazards. For example, in the aftermath of Chile's 2010 earthquakes, similar small public spaces were used to house temporary and emergency shelters in Concepción (Allan, Bryant, Wirsching, Garcia, & Teresa Rodriguez, 2013). Thus, similar to latent spaces, these breathing spaces potentially facilitate an open-ended process to incorporate changes and to accommodate uncertainty.

To understand the latent spaces at the building scale, Hertznerger's (1991) polyvalent space, also known as spaces with no label, can be extended as a design approach to enhance the resilience of urban forms where such spaces may serve different uses without the need to experience major physical changes. The word 'polyvalent', which signifies the *sale polyvalente* or multi-purpose hall in French villages, is usually used for musical and theatrical performances and for weddings and parties, and primarily underscores the interchangeability of the activities within a given system rather than physically changing this system as with the modularity of heterogeneity (Leupen, 2006). In the same vein, Roggema et al.(2012) explore a hypothetical case that deploys the undetermined spaces of a city, such as the urban nodes of the Netherlands, which they dubbed "unknown spaces", in adapting to the impacts of climate change. These nodes hold the potential to function differently during disasters, for instance, to accommodate the erection of emergency shelters.

The underlying concepts of these latent spaces within urban form parallel several concepts from the climate change and socio-ecological literature, such as Walker and Salt's (2006) biodiversity within ecosystems. To define biodiversity, Lister (2007, p. 44) used the metaphor of a "library of knowledge", some of which are familiar and valued, while others are yet to be discovered. Similarly, they parallel Smets's (2002) proposition of "leaving things open" to deal with uncertainty, which supports the adoption of inherent design approaches that improve resilience. The analogy "open" here reserves room for tactics that can potentially accommodate any program needed to deal with future uncertainty.

Moreover, all the aforementioned concepts consider long-term proactive approaches for dealing with future uncertainty and provide a number of design variables that are associated with urban form. The following sections synthesize the potential of these variables and propose a multi-dimensional and multi-scale framework to understand how the design of urban morphology can influence the resilience of urban form.

4.4 Toward a framework for enhancing the resilience of urban form

4.4.1 Rationale and theoretical discourse of the framework

Most planning and design interventions are based on a belief that knowledge "leads to certainty, and therefore, predictability and the success of the design and plan" (Lister, 2007, pp. 44-45).

However, in reality living systems grow “discontinuously and intermittently”, and even after a sudden disturbance an entire living system (e.g., a city) reorganizes or renews in a way that may turn it to a similar or different state –more or less desirable to humans. At this point, Gunderson and Holling’s (2002) panarchy[7] model links various adaptive cycles in a nested hierarchy to represent dynamic cycles of ecosystem and the ever-changing and multiple states of a system and establishes their relationships in terms of time and space (Figure 4.3). These adaptive cycles illustrate that changes are episodic and are controlled by interactions between slow and fast variables. These cycles include four basic stages of ecosystems: reorganization (renewal), exploitation (birth), conservation (growth), and release (creative destruction) (see Gunderson & Holling, 2002). Among these stages, the renewal stage is crucial with regard to pre-emptive planning and design as it represents the time for innovation and restructuring of a system. Although this stage involves high uncertainty, it can hold the highest resilience. Thus, this stage offers opportunities for planning and design innovations because of two reasons. First, it is the stage when a system’s resilience is increasing and can reach its highest level. Planning interventions could capitalize on this opportunity to enhance the resilience of a system (e.g., an urban area). Second, this stage also provides an opportunity to monitor and measure resilience as a system goes through the entire processes of maximizing and minimizing its resilience and eventually will reach its next renewal stage. A system’s successful renewal in terms of planning and design, which also influences the future pathway of change, depends partly on the ecosystem’s biodiversity in terms structure and functions and partly on the ecosystem’s ability to regenerate and reorganize. Thus, a flexible, adaptive, and responsive system holds the maximum potential to incorporate these changes at every phase and to allow the system itself to cope better with change over time as well as with the uncertainty that ensues from climate change.

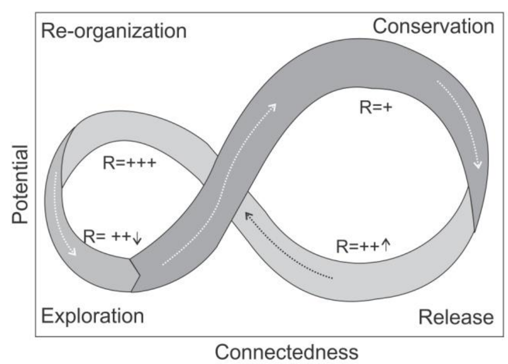


Figure 4.3 The model of adaptive cycles.

Note: The sign (+) indicates the level of resilience (R) at different phases where ↑ and ↓ show the increase and decrease of R respectively (Adapted from Gunderson & Holling, 2002)

[7] Panarchy represents a conceptual framework to portray an image of change in the socio-ecological system. Panarchy focuses on rationalizing the interaction between persistence and change and also between predictability and unpredictability while allowing a system’s adaptive evolution. Accordingly, the panarchy framework links various adaptive cycles (see more Resilience Alliance at www.resalliance.org).

4.4.2 Urban design resilience index (UDRI): a proposed framework

This paper considers the several design concepts discussed and their links to resilience and adaptation, as the conceptual foundation, to propose a resilience framework so as to enhance resilience (and adaptive capacity) of urban form. Urban form refers to the "physical environment" of a city, including the spatial pattern of its permanent and its inert physical objects whether natural (e.g. hills, rivers, and even trees) or morphological (e.g. streets, buildings, and infrastructure) (Lynch, 1981). Michael Conzen (1969) delves further into the links between urban form and the city's unique morphological characteristics which exhibit its physiognomy or townscape. Thus, our proposed Urban Design Resilience Index (UDRI) integrates the different elements of urban morphology and their design potential to balance the interfaces between human and natural systems to understand and enhance resilience of built environments. The UDRI considers the pre-emptive approach of reducing shocks and the holistic approach of anticipatory adaptation, and also, incorporates open-ended planning and design that facilitates incremental and generative urban development. Collectively, the dimensions of UDRI yield urban planning and design processes that also strengthen the innate ability of urban systems to be transformed physically, functionally, and spatially in a manner that accommodates new changes in society, economy, and/or environment over time.

Similar to the adaptive cycles in the panarchy model, *temporality* and *uncertainty* are two key attributes of the UDRI framework. This multi-dimensional framework also offers a set of interrelated design indicators that facilitate an understanding of its dimensions at different scales (Figure 4.4).

4.4.3 UDRI and its dimensions, scales, and indicators

There is uncertainty in predicting long-term climatic scenarios and their impacts on urban areas: the further the projection, the higher the uncertainty. For example, current climate change projections cover scenarios until the end of the twenty-first century in eighty four years from now, but the physical planning and design of built infrastructure like streets tackle a life span that exceeds 100 years (Auld, 2008). In addition, the ever-changing dynamics of a society and its ensuing urbanization further amplify the level of uncertainty due to the emerging impacts of climate change. Therefore, our proposed framework encourages progressive, non-linear, and incremental design approaches in order to allow the possibility of accommodating these changes into the built environment; in other words, they facilitate the exploration of opportunities during the renewal stage of the adaptive cycle model (Figure 4.3). The theoretical basis of the proposed framework considers four interrelated dimensions: ecological, physical, functional, and spatial and includes a set of urban design concepts that incorporate the urban morphological components of the built environment. Table 4.2 describes these concepts and the potential of applying them to a particular context as a means of enhancing the resilience of urban form, and

Figure 4.6 includes the indicators and variables of these concepts to elaborate their scope to enhance resilience while illustrating their abstract applications.

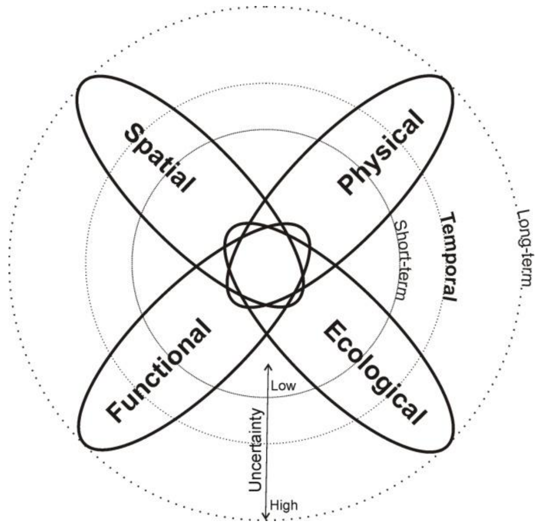


Figure 4.4 The dimensions and the scales of the proposed framework

Firstly, the ecological dimension refers to the integration of built forms and nature, which capitalizes on natural ways of reducing shocks. Various contemporary forms of ecological design, such as landscape urbanism, are able to address this integration while simultaneously advancing green infrastructure that between man-made features and natural systems. Recent applications of green infrastructure go beyond ecological services. For example, such applications, as guided by the United States Environmental Protection Agency (USEPA) (2016), now include "an array of products, technologies, and practices that use natural or engineered systems that mimic natural processes" to enhance resilience (similar to a bounce-forward model). Thus, this dimension reflects ecological design that increases the ecological resilience of urban form, thereby facilitating the ability of urban form to bounce-forward as recommended by the IPCC's fifth assessment report for urban areas (Revi, et al., 2014). Additionally, such ecological design are conceptually similar to ecosystem-based adaptation, an emergent approach of climate change adaptation that combines ecosystem services and natural resources in adapting to climate change (Dhar & Khirfan, 2016). They both ensure preserving the ecological processes and guiding human actions to strengthen the connection between urban form and nature. For example, avoiding surface sealing and deforestation in urban areas enhances the discharge of runoff water to regional and ground water systems, and thus reduces the impacts of flash floods. An urban area with 75% impervious surface land cover experiences three times more runoff compared to an area covered by 35-50% of impervious surface and five times more than a natural area (Watson & Adams, 2011, p. 92). To ensure this natural flow, often ecological design approaches lean toward dispersed developments, which may seemingly contrast with compact urban forms that are considered one the established norms of sustainable development (Jabareen, 2004). In order to balance these seemingly opposing approaches, Chicago's Green Alley program (CDOT, 2010) introduced a street design that deployed porous recycled materials that are sensitive to the environment, similar to mat-urbanism's loose scaffold base, that simultaneously catered to a compact and sustainable development as well as an ecological dimension that balances built form and nature.

Secondly, the framework's physical dimension tackles the physical characteristics of streets and street networks, blocks, and buildings in order to capitalize on their design's potential to incrementally transform so as to enhance resilience. The concepts behind half-determined, undetermined, or heterogeneous forms underscore the separation between the various parts constituting these forms so that should any part be changed, be retrofitted or even fail, the other parts remain unaffected. For example, in the Netherlands, the national policy promotes the separation between rain water drainage systems and the sewer networks in urban areas in order to increase flood resilience (EEA, 2012). Likewise, mat urbanism promotes clusters or modular developments through well connected stems (e.g., street networks) and establishes connections between clusters, clusters and stems, or built-forms and nature. Thus, inter-dependency and connectivity between the parts of a system maximize the flexibility to change these parts in due course. A combination of multiple connections and their variety produce hierarchical structures, which are often redundant but generate ambiguous relationships within and around systems, that enhance resilience (Mehaffy & Salingaros, 2015). Lessons from latent and generative spaces also reveal that the multiple connectivity in achieving these ambiguous (or casual) relationships between spaces can increase the resilience of urban form if these connections are designed in a way that allows incremental change, for example modular development.

Thirdly, the functional dimension includes land uses and different planned or unplanned activities. It is equally important for an area that is not yet known to be prone to natural hazards or where there are no other choices except to continue living in a hazard-prone area. The concepts of unlabeled spaces, polyvalent spaces, diversity, and unknown spaces highlight the potential of built-in design in increasing the resilience of urban form by altering this form's functions. Through this capacity, for example, the streets of Port-Au-Prince, Haiti helped municipalities in accommodating temporary shelters immediately after the 2010 earthquake (Norton, 2013, p. 216). Roggema, et al. (2012) also illustrate the potential of the links between these adaptable spaces (also called unplanned spaces) and the street network of a Dutch city (Figure 4.5).

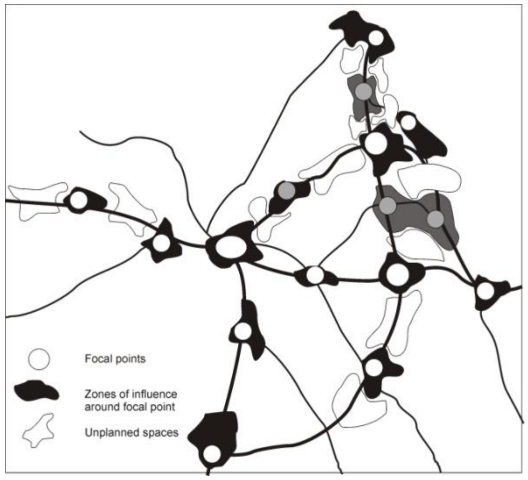


Figure 4.5 Unknown (unplanned) spaces and street network (Adapted from Roggema, et al., 2012)

Lastly, the spatial dimension focuses on the layout pattern and heterogeneity of urban form, such as the spatial planning of Figure 4.5 itself. Minimizing impermeable surfaces in an urban area through land cover classification can provide ecological benefits and also reduce the impacts of climate change, such as floods and sea-level rise. For example, Malmö in Sweden deploys a green scoring factor that ensures a certain portion of any new development consists of either green infrastructure or a land cover with porous surface (EEA, 2012, p. 52). Accordingly, the city uses different values for scoring systems to measure the efficiency of different land covers like 0 for sealed surface, 0.7 for green roofs, and 1 for ground vegetation. Cadenasso, et al. (2013) also propose a system called HERCULES[8] that measures the ecological benefits of urban forms by focusing on their different land covers, including buildings, surface materials, and vegetation.

Moreover, these interrelated four dimensions underscore many planning concepts and approaches that have been used over decades to enhance how built environments respond to uncertainty that is not necessarily related to climate change. Only a few approaches include evidence related to climate change. By extracting urban design potential to facilitate pre-emptive adaptation, the proposed URDI framework highlights a number of concepts useful in understanding the influence of design in enhancing urban resilience (Table 4.2). From a methodological point of view, a concept helps build only perceptions (i.e., abstract understanding), which can vary markedly by individuals and are often too elusive to apply without associated measurable variables (Kumar, 2011). Building on the interrelationship between the theoretical underpinning of these concepts and the different models of resilience discussed so far, this section develops the indicator and associated variables of the concepts that are missing from the literature. Table 4.2 lists these concepts with their corresponding sample

[8] HERCULES (High Ecological Resolution Classification for Urban Landscape and Environmental Systems) focuses on land cover, not land use, and recognises cities not as separate between built and vegetated landscape, but as a patchwork of finely differentiated combinations of different land covers (Cadenasso, 2013, pp. 272-276).

variables and demonstrates their links to urban design. For example, the first concept, *harmony with nature* demonstrates urban form's organization that has minimal impacts on the environments and that strengthens natural systems to take control to absorb risks. To reduce the impact of water runoff naturally, many ecological design innovations commit to preserve this natural flow by minimizing urban imperviousness and preserving urban wetlands, thereby boosting resilience. Thus, the possible variables to determine resilience of a given area involve the amount of porous urban surface and its historical trend (whether increasing or increasing). For another example, the concept *indeterminacy* underscores a pre-emptive design framework of urban form that allows end-users/policy makers to change, modify, and manipulate the urban form to a certain degree to cope with unknown circumstances. A distinction between fixed/determined morphological elements and flexible (non-determined, relatively more adaptable) ones of a system's design guides end-users in modifying elements as needed and acts as an indicator of resilience. Accordingly, the degree of indeterminacy indeed influences a system's resilience: the more indeterminate a system is, the more resilient it is. Because of the limited length of this paper, the rationale behind establishing sample indicators and variables of all other concepts is briefly presented in Table 4.2. Additionally, Figure 4.6 represents abstract design applications of these concepts to clarify their potential contribution to the realm of urban design. Yet, in a relatively subjective and creative domain like urban design, the operationalization might differ significantly based on how designers use and nurture these concepts. Thus, the variables listed, along with the visualizations used here, are meant to offer only a few suggestions for these concepts' potential and for their use in urban design approaches to uncertainty and resilience.

Table 4.2 *Urban design concepts of UDRI*

Concepts	**Descriptions**	**Sample indicators (variables)**	**Sources**
Harmony with nature	Harmony and consistency between nature and urban forms promote ecological resilience (i.e., bounce-forward model). Ecological design advocates several techniques for maintaining the dynamic of natural system to enhance resilience. For example, porosity of urban surfaces could influence and manage water runoff. Similarly, incorporating green infrastructure in design thus reduce climatic impacts, particularly from flash floods and urban heat island.	Imperviousness (in terms of land area) and links between green and gray infrastructure (the degree of design potential to facilitate these links)	(McHarg, 1969; Smithson, 1974; Waldheim, 2006b)
Latency	Latent urban form holds innate design opportunities of an urban system to cope with uncertainty while accommodating different future uses which are not essentially in use now. It includes pre-emptive urban design strategies that differentiate urban form and its uses from explored to unexplored domains.	Predefined room for future functions to be accommodated (clarity between explored and unexplored spaces)	(Anderson, 1978; Moudon, 1986)
Polyvalent spaces and diversity	Polyvalence spaces and their design highlight the capability of an urban system (e.g., a street or building) to serve diverse uses at the same time. The design of it could enhance this potential to increase resilience during and after a disaster.	Capacity to serve diverse functions needed particularly during a disaster (the efficiency and number of these uses)	(Hertzberger, 1991; Roggema, et al., 2012)
Indeterminacy (or half determinacy)	Indeterminacy leaves a range of possibilities to cope with unknown changes–functional, spatial, and environmental–over time. Most importantly, it prescribes several design strategies to control over these changes that might involve partial or full physical changes of certain urban form.	Distinction between determined and not-determined components of urban form (the degree of clarity in terms of design)	(N John Habraken, 1972; Kendall & Teicher, 2000; Lynch, 1981)
Heterogeneity	Heterogeneity separates different components of urban form into different parts and spreads out risk across time and space. The degree of heterogeneity offers varieties within a given urban system that potentially include multiple scopes to deal with uncertainty.	Hierarchies of urban forms according to their life-time and spatial positions (the clarity of these classifications through design)	(Auld, 2008; Cadenasso, 2013; Czerniak, 2007)
Modularity	Modularity of an urban system facilitates to control and group different parts of it and enables them to be changed/modified without out affecting others. Thus, it welcomes professionals and communities to retrofit or change of parts only which are affected by a circumstance.	Clear/virtual clustering of urban form (number and size of each module/cluster and their degree of independence)	(Ahern, 2011; Lister, 2007)
Connectivity	Well-connected and hierarchical networks of urban infrastructure increase the scopes for future development and they facilitate emergency recovery actions, including evacuation planning.	Interplay between streets and blocks (the size/number of blocks or superblocks and number of nodes)	(S. Allen, 2001; Mehaffy & Salingaros, 2015; Smithson, 1974)

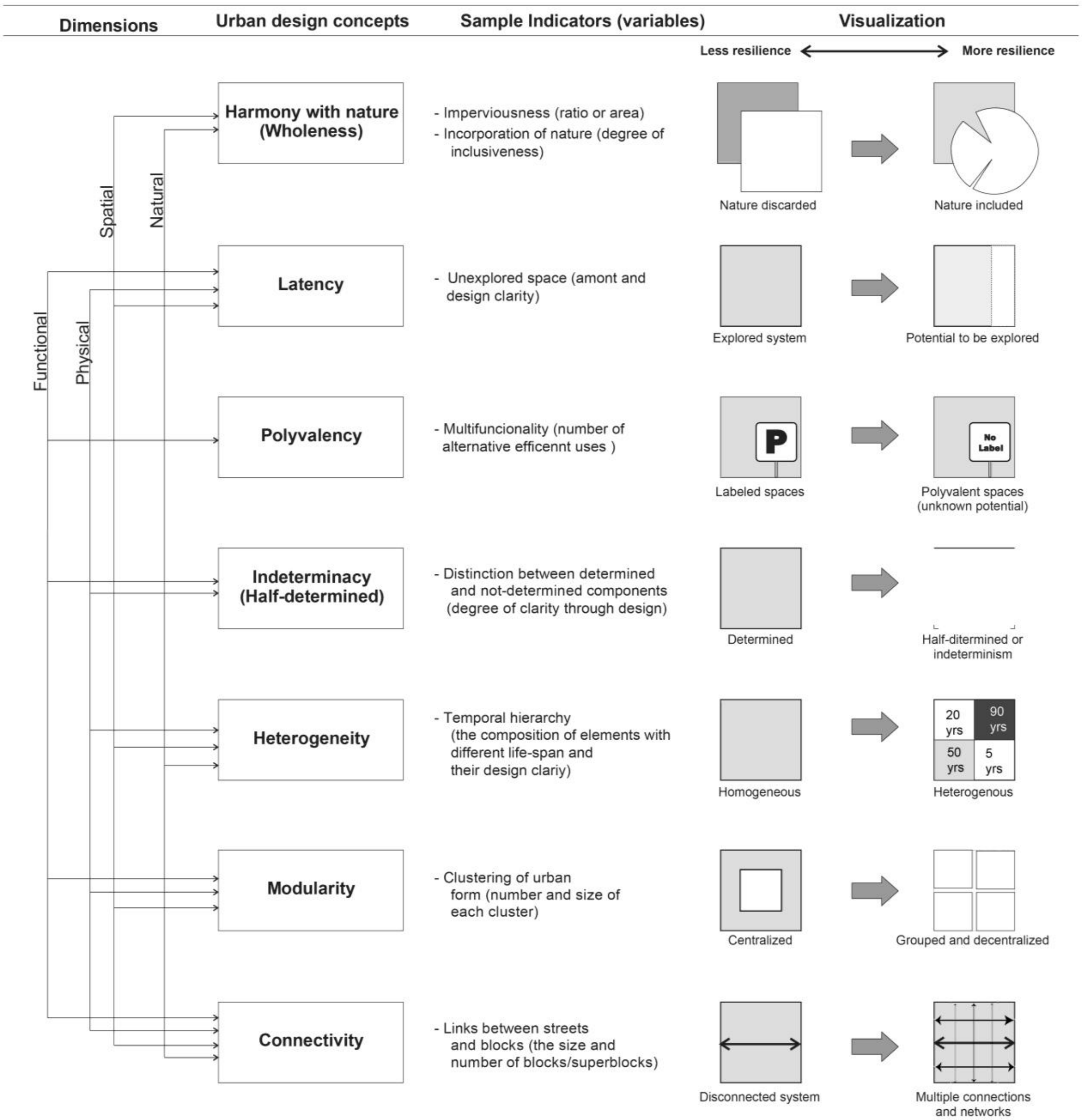


Figure 4.6 The UDRI's design concepts and sample variables

More specifically, the dimensions of our proposed UDRI include a list of interrelated concepts to understand resilience thinking and adaptation and their links to the urban morphological elements. The theoretical discourses of resilience have rarely addressed the issue of climate change adaptation (Davoudi, et al., 2012) and/or the connection between resilience and the design of urban forms (Allan, et al., 2013). The UDRI framework addresses this where, along with its design indicators, it can be applied in any given urban setting to assess its form's adaptive capacity and resilience to climate change. Some of these indicators implicitly allude to Walker and Salt's (2006) widely cited basic principles[9] of a resilient world, however, these principles are not immediately relevant to understanding the design of urban form –something that our proposed UDRI tackles. Therefore, and in order to facilitate such an understanding, Figure 4.6 illustrates through easily decipherable abstract visuals how to simplify the applications of the proposed UDRI framework through urban design interventions. Surely, the practice of climate change adaptation varies across time, scale, and space, and therefore, its specific actions are grounded in the locality and are dependent upon the nature and the degree of vulnerability. For example, the vulnerability of coastal urban forms that ensues from sea-level rise, storm surges, and flooding varies significantly from that of inland urban forms whose vulnerability ensues from drought. The proposed UDRI framework presents a generic and a global framework whose concepts and indicators can be wholly applicable in some instances, but partly in others. Thus, empirical research in the future will further enhance the details of this framework's variables, their indicators, and their operational measures. Such research will also lead to enhancing our understanding of the resilience of those urban forms that are vulnerable to the impacts of climate change, hence, lead to the development of relevant policy recommendations.

4.5 Conclusions

Successful climate change adaptation includes actions not only for reducing the current and emerging impacts of climate change but also for capitalizing on other benefits of those actions. However, only 7% of climate change adaptation research pays attention to exploring the latter opportunities of adaptation actions (Berrang-Ford, et al., 2011). A workshop on climate change adaptation, organized by Balsillie School of International Affairs (BSIA, 2014), considered successful adaptation as a part of sustainable development, and thus, it also integrates the socio-economic and environmental systems of an urban development. Additionally, an urban system and infrastructure will last even longer than the period projected by current climate models. Thus, this paper sees adaptation not only as a part of resilience thinking addressing our ever-changing environment and urban systems but also as a part of sustainable development effort. Thus, the resilient urban form could also optimize resources and promote sustainable development while maximizing the benefits of resilience thinking and adaptation. The proposed UDRI framework helps understand, measure, and improve urban resilience and also promotes sustainable development.

Specifically, the UDRI framework along with its concepts and possible variables helps people and communities understand the characteristics of resilience and adaptive urban forms and urban design strategies as potential adaptation actions to cope with an unknown future. So far there has

[9] The nine principles of a resilient world: diversity, ecological variability, modularity, acknowledging slow variables, tight feedback, social capital, innovation, overlap in governance, and ecosystem service (Walker & Salt, 2006, pp. 145-148) .

been a dearth of establishing urban design frameworks that identify the characteristics of resilient urban forms. Certainly this UDRI that combines the various concepts from the planning literature–henceforth never placed together in one place–promises to be a useful tool. This comprehensive and flexible (or more open) framework allows selecting from among its *theoretical* components (concepts, their ensuring indicators and variables) that suit particular conditions of an area and its different vulnerabilities to which its urban form is susceptible, thereby making advantage of different resilience requirements. Beyond this theoretical foundation of resilience through the urban form, the *practical* contribution of this framework would render developing design criteria, guidelines, and polices for urban landscape and green infrastructure – in other words, implication and contribution to contemporary planning practices. For example, the concept of mixed-use development–a common planning motto for advocating sustainable development–could also facilitate climate change adaptation by accommodating uses particularly needed during natural disasters similar to what polyvalent and indeterminacy promote (Table 4.2 and Figure 4.6).

The proposed framework promotes the concepts of ecological and evolutionary resilience that advocate long-term anticipatory adaptation strategies. Further research needs to confirm its variables appropriate for a particular context and test the framework using its operational strategies. The underlying concepts of this framework, including its indicators, show a path toward increasing resilience of urban form that can meet the challenges of ever-changing phenomena of our societies and environment, including climate change.

Chapter 5 : Manuscript IV

Six Urban Design Measures for Assessing Climate Change Resilience: Negril, a Caribbean case study

[Ready for submission to *Planning Theory & Practice*]

Abstract

Limited information on local climate change impacts and resulting uncertainty hinder the identification of appropriate urban design and planning approaches to enhance the resilience of urban form. To facilitate these approaches, this paper proposes a theoretical framework–integrating urban resilience, urban design and planning, and adaptation–that includes six measures associated with urban morphology and that is operationalized in Negril, Jamaica, vulnerable to sea-level rise. Empirical evidence reveals that Negril's adaptation planning is goal oriented and predominantly considers the impacts from extreme climatic events while maintaining its current development patterns and overlooking progressive and incremental changes that could address climatic uncertainty.

Keywords: Resilience, climate change adaptation, and urban form and design

5.1 Introduction

Climate change has given urbanism the opportunity for exploring new possibilities (Costa, et al., 2014). Urban resilience is one such opportunity that can enhance the ability of urban systems to cope with the challenges, complexities, and uncertainties posed by climate change and the ever-changing dynamics of cities.

Planning scholars are becoming aware of the need to strengthen the theoretical links between resilience and climate change adaptation, and also, of the need to investigate their applications in physical planning and design (Beatley, 2014; Davoudi, et al., 2013; Davoudi, et al., 2012; Jabareen, 2015; Lennon, et al., 2014). Existing links remain generic, with few urban design guidelines for enhancing the resilience of current or future developments (e.g., Allan, et al., 2013; Sharifi & Yamagata, 2014). They also fail to offer any operational frameworks for applying these guidelines in specific contexts (e.g., coastal settlements), even though 'context' is key for determining adaptation responses and system resilience. As adaptation responses differ by context, places, and time, therefore, knowing a system's current resilience becomes essential. Specifically, urban design until now indicators and variables that gauge the resilience of human settlements remain lacking –a lack that hinders the development of context-specific urban designs that are conducive to adaptation. Thus, this paper investigates how the spatial layout and the physical design of a settlement influence its resilience and the ways by which to assess this resilience. In particular, this paper identifies then investigates a set of six urban design measures that establish links among (urban) resilience, urban design, and climate change adaptation. Accordingly, this paper responds to Yosef Jabareen's (2013, p. 225) questions: how can plans for infrastructure design reduce vulnerabilities and make cities resilient? And, what adaptation measures can address future uncertainties?

The paper first establishes a theoretical foundation for an urban design framework linking (urban) resilience, urban design, and adaptation, then it identifies variables that could potentially influence the resilience of urban form. "Urban form" in this article encompasses the unique morphological characteristics of a town, i.e., its "physiognomy or townscape", which combines the town plan, the pattern of building forms, and land use (Conzen, 1969, p. 3). In other words, this study adopts urban morphology, one of the dimensions of urban design[10], to operationalize the proposed framework, which is then applied to Negril, Jamaica, a coastal area vulnerable to sea-level rise in order to measure its resilience in terms of urban form characteristics. The study uses in-depth interviews with planners and with environment professionals who work at government agencies related to planning, development, and climate change. In addition to secondary information, such as maps and policy documents, direct participatory observations were also used to collect information on the study area's existing physiognomy. Based on the empirical findings, this study proposes a resilience benchmark for Negril's development that

[10] According to Carmona et al. (2010), the six dimensions of urban design are the morphological, perceptual, social, visual, functional, and temporal.

facilitates an understanding of the current resilience of its urban form and which will also inform future planning and urban design initiatives for enhanced resilience whether for new or for retrofitted (coastal) urban development.

The following sections review the concept of resilience as discussed in both the socio-ecology and in the urban planning literature to identify its theoretical links to adaptation. Then, based on these links six urban design concepts associated with their indicators and variables are identified and then tested by assessing Negril's resilience. The paper then introduces potential design practices that could improve Negril's resilience are discussed before ending with the conclusion and recommendations.

5.2 Contemporary discourses on urban resilience

Resilience, first conceptualized by socio-ecologist C.S. Holling (1973, p. 14), is "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables." Accordingly, urban resilience is the ability of urban systems "to withstand a wide array of shocks and stresses" (Leichenko, 2011, p. 164), and also, a city's capacity to rebound from destruction, including that which ensues from climate change-related extreme events (Campanella, 2006). Many authors have highlighted the commonalities between resilience and adaptive capacity[11], as both focus on a system's ability to reduce vulnerability, hence, both represent antidotes to vulnerability (Beatley, 2014; Davoudi, et al., 2012). Securing the conditions for long-term human wellbeing is the key objective of urban resilience (Kumagai, Gibson, & Filion, 2014), which represents a conceptual synthesis of resilience and climate change adaptation together with the complex interactions between the urban biophysical and human agents.

The recent discourse on urban resilience reflects "an increasing sense of complexity, uncertainty, and insecurity about cities and a desire to identify new adaptation and survival strategies" (Stead, 2014, p. 17). Uncertainty refers to "a perceived lack of knowledge...that is relevant to the purpose or action being undertaken and its outcomes" (Abbott, 2009, p. 504). Combining the complex socio-ecological dynamics and uncertainty of a system, Simin Davoudi et al. (2012, p. 306) identify evolutionary resilience as a system's "inherent uncertainty and discontinuities, and insight into the dynamic interplay of persistence, adaptability and transformability". This evolutionary resilience, in fact, is a theoretical proposition of the evolutionary perspective of a society. It challenges, as Carl Folke (2006) asserts, previous notions of equilibrium, including engineering resilience (bounce-back) and ecological resilience (bounce-forward). While engineering resilience refers to a system's ability to return to a state of equilibrium after a

[11] Adaptive capacity, a key concept of climate change adaptation literature, refers to "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2007, p. 869). It is closely associated with other concepts, including resilience, coping ability, adaptability, and flexibility (B. Smit & Wandel, 2006). These analogous forms of resilience are particularly important because planning literature considers only them.

disturbance, ecological resilience underscores the "magnitude of the disturbance that can be absorbed before the system changes its structure" (C.S. Holling, 1996, p. 33). In addition to challenging equilibrium, evolutionary resilience relies on multiple alternative states and advocates for their natural transformation over time‒even with the absence of external disturbances. Especially in the context of climate change, Susan L. Cutter et al. (2008, p. 601) note two other resilience qualities of a system: i) inherent resilient, in which a system still functions well during non-crisis periods, whether or not it is impacted by slow onset climatic events (e.g. sea-level rise) and ii) adaptive resilience, in which a system's flexibility increases during disasters including when it is impacted by rapid onset climatic events (e.g. hurricanes). Both the inherent and adaptive resilience are in fact akin to the evolutionary resilience and are thus transformative as opposed to the engineering resilience (i.e. bouncing-back to the system's previous state). The IPCC's recent report favours this evolutionary form of resilience for urban areas that promotes urban infrastructure's transforming ability to cope with current climatic events and with future climatic uncertainty (Revi, et al., 2014).

In an attempt to pin down this notion of urban resilience, Robin Leichenko's (2011) review of the literature identifies four definitional tracks. The first is the *urban ecological resilience* which underscores uncertainty, the self-organizing ability of ecological and coupled human-environment systems, and systems' complex adaptive mechanisms. The second is the *urban hazards and disaster risk reduction* which represents the largest branch of urban resilience and which focuses on enhancing the capacity of urban systems (e.g. built environments, infrastructure, and communities) in order to recover from man-made and/or natural hazards – climate change included. This group primarily considers rapid onset climatic events and works during and immediately after a disaster while overlooking measures to address slow onset scenarios (Cutter, et al., 2008). The third is the resilience of *urban and regional economics* which identifies factors that describe the diversity and growth of urban and regional economics, and explores why resilience varies across places. Lastly, the fourth track is dedicated to the promotion of resilience through *urban governance and institutions*, hence, advocates different types of institutional arrangements and local governance, such as community-based adaptation plans that influence the resilience of the local environment and local communities. For example, Thomas Tanner et al. (2009) identified several characteristics of governance, including transparency and accountability, polycentricism, flexibility, and inclusiveness.

The *urban ecological resilience* and the *urban hazards and disaster risk reduction* definitional tracks are particularly important for this paper's objective to link climate change adaptation and urban design and planning. *Urban ecological resilience* deploys proactive *ex-ante actions* that are based on climatic models and forecasts in order to address future risks with the objective of preventing and/or reducing the impacts of future disasters, thus, such actions entail pre-emptive planning and design strategies (e.g. ecological design). Conversely, *disaster risk reduction* entails reactive *ex-post actions* that are tackle the actual outcomes of particular disasters, including emergency responses with the objective of post-disaster recovery (Jabareen, 2013).

The literature on climate change, resilience, and sustainable development particularly recommends ex-ante actions, which are similar to proactive adaptation[12], since they involve less effort, energy, and cost than the reactive ex-post recovery actions (Revi, et al., 2014; B Smit, et al., 2001). Yet, the literature on urban resilience advocates a combination of proactive and reactive actions in order to deal with disturbances and uncertainty –whether from climate change or any other cause. Indeed, the combination of these actions holds the potential to link urban resilience and adaptation through incorporating ecosystems, socio economic factors, local governance, and community-based adaptation. Moreover, these actions' theoretical and empirical connections to urban design remain as yet unexplored –a feat that this article tackles through the proposed theoretical framework. In order to establish this framework's foundations, the following sections review the concepts, measures, and frameworks for assessing a community's resilience.

5.3 Insights on resilience in the age of climate change: a review

Climate change-related resilience remains a relatively new concept in urban planning and design (Davoudi, et al., 2012; Lennon, et al., 2014). Nevertheless, resilient systems and communities are regarded as less vulnerable to disasters, but in order to validate this assumption and to apply resilience in the context of climate change warrants firstly, an understanding of the determinants of resilience and secondly, an operationalization mechanism of these determinants that facilitates their measurement/assessment, maintenance, and enhancement (R. J. Klein, Nicholls, & Thomalla, 2003). From socio-ecological, infrastructural, and planning viewpoints, community resilience encompasses numerous indicators and variables –albeit, not necessarily directly related to urban design and physical planning. In this article, we argue that the underlying concepts of operationalizing community resilience are interlinked with urban form. In the subsequent parts of this section therefore we link the currently existing resilience indicators and variables with urban design approaches that promote flexibility, adaptability, alternative stable states, and transformability that we argue are also analogous to resilience in its opposition to permanency, rigidity, and stability (Beatley, 2009; Davoudi, et al., 2012; Gunderson & Holling, 2002; B. Smit & Wandel, 2006).

5.3.1 Understanding community resilience: a socio-ecological viewpoint

Several authors have identified what they consider as fundamental processes for achieving resilience, including: ecosystems, livelihood outcomes, and institutional arrangements (Plummer & Armitage, 2007). Kathleen Tierney and Michel Bruneau (2007) highlighted how some resilience frameworks for natural disaster reduction underscore engineering systems that foster resourcefulness, redundancy, robustness, and rapidity in an attempt to reduce the likelihood of failures in a manner akin to a bounce-back model. Yet, these frameworks often overlook a

[12] Proactive adaptation, as preparatory planning, occurs before climate change impacts are observed, whereas reactive adaptation occurs after such impacts become evident (R. Klein, et al., 2001).

community's values and the local ecosystem's vulnerability and resilience (Cutter, et al., 2008).

Furthermore, to measure and monitor the resilience of a socio-ecological system over time, organizations have used criteria derived from various aspects of human settlements whether natural, social, economic, or physical. For example, the UN's Sendai Framework[13] (2015-2030) underscores strengthening the resilience through the management of "disaster risk" (i.e. risk reduction) rather than the management of the disaster itself (UNISDR, 2015). Therefore, the Sendai Framework considers ex-ante (proactive adaptation) actions that address disaster risk factors more cost-effective than a reliance on ex-post (reactive adaptation) actions. Yet, early preparedness through ex-ante actions also facilitates ex-post actions since they promote a "building back better" approach, which is the motto of engineering resilience. Surely, the Sendai Framework's priorities for proactive adaptation resemble other frameworks recommended by an array of organizations like the joint report by the Asian Disaster Preparedness Center (ADPC), the United Nations Economic and Social Commission for Asia Pacific (UNESCAP), and the European Commission Humanitarian Aid at the regional level (ADPC, 2006). The World Bank underscores community participation and political engagement along with ex-ante actions (Jha, Miner, & Stanton-Geddes, 2013, p. 39). In fact, most these frameworks suggest place-based actions that ensure community participation that builds local understanding and improves resilience to the extent that place-based action is considered a measure of the resilience of a socio-ecological system.

Building on place-based actions, Susan L. Cutter, et al. (2008) devised the Disaster Resilience Of Place (DROP) model to assess resilience in which local antecedent conditions highlight place-specific multi-scalar processes occurring within and between natural systems, social systems, built environments, and a community's inherent resilience and vulnerability that collectively present a "snapshot" in time or a "static state" (p.602). According to DROP, disaster impact represents the sum of these antecedent conditions together with the characteristics of the event/disaster and the coping responses. Embedded within the latter is the local absorptive capacity that holds the potential to moderate the event's cumulative impacts where absorptive capacity refers to the community's ability "to absorb event impacts using predetermined coping responses" (Cutter, et al., 2008, p. 603). Unlike adaptive capacity, which deals with both anticipatory and reactive adaptation actions, absorptive capacity is concerned only with anticipatory responses –whether climatic or non-climatic. Likewise, Rajib Shaw et al. (2009) and Jonas Joerin et al. (2014) developed a Climate Disaster Resilience Index (CDRI) to measure resilience related to hydro-metrological disasters (i.e. that ensue from floods, droughts, cyclones,

[13] The Sendai framework for Disaster Risk Reduction 2015-2030, adopted at the UN World Conference in Sendai, Japan on March 2015, builds on the Hyogo Framework for Action (2005-2015), which provided guidance to reduce disaster risk and has contributed to progress towards the Millennium Development Goals. This recent framework sets strategies to meet global targets of risk reduction related to environmental, technological, and biological hazards and risks. Investing in disaster risk reduction for resilience is a major priority of the Sendai Framework.

and rain-fall-induced landslides among others) and which includes natural, physical, economic, institutional, and physical variables. In Table 5.1, we summarize these frameworks along with their indicators and variables. In general, these frameworks highlight disaster preparedness and incorporate ex-ante or ex-post actions to reduce climate change risks, particularly those that ensue from rapid onset climatic events. Although, not all the variables are directly relevant to urban design and planning, those variables that relate to enhancing the resilience of the physical environment will influence urban form, such as the physical infrastructure sector that bears a strong impact on the morphological attributes of urban forms through impacting factors like street connectivity (Table 5.1). Moreover, this sector prioritizes local and goal-oriented actions to tackle natural disasters posed by climate change. Thus, physical infrastructure indicators measure resilience only in relation to an expected natural hazard and associated impacts and focus more on defensive strategies, strengthening structures for instance, than incremental transformability to cope with unknown circumstances.

Table 5.1 *Indicators and variables to assess a community's resilience: a review*

Frameworks	Indicators	Variables
Integration with nature	Wetland (increase/loss)	Increase or loss of land area over time
	Erosion and land degradation	Annual average rate
	Porosity of built infrastructure	Percentage of impervious surface
	Biodiversity	Extent of local species
	Ecosystem services	Extent of preserved ecosystems
Social wellbeing	Demographic profiles	Population – number, age, health, gender, education, among others.
	Social capital and networks	Community value-cohesion Faith-based organization
	Equity	Access to transportation, resources, and services (health care, education, … etc.)
	Livelihood protection	Amounts of livestock and working animals, tools, and seeds
	Cultural protection	Cultural and heritage resources and religious sites
Economic strength	Employment and assets	Household income, single sector dependency, property values, and business sizes
	Community disaster reduction fund	Amount of resources and accessibility to them Financial protection, subsidies, and insurance availability Public-private partnerships
Institutional capacity	Institutional networks	Degrees of collaboration and coordination at different layers
	Disaster management	Progress of risk assessment, mapping, management, and preparedness plans
	Enforcement capacity	Application of zoning and building regulations
	Governance and local competence	Political fragmenting Involvement of communities in disaster management process Knowledge dissemination and management Early warning Local understanding of risk and preparedness

Urban form and physical infrastructural attributes	Protection strategies	Number of defence structures (e.g., in coastal areas)
	Lifelines and critical infrastructure	Age and quality of infrastructure (electricity, water supply, sanitation, and solid waste disposal)
	Transportation networks	Accessibility of roads Connectivity of internal road network Quick and safe evacuation
	Residential, commercial, and manufacturing establishments	Establishments' age, stock, and availability Construction and design safety

5.3.2 Understanding urban form's resilience: planning and design viewpoints

The emergence of the term resilience is relatively recent in the urban design and planning literature and practice. We argue that at least six concepts, namely: ecological sensitivity, multi-functionality, polycentricism, redundancy, connectivity, and indeterminacy, that influence built environment's resilience have already existed within notions such as open architecture, landscape ecological urbanism and mat urbanism among others.

To begin with, N. John Habraken's open architecture, which emerged as a response to the alienation of end-users and to the rigidity of modernist architectural layouts, hence, advocated for the needs and preferences of end-users through flexibility and diversity in the design of mass housing after WWII (Ellin, 1999). By considering future socio-economic and personal changes as unknowable, uncertain, and variable, and by underscoring future needs for technical upgrading, open architecture thus distinguishes between the structurally fixed and durable supports (or hard elements) and the undetermined and changeable in-fills (or soft elements) (N John Habraken, 1972). Thus, open architecture facilitates in achieving adaptability and fit; a well-adapted place represents the well fit between form and function, as Kevin Lynch (1981) noted. Open building (Kendall & Teicher, 2000) and flexible housing (Schneider & Till, 2007) emerged later from open architecture. At the urban scale, open architecture promotes polyvalence or ***multi-functionality*** where the urban form is designed to accommodate multiple functions (Hertzberger, 1991; Leupen, 2006) that Peter Allan et al. (2013) and Ayyoob Sharifi and Yoshiki Yamagata (2014) later redefined as the ability of urban form to accommodate mixed-uses specifically with the objective of enhancing urban resilience.

Secondly, a group of –mostly- landscape architects have been advocating for ecological design and planning to become the basis for urban form that is in harmony with nature and that responds to environmental change (Steiner, 2011). Building on Ian McHarg's (1969) Design with Nature, landscape ecological urbanism underscores ***ecological sensitivity*** by considering the eco-system's components as the fundamental blocks for urban development (in lieu of the morphological components) that respond to "temporal change, transformation, adaptation, and succession" (Waldheim, 2006a, p. 39). Thus, projects based on landscape urbanism's principles reflect the indeterminacy and flux of contemporary urbanism while deploying ecological functions as catalysts for urban wellbeing. This emphasis on ecological resilience through ecological design and green infrastructure by integrating natural and human systems yields "ecologically sound development" –a term often used interchangeably with "sustainable development" or "ecologically sustainable" development (Lele, 1991, p. 608). Surely, ***ecological sensitivity*** enhances a system's ability to survive disruptions and enables it "to adapt to the irreversible, unpredictable, and ongoing changes that follow" (Freitag, Abramson, Chalana, & Dixon, 2014, p. 334).

Akin to McHarg, Allison Smithson's (1974) mat urbanism is extrapolated from mat architecture where the on-going functions and events configure spaces. Accordingly, mat urbanism underscores ***indeterminacy*** through flexibility, continuous evolution over time, the absence of boundaries, and through the active interstitial spaces or "the space between things" (S. Allen, 2001, p. 123). Mat urbanism also promotes ***modularity*** through clusters and ***connectivity*** through the stems between them where such stems may refer to the street networks, or to the weaving or knotting together of the landscape's components through functions where "The variations within the natural surfaces –the tree canopy, the hard-surfaced roads, the undergrowth of the rambles, the springy mat of the lawns– each support distinct and interrelated functions that make up the varied social ecology" (S. Allen, 2001, p. 123).

Building on this notion of functional linkages, ***connectivity*** in a city's spatial organization and street network enhances its resilience which is achieved in the "gridiron" form whose horizontal surface expansion conforms to pre-established regulations (Corner, 2006; Smets, 2002). In fact, within human environments these regulation allows differentiation with connectivity and creates hierarchical structures while simultaneously linking all scales (Mehaffy & Salingaros, 2015). Such pre-established regulations may also include adaptation strategies whether for rapid onset events (such as evacuation plans) or for slow onset events that entail long-term changes. For example, the Seine River-Gauche development in Paris deploys the grid as a coherent urban layout that exhibits predetermined ways to attain flexibility without impeding future opportunities or changes. Additionally, due to the combination of the grid's connectivity and modularity, a failure of any part of the system precludes impacting the safety of the system's other parts. This "safe-to-fail" idea has in fact become a popular notion for sustainable and resilient developments, particularly in landscape design (Ahern, 2011; Lister, 2007). Safe-to-fail also promotes ***redundancy*** and ***polycentricism*** (or distributed system). Redundancy is associated with modularity since it similarly entails damage to some parts instead of the whole while polycentricism distributes the risk across a wide area and a diversity of systems. Together, redundant connections and polycentric systems generate alternatives that function as back-up plans when responding to rapid onset climatic events, thus they enhance resilience and address uncertainty (Sharifi & Yamagata, 2014; Walker & Salt, 2006).

Stanford Anderson (1978) delves further into uncertainly through ***indeterminacy*** by identifying a triad of urban domains based on potential, namely: exploited potential, recognized but unexploited potential, and unrealized potential. As an innate design feature, indeterminacy incorporates the latter two potentials and refers to urban spaces and buildings whose purposes are not predetermined in order to enable urban forms to cope with uncertainty by accommodating functions as they arise whether they ensue from rapid or slow onset climatic events. For example, Moudon's (1986) study of San Francisco identifies undetermined spaces with yet unrealized potential that are generated by the accidental intersection of irregular streets and which allow adjacent communities to accommodate their arising needs. More recently, Rob Roggema et al. (2012) have associated such unrealized potential spaces with the existing urban nodes of Dutch cities, which they dubbed "unknown spaces" whose objective is to facilitate coping with rapid onset climatic events by accommodating a variety of functions during and immediately after a disaster like debris collection and emergency shelters.

In summary, the review of resilience thinking both from socio-ecological and planning viewpoints reveals that while they recommends a few similar approaches (e.g. ecological awareness), their objectives differ fundamentally. For example, the socio-ecological frameworks advocate *predict-and-prevent approaches* that focus on early preparedness and recovery actions primarily related to climatic extreme events. More specifically, these frameworks have yet to consider three important characteristics of adaptation and/or resilience thinking. First, they generally underscore rapid onset climatic events and thus miss the capacity to cater for gradual and long-term changes that are needed in the process of coping with climate change and uncertainty. Second, they involve preventive strategies for dealing only with impacts predicted or experienced, thus overlooking indirect climatic impacts and uncertainty. Last, they include actions only to protect communities and infrastructure from disasters, following a bounce-back model, but fail to exploit the potential benefits of a changing climate –a key attribute of adaptation. In contrast, planning and design viewpoints essentially consider *uncertainty-oriented-approaches* to deal with relatively long-term coping ability of built environments (except Roggema et al.'s proposition). In other words, planning viewpoints address the three shortcomings of socio-ecological frameworks while promoting pre-emptive approaches deal with gradual but primarily non-climatic events and adopting bounce-forward resilience, similar to the absorptive capacity of a socio-ecological system. The planning literature generally highlights the innate design potential of urban forms to be transformed incrementally over time to cope with uncertainty–albeit not directly related to climate change but pays little attention to rapid onset events. Table 5.2 compares the resilience thinking between the socio-ecological and the urban planning literature. Against aiming for this enormous adaptability and resilience, Lynch (1981, pp. 174-175) warns us that "desire for increased manipulation must be limited at least by two qualifications: never so easy as to threaten psychological continuity or so broad of range as to unleash unmanageable social conflict".

Table 5.2 *Resilience in socio-ecology and planning literature*

Literature	Types of resilience (conceptual)	Application strategies (resilience)	Focus (potentials)	Adaptation types	Primary concerns
Socio-ecological	Bounce-back	Predict-prevent approach	Rapid onset	Proactive and reactive	Emergency preparedness, recovery actions
Planning and design	Bounce-forward	Incremental transformation over time	Mostly slow onset	Proactive	Ability to cope with unknown circumstances (not related to climate change)

The adaptations, recommended by the IPCC regarding urban settlements consider a balanced response between post-ante and ex-post actions, and slow and rapid onset events; however, priority is given to the long-term transformability of city forms to enhance resilience (Revi, et al., 2014). Since the details of rapid onset events remain unavailable, particularly at the level of a city itself representing complex interactions among many biophysical and human agents, planning city infrastructure and resources to seek only to reduce predicted climatic impacts without exploiting other potentials is undesirable. Therefore, integrating concepts from both the socio-ecology and the planning literature, particularly those are related to attributes of urban forms, would help achieve the balance.

5.4 An urban design framework to measure resilience: concept, indicators and variables

The key objectives of resilience discussed in the urban planning literature are: i) to cope with an unknown future, not necessarily resulting from climate change, and ii) to promote the physical and functional ability of urban forms to respond to incremental changes in both the natural and the human systems. Thus, these objectives adjust Folke's evolutionary changes of a society while moving toward ecological and evolutionary resilience. While both the ecological and evolutionary resilience address slow onset events, their capacity to handle rapid onset events is limited. However, in responding to such events most socio-ecological frameworks include protective strategies rather than evolutionary ones and emergency disaster management and often exclude physical planning and design interventions (Table 5.1).

Thus, to overcome this limitation and integrate different forms of resilience and adaptation discussed across disciplines, this paper proposed a comprehensive framework consisting of six concepts for understanding and measuring resilience of urban form. The selection of these concepts entails their urban design potentials that influence the resilience of urban form while simultaneously balancing reactive and proactive adaptations and short- and long-term planning responses. Figure 5.1 plots them into a conceptual resilience-adaptation framework to understand their scope.

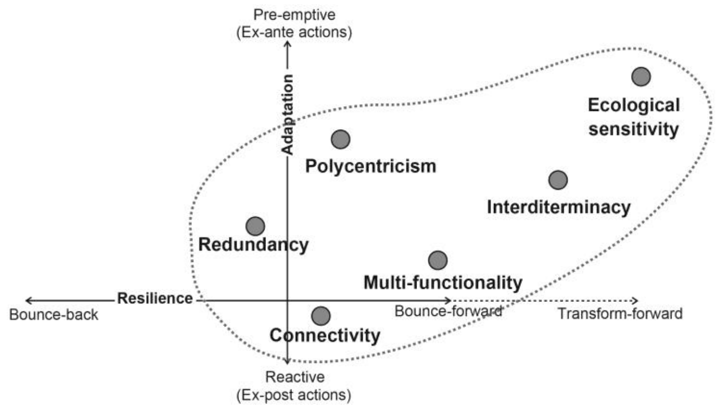


Figure 5.1 The six urban design concepts and their relation to adaptation and resilience

Although these concepts may or may not be directly associated with urban form, they may enhance urban infrastructure resilience to climatic uncertainty. Drawing on the potential links between shaping urban form and building resilience, Table 5.3 identifies possible indicators and variables that influence the transformability of built environments, as in evolutionarily resilience advocacy.

Table 5.3 *The urban design framework and its six variables and measures*

Concepts	**Brief description**	**Indicators**	**Variables**	**Sources**	
				Socio-ecology	Planning and design
Ecological sensitivity	Incorporates ecosystems into design and planning to promote long-term resilience of built environments to cope with variability rather than just reduce it	Ecological conservation Impervious urban surface Open or green areas	Amount of areas conserved and their conditions Floor area ratio Size of building footprints	(Cutter, et al., 2008; Joerin, et al., 2014)	(McHarg, 1969) (Sharifi & Yamagata, 2014)
Multi-functionality (polyvalence)	Includes design opportunities to accommodate several programmatic requirements over time while involving no/few additional resources	Mixed-uses and variability Spatial heterogeneity, Variety of buildings Adaptive land use	Mixed land use: both in human and natural system Land uses avoiding disaster prone area Building ages and density	(Walker & Salt, 2006)	(Jacobs, 1961) (Cadenasso, et al., 2013; Sharifi & Yamagata, 2014)
Polycentricism (distributed/ modular system)	Promotes “safe-to-fail” approaches that spread out risks of a system spatially and temporally without affecting other parts of it. It thus discourages centralized systems.	Polycentric urban form and land use, Potential of street networks (grids) to support distributed system	Degree of decentralization (e.g., water supply and energy) and their independencies	(Walker & Salt, 2006)	(Batty, 2001; Lister, 2007; Moudon, 1986; Smets, 2002)

Redundancy (diversity)	Advocates multiple components of an urban form for serving the same or similar functions to prevent collapse of whole system if one part fails	Adaptation strategies available Diversity in physical infrastructure Evacuation routes/plans Infrastructure redundancy	Number of adaptation measures taken (e.g., presence of sea walls) Number of alternative sources/services (water, energy, waste management, evacuations, etc)	(Low, Ostrom, Simon, & Wilson, 2003; Tierney & Bruneau, 2007)	(Allan, et al., 2013; Sharifi & Yamagata, 2014)
Connectivity (permeability)	Enhances accessibility on various scales, facilitates disaster management and emergency evacuation, and maximises development opportunities to incorporate long-term change	Street connectivity, small blocks, pedestrian route Accessibility to evacuation routes (disaster plans)	Block size Number of node pedestrian and vehicular Proximity and visibility of evacuation path	(Cutter, et al., 2008; Joerin, et al., 2014)	(Allan, et al., 2013; Sharifi & Yamagata, 2014)
Indeterminacy (openness)	Highlights flexibility and innate potential of urban form through planning and design; transforms as needed to cope with uncertainty	Ability of urban form during emergency Transformability to address unknown circumstances	Type and range of functions (or potential) served The extend of urban form to change (physically or functionally)		(Corner, 2006; N John Habraken, 1972; Roggema, et al., 2012)

5.5 Case study and methods

5.5.1 Geographical focus

The case study focuses on Negril, a small city on Jamaica's north-west coast and one of the most-popular Caribbean tourist destinations (Figure 5.2). Its tourism industry alone contributes over 5% to the national GDP. Long Bay, a seven-mile transect of Negril's densest and low-lying area, has experienced climate change impacts including beach erosion in recent decades. Based on historical data, a recent technical report (CEAC, 2014) confirmed that Long Bay's erosion, which is higher than its neighbours', ranges between 0.2 and 1.4 m/year and 43% to 91% results only from sea-level rise (Figure 5.3). Several agencies provide planning and design strategies–predominately focusing on coastal protection–to enhance Negril's resilience to climate change. This study investigates those strategies implemented or proposed for designing of urban form and how they influence the resilience of Long Bay's built environment.

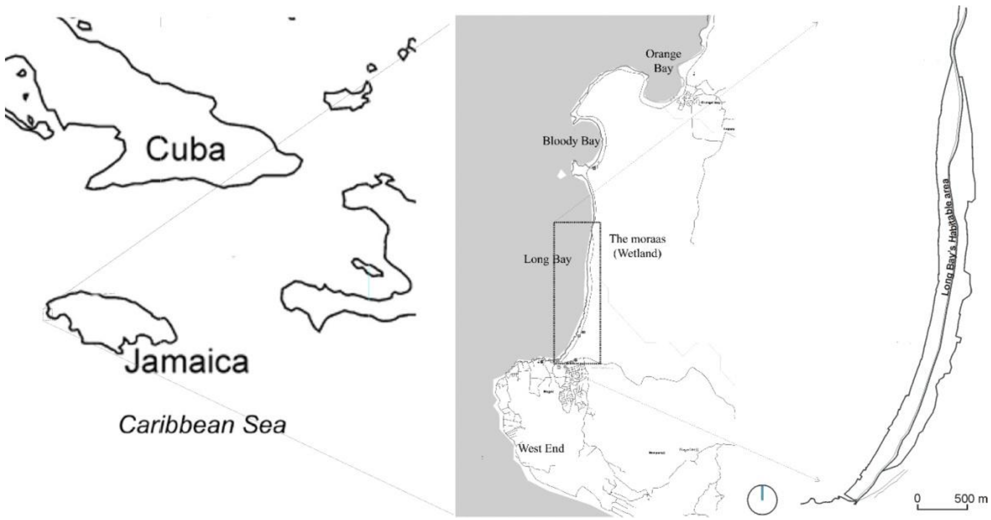


Figure 5.2 Long Bay, the study area

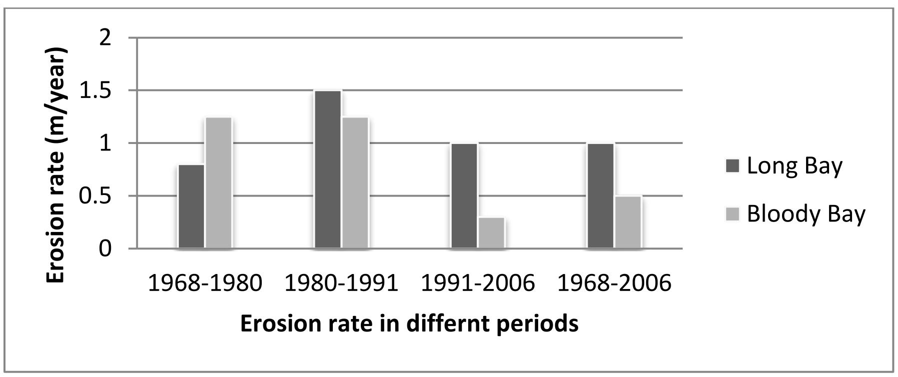


Figure 5.3 Long Bay's beach erosion compared to its neighbour (adapted from SWI 2007 in (CEAC, 2014)

5.5.2 Insights of adaptation planning

Empirically, this research began with semi-structured in-depth interviews with planning, design, and environmental professionals directly involved in local physical development to tackle climate change impacts. Interviewees were selected using both purposeful and snowball sampling approaches, and interviews ceased when the investigation reached saturation–when no new information was emerging. Firstly, relevant agencies and divisions were identified through reviewing web sites and consulting with the researchers' network of academics and professionals, including local journalists, graduate students, environmentalists, who helped identify suitable contacts for this research. As the agencies' head offices in Kingston make planning and development decisions for the entire island, the researchers began meeting people representing these incubators during the fieldwork in 2015, then those in Negril. Sixteen professionals were initially invited by phone and/or email and requested to share contact information on peers who could also contribute to and support this research. This snowball approach resulted in interviews with 19 professionals, in total, with 16 years experience on average. Table 5.4 lists their departments and locations. Most sessions encompassed an hour-long in-person discussion highlighting i) climate change in Negril, ii) adaptation planning strategies and challenges, and iii) the six urban design concepts for enhancing and measuring resilience in Long Bay. However, three participants discussed the two former topics in the context of the entire island and were reserved in responding specifically about the study area as they were not fully aware of Long Bay's built environment.

Table 5.4 *The agencies that considered for the interview*

Agencies	**Agency types**	**Head office (Kingston)**	**Local office**
National Environment and Planning Agency (NEPA)	Govt	√	√ (Enforcement branch, Negril)
Urban Development Corporation (UDC)	Govt	√	
Ministry of Water, Land, Environment & Climate Change (MWLECC)	Govt	√	√ (Negril Green Island Local Planning Authority) (NIGALPA)
Office of Disaster Preparedness And Emergency Management (ODPEM)	Govt	√	√ (Westmoreland parish)
Negril area Environment protection trust (NEPT)	Non-Govt		√
Jamaica Hotel and Tourist Association	Non-Govt		√ (Negril Chapter)
National Best Community Foundation	Non-Govt	√	

5.5.3 Observed scenarios

With the formal interviews, this study used direct observation to clarify, document, and compare the current scenarios for Long Bay's built environment, focusing on urban morphological dimensions. In support, urban morphological information was collected from the Mona Geoinformatics Institute at the University of West Indies and the National Land Agency of Jamaica. Local people and tourists also informally shared observations about changes to the coastal built environment.

5.5.4 Data management and Analysis

Interview data were transcribed into text, and observations were documented using field notes, photographs, and relevant software (e.g., AutoCAD), integrated with secondary urban morphological information. This study followed a structured and time-efficient approach, recommended by Crabtree and Miller (1992), which includes a priori coding system and content analysis to encode and organize the interview data and develop themes (Fereday & Muir-Cochrane, 2008). A theme refers to "a pattern in the information that at minimum describes and organises the possible observations and at maximum interprets aspects of the phenomenon" (Boyatzis, 1998, p. 161). To facilitate coding and interpretation, interview scripts were classified as dealing with i) climate change threats to Negril's built environment, ii) professional viewpoints on adaptive designs of Negril's urban form, and iii) the six design concepts to measure Long Bay's resilience. Next, the results were plotted in a matrix using a Likert scale that weighed qualitative values that were then triangulated with physical information observed and obtained elsewhere to ensure the study's validity.

5.6 Long Bay's urban form and vulnerability

Jamaicans are very aware of climate change's local impacts: "the issue with flood and drainage is not right now associated with natural or normal rain falls; it is really a climate change phenomenon", a respondent stated. Beach erosion is a major threat, and different sources confirm that Long Bay, one of Jamaica's fastest eroding beaches, has consistently narrowed by an average of 0.8 m/year. (CEAC, 2014; Veira, 2014). Moreover, extreme events severely impact Long Bay's coastal built environment and tourism industry. According to the IPCC report, more-intense extreme events are expected globally, although their frequency might be reduced. Intense events (e.g., category 3 to 5 hurricanes) have increased locally, with surges ranging between 1.2 to 3.2 m (Figure 5.4) (CEAC, 2014).

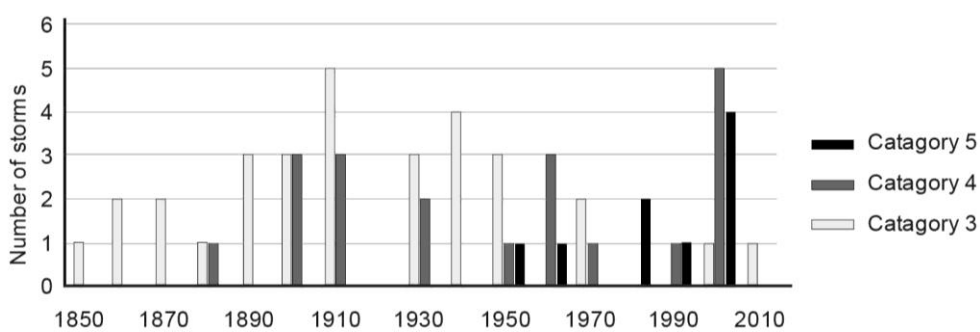


Figure 5.4 Hurricane records of categories 3, 4, and 5 passing within 300 km of Negril between 1851 and 2012 (adapted from CEAC, 2014)

Interviews revealed that local climate change issues are interrelated (Figure 5.5), and thus solutions require integrated planning and development. Yet Jamaica's contribution to global emissions of carbon dioxide has been calculated at only 0.02%, ranking 106th worldwide in 2012 (UNFCCC, 2015). Impacts attributed to global climate change (e.g., rising sea temperature and ocean acidification) and anthropogenic actions (e.g., sewage pollution and illegal farming in wetlands) have collectively contributed to the degradation of coral reefs and sea grass beds. These marine ecosystems would normally reduce wave energy, facilitate sand production, and increase ecological resilience. Now, both local communities and ecosystems are at risk, with Long Bay experiencing greater beach erosion. The increasing intensity of rapid onset events has also affected Negril's coastal settlements, accelerating this erosion. The 2012 upgrade of the sewage treatment plant (in Sheffield) dramatically reduced sewage pollution; however, only limited efforts have been made to control other accelerating climate change risks.

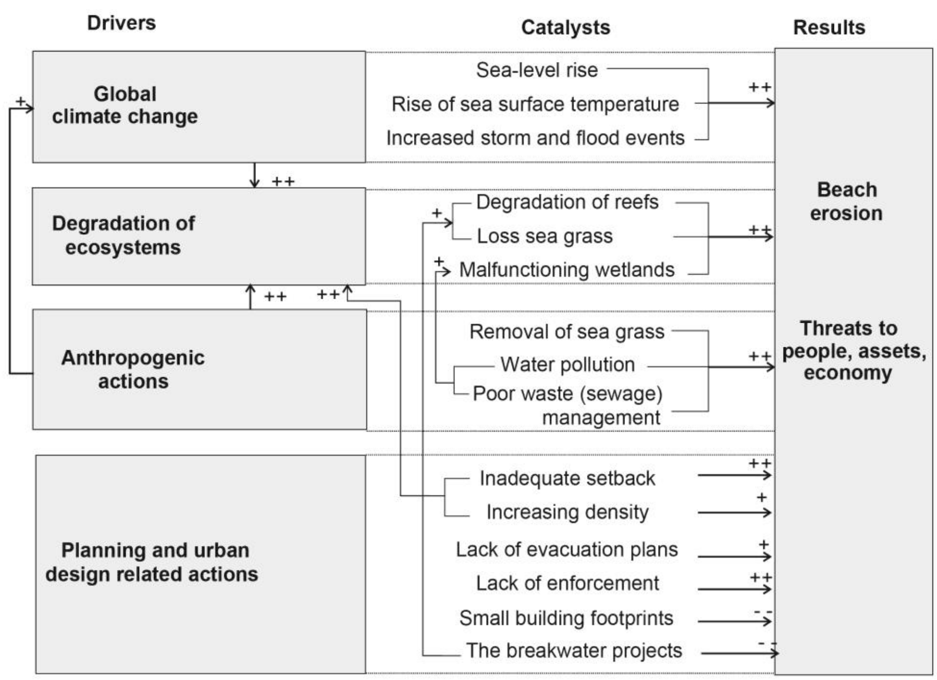


Figure 5.5 Long Bay's interrelated problems
Note: (+) indicates the increase of vulnerability or its causes, whereas (–) means their reductions

Lack of preparedness through planning and design amplifies these problems. As Freitag, et al. (2014) argued, conventional preparedness and pre-disaster planning (i.e., anticipatory adaptation) begin with anticipating hazard scenarios that forecast likely climatic events and estimating their impacts on built environments. Responses include reinforcing building/structures (i.e., with hard-engineered constructions and bounce back models) or relocating structures from hazard prone areas (i.e., retreat). Jamaica's government is about to submerge a breakwater, a protection-adaptation approach, one mile offshore, despite locals awareness of its negative impacts on ecosystems. Nevertheless, the project's anticipated positive outcomes have led the government to expand tourism and raise building-height restrictions by one floor, thus increasing density and consequent revenue. Local planners argued for a study of Long Bay's carrying capacity to precede this development as the area is highly vulnerable to sea-level rise. Against a legal setback of 45 m, existing buildings are very close to the sea, on average distance of 15 m from shore. New or retrofitted properties adjust their buildings to improve the setback. For example, recent renovations to Veraclub Negril (previously Merrill Beach Resort I) included partial demolition of old buildings to increase the setback (Figure 5.6). Such adjustment is still possible for properties with low density and small building-footprints. As retreat/relocation is impossible without sufficient room, respondents have advocated stilt developments and innovative design strategies, including amphibious and floating developments, and improved reinforcement of building codes. The following sections discuss the six urban design variables used to measure Long Bay's current resilience and thus improve it through design based on local professionals' opinions.

Figure 5.6 Increasing setback: Veraclub Negril in 2014 (left) and in 2015 (right)

5.7 Measuring Long Bay's resilience

5.7.1 Ecological sensitivity

Degradation of marine ecosystems has reduced their natural ability to lower wave energy and produce sand for Long Bay's beach. Several resorts have adopted adaptation strategies using ecology and ecosystem services, including providing substrates for colonizing reefs, which align with ecosystem-based adaptation (Dhar & Khirfan, 2016). The Town and Country Planning Provisional Order for Negril (2013) also recommends enhancing and maintaining healthy local ecosystems. Most respondents agreed the trends toward small building footprints permits more open areas, providing room for local vegetation and pervious surfaces that decrease surface runoff. For example, blue mahoes (i.e., *Hibiscus elatus*), sea grapes (i.e., *Coccoloba uvifera*), and mangroves can reduce storm impacts by cutting wind energy. Sea grapes are widely preserved and planted across the bay, and local people and professionals are aware of their benefits (Figure 5.7). They also agreed that ecological and landscape design features, such as bioswales and streetscapes, minimize flood and surface runoff impacts and reduce pollutants during heavy rain.

Figure 5.7 Sea grapes protect Long Bay's built environment by reducing wind energy

5.7.2 Multi-functionality

Currently, Long Bay supports mixed land use, including tourism, light commercial and residential developments, but resort-oriented developments dominate. When asked to speak about sea-level rise and its impacts, local planners considered retreat (e.g., moving structures away from existing or potential hazards) as the ultimate option. Considering future risks and beach-tourism, they advocate partial retreat, perhaps relocating residences and tourists' accommodations to safer places, e.g., nearly Sheffield. However, the existing Long Bay area could still provide light commercial and entertainment activities, e.g., bike rental and souvenir shops, restaurants, and bars. Tourists would enjoy the beaches and these activities only during daytime. Based on the area's carrying capacity, current land uses and proposed development polices need to be flexible enough to adapt to future needs.

5.7.3 Distributed systems (polycentricism)

Distributed systems can be conceptualized as spatial classification of an area based on various infrastructural facilities. Long Bay's linear built environment depends on a single street, Norman Manley Highway, and centrally managed urban amenities and services, including electricity, waste management, and water. Even partial damage to any of these services makes the entire area vulnerable. For example, a 2010 flash flood impacted the highway and resulted in the entire area being inaccessible for ten days. The centralized layout results from the topography and prevailing development patterns. Yet, a few local planners believe that with additional physical infrastructural networks, the entire area can be divided into several zones (modules); however, their integration is also necessary (Figure 5.8). Many recommended a centrally managed sewage system to reduce operational costs and resource use.

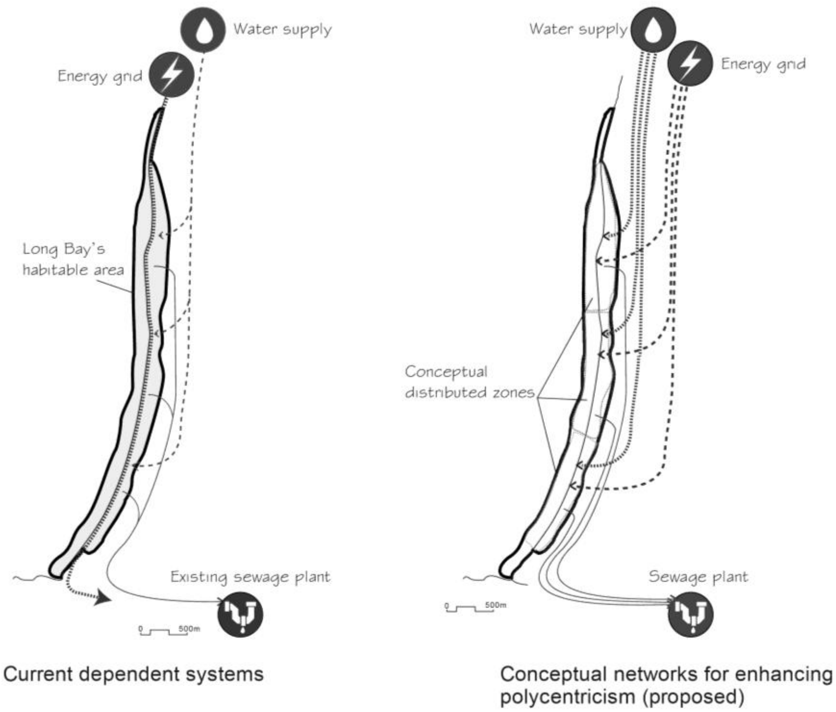


Figure 5.8 Long Bay's current polycentrism and potentials

5.7.4 Redundancy

Redundancy is useful, particularly in dealing with rapid-onset-event impacts; it offers back-up and alternative strategies, services, and infrastructure that are safe-to-fail and enhance passive survivability[14] during emergency period after a disaster. Local professionals report that Negril has such redundancy in its telecommunication system; land-lines may substitute for mobile networks or vice verse. Long Bay's urban form depends on only one street, as well as the centrally managed water and waste systems. The government is now promoting solar or renewable energy sources to reduce dependency on the national grid, and also rainwater harvesting at the individual-project level. However, renewable energy plants are evident only at Rick's Cafe in the West End and the Fiesta Hotel in Hanover, not in Long Bay, where fossil-fuel-driven generators act as back-up for everyday use, not just emergencies and emit greenhouse gases. Local planners agree on the potential benefits of redundant systems but are concerned about the additional resources needed. Figure 5.9 illustrates the areas's dependency on a single system and an alternative layout to improve redundancy.

[14] Passive survivability refers to built environment's ability that offers critical life-support conditions for its users for an extended periods even without basic amenities during or immediately after a disaster (A. Wilson, 2006).

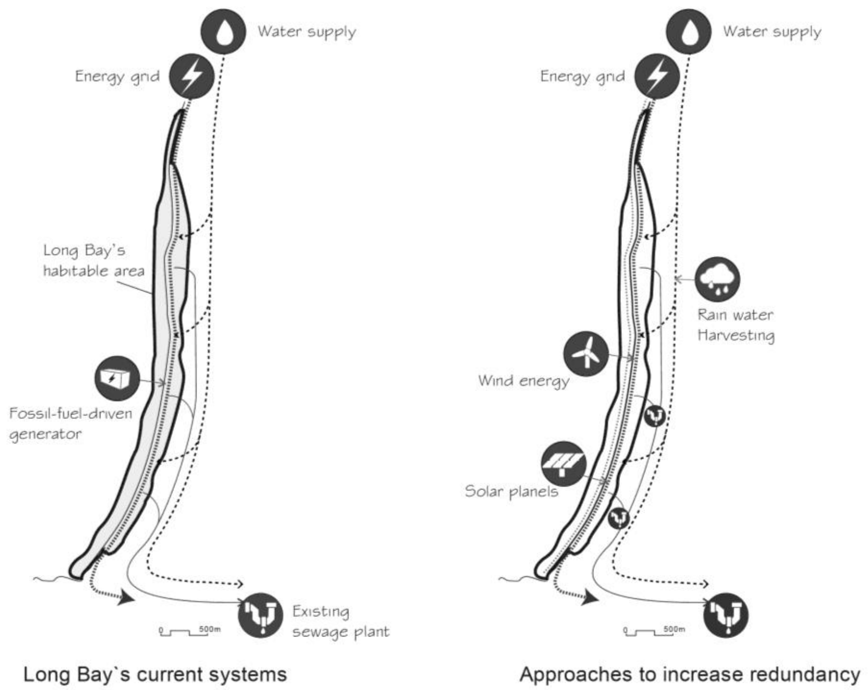


Figure 5.9 Long Bay's existing infrastructure and potential redundancy

5.7.5 Connectivity

Long Bay's current spatial layout lacks efficient street networks, making the beach somewhat publicly inaccessible from various places, including the highway. Local professionals recommend paths or walkways parallel to the highway, to increase connectivity between buildings and properties and so facilitate both emergency evacuation and recovery actions (Figure 5.10). Street networks could connect the potential polyvalent spaces along the bay provided by properties and so accommodate people during emergencies. In addition, they would enhance socio-cultural tourism while hosting current street/beach vendors.

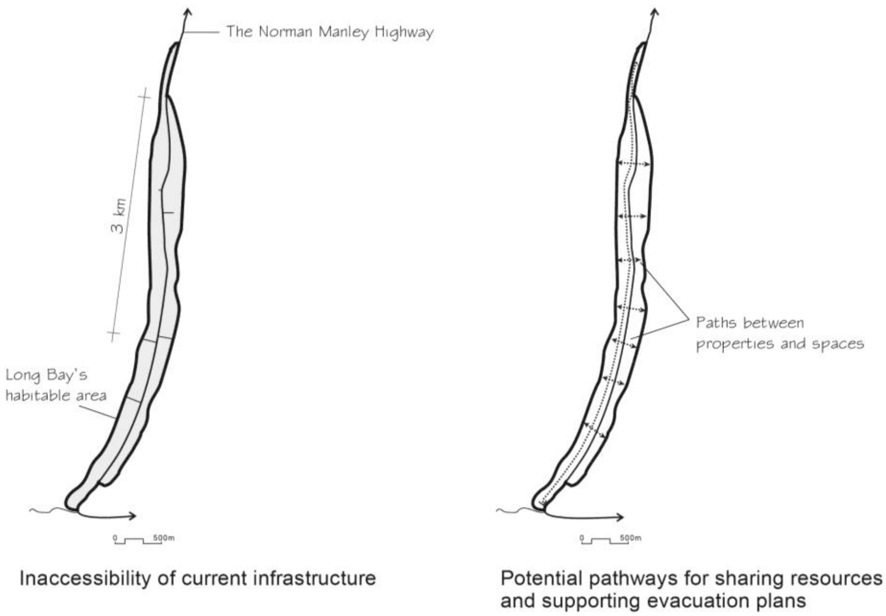


Figure 5.10 Multi-level connectivity enhances Long Bay's resilience

5.7.6 Indeterminacy

Currently, the Negril Planning Authority's community hall serves as the area's emergency shelter. The two public beach-parks at opposite ends of the bay could also act as temporary shelters for people at risk and help recovery actions by piling up building debris and seaweed. Hardly any similar open spaces are available within this seven-mile bay (Figure 5.11). Local professionals recommend that during disasters everybody should move to emergency shelters; however, moving is not mandatory in Jamaica, as it is in Cuba. Thus, respondents recommend that each hotel have its own emergency plans, including emergency shelters and evacuation paths, integrated with the area's anticipated central disaster plan. Such shelters should be located in permanent structures, be polyvalent, and be situated above predicted storm-surge levels (i.e., 3.2 m). A few hotels, e.g., Travellers Beach Resort, have already addressed the need for evacuation and shelter and made their lobbies (as polyvalent spaces) available during emergencies. Additionally, current low-rise development (e.g., temporary structures along the beachfront) and small building footprints hold potential to incorporate such flexible spaces and to support future development decisions based on climatic uncertainty.

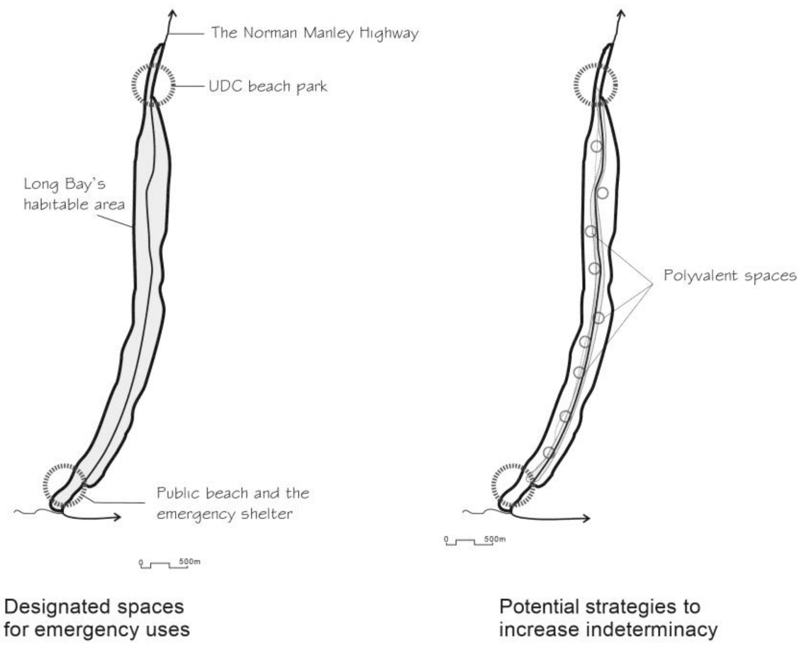


Figure 5.11 Long Bay's current indeterminacy and its potential

In summary, empirical evidence confirms that Long Bay's planning and design still lack resilience and fail to incorporate ecological design and sufficient redundancy (Figure 5.12), even though one respondent claims that "in general, good planning should have some redundancies...in terms of physical, economical and environmental development". However, there is clear potential to enhance resilience (Figure 5.8-5.11). So far, the local adaptation planning predominantly includes strategies to reduce the direct impact of climate change and facilitate recovery actions, but considers Long Bay's current state of built environment as *normal* and highly acceptable. These strategies aim to maintain this state or return to it after any disturbance (i.e., similar to a bounce-back model) rather than to increase its inherent and transformative abilities so as to cope with long-term uncertainty. For example, the breakwater project, a protective measure, represents resistance but not resilience; however, integration is essential in adaptation (Stead & Taşan-Kok, 2013). What will happen after the lifespan of the project or if it fails is still uncertain. In enhancing overall resilience, the government is reluctantly implementing and enforcing other adaptation strategies (short- and long-term) in terms of physical planning and design, including setbacks and evacuation plans, and stilt developments, but simultaneously and paradoxically exposing more people and assets by approving more density.

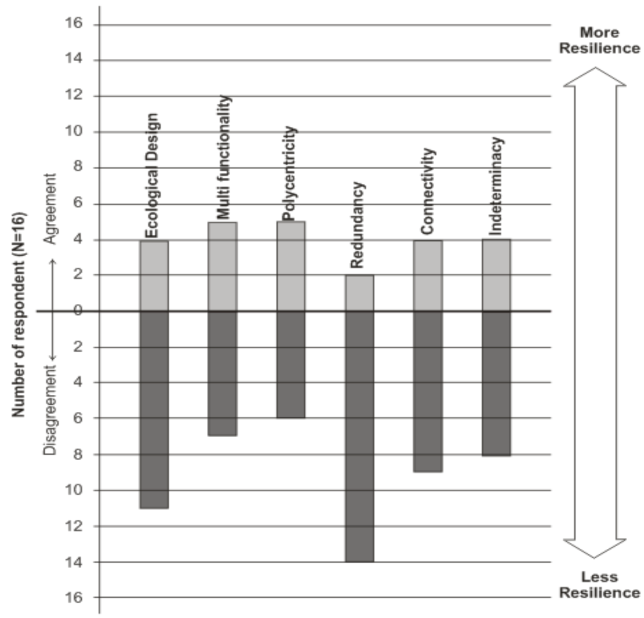


Figure 5.12 Long Bay's current resilience based on the six concepts

5.8 Conclusions

Climate change poses enormous challenge to human settlements, with effects ranging from short-term emergency recovery to long-term changes and uncertainty. In general, adaptations related to the design of physical infrastructure so far consider engineering resilience (i.e., a bounce-back model) and deal primarily with rapid onset events. Most coastal areas like Negril still depend on this model, which usually ignores the ecology or evolutionary form of urban resilience that advocates for incremental transformation ability of urban form to tackle climatic uncertainty. Assessing an area's current resilience influenced by the design of urban form is thus essential for informing future adaptation planning. Successful adaptations often integrate socio-ecological and physical characteristics, relying on unique local features (e.g., resources and technology available) that could enhance resilience not only to absorb observed direct climatic impacts (e.g., slow and rapid impacts) but to tackle long-term uncertainty occurring incrementally and indirectly. This assessment can even facilitate generating context-specific urban design guidelines to nurture the unique potential of an area. The proposed six urban design concepts and their variables provide a framework for assessing resilience from the point of the complexity between urbanization and socio-ecology systems challenged by climatic change.

The underlying foundation of the proposed framework connects different viewpoints of resilience discussed in socio-ecology and in urban planning literature–hitherto isolated–and explores theoretical links to contribute to climate change adaptation. Overall, this integration advances resilience discourse and potentially links to sustainable development so as to address theoretical shortcomings. As Roger (2015, p. 64) argued: interaction "between socio-ecological sustainability, and discourses of disaster preparation, prevention, responses, and recovery" has yet to be achieved. These concepts provide urban design guidelines, albeit narrowed to the Negril context, for design and planning professionals and related policy makers to best use them on a local scale. These concepts and their associated variables, identified in Figure 5.3, are essentially abstract and context-free and thus can be generalized and applied to similar contexts and situations.

Thus, this paper advances the understanding of conceptual and practical links among urban resilience, urban planning and design, and adaptation, for use in measuring and improving the resilience of an area through design for an unknown future while optimizing resources in a sustainable manner.

Chapter 6 : Synthesis and Conclusions

6.1 Introduction

This chapter begins by presenting the significant findings of this research in relation to meeting the research objectives. As mentioned previously (in Chapter 1), this dissertation includes four stand-alone manuscripts. The following sections discuss the background of and rationale for these manuscripts while sequentially investigating the research questions and highlighting key lessons learned from this research and potential contributions from the Caribbean and global perspectives. Eventually, such lessons lead to a discussion of several possible directions for future planning research vise-e-vise linking resilience, adaptation, and contemporary agendas on climate change and sustainable development, followed by concluding remarks.

6.2 Study synopsis: adaptation is a process

For Negril, an integrated plan is highly recommended, one that combines several adaptation strategies, including hard engineering to soft ecosystem based ones and urban (ecological) design strategies that promote resilience and flexibility. The future adaptive urban form would reflect a fusion of these approaches, even though adaptation varies depending on the degree of vulnerability and exposure of a system to climate change. Most importantly, this integrated approach should begin by incorporating local preferences, resources, technology, and knowledge available to operate and maintain the system over time in a sustainable manner. In doing so, for example, landscape ecological urbanism prioritizes ecology-based approaches for planning and development and certainly facilitates such strategies. This dissertation highlights the incremental transformability of urban forms so that they can be changed to address the complexity and challenges of urban systems coupled with climate change.

The explicit goal of ideal planning is to facilitate real-world decision making (Fischer, 2012). Similarly, good adaptation lies in its processes, not in its outcome, often as a part of long-term planning for a city. This dissertation emphasizes this similarity between good planning and good adaptation and places adaptation thinking onto a trajectory for long-term planning to meet the challenges posed by climate change. Thus, successful adaptation requires integrated approaches and aims to promote sustainable development while simultaneously optimizing natural recourses. If the scope for managing retreat is limited as in an area like Negril, accommodative adaptations offer more opportunities to promote such long-term sustainable strategies than protective ones. Thus, from a global perspective, adaptation can be viewed as relatively short-term actions, some of which are intended to reduce the specific risks from climate change (goal-oriented) and some others to increase resilience (or coping ability) to cope with uncertainty so as to support urban resilience and sustainable development (Figure 6.1). The latter approaches indeed lead to uncertainty-oriented planning – a shift of traditional predict-prevent or goal-oriented planning – and thereby facilitate adaptation to capitalize on other benefits of adaptation actions. As a result, the concept of resilience, which is deeply grounded in socio-ecology literature, can take local inputs from adaptation (in term of space and time). Its incremental transforming capability can also deal with other long-term challenges and uncertainty and optimize resources. In the long run, adaptation and resilience should facilitate a planning process to achieve carbon neutral, environmentally sensitive, and low-impact development – in other words, sustainable development (Figure 6.1). Therefore, successful adaptation is a part of sustainable development and can reduce maladaptation. In fact, some conditions of maladaptation are often similar to those of sustainable development, such as reduction of greenhouse gas emission and use of local resources.

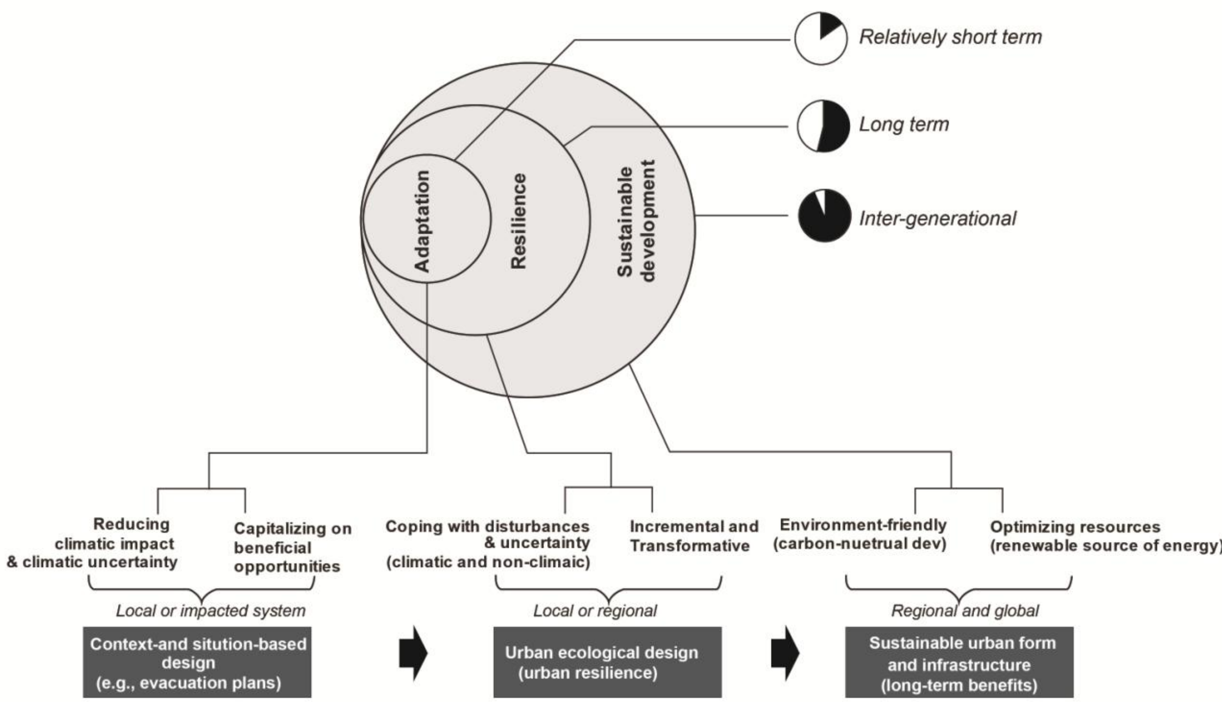


Figure 6.1. Conceptual position of adaptation in the framework of sustainable and resilient development

6.3 Foundation of the manuscripts: *rationale, coherence, and sequence*

The four manuscripts (Chapters 2 to 5) address the research questions and establish the links between climate change adaptation and urban planning. Figure 6.2 illustrates how these manuscripts have responded to the central research question and its sub components in a sequential manner. While building the theoretical links, this dissertation pays more attention to operationalizing these links with empirical evidence. In other words, they investigate physical and structural measures of adaptation associated with urban planning and design so as to facilitate adaptation actions. Adaptation scholarship pays little attention to adaptation actions, particularly those that include physical planning and design. Only 10% of adaptation studies include structural measures or physical interventions of adaptation, as Ford et al. (2011) noticed.

Limited efforts at crossing disciplinary boundaries and lack of research collaboration have also hindered establishing links between planning and climate change research (Dhar & Khirfan, in press; Pizarro, 2009; Roggema, et al., 2012). In addition, as a reason for such isolated efforts, different studies claim inadequate climate change information, in terms of content, format, and scale, that impede planning research to address climate change adaptation (Hallegatte, 2009; Jabareen, 2013; Pizarro, et al., 2006). These scholarly debates confirm the shortcoming of planning discourse from different points of view and require enquiry into to what extent this lack has affected planning literature. Investigating state-of-the-art planning research that addresses climate change (adaptation in particular) is imperative to setting future research agendas so as to establish the value of this dissertation. Accordingly, the ***first manuscript*** takes this opportunity and identifies precise gaps that future planning research can address in contributing to adaptation research, or vice versa. As a result, a number of research shortcomings and opportunities have come out; among them the following are important to answering the research questions.

- Several concepts and approaches that have long existed in both field (i.e., planning and climate change) but still remain parallel. For example,
    - *Theoretically*, ecological design and ecology-based adaptation have similar views about the use of ecology and ecological services, and (urban) resilience and adaptive capacity (i.e., planned and proactive adaptation) both highlight pre-emptive long-term preparedness to better cope with uncertainty.
    - *Methodologically*, public participation is widely used in adaptation and vulnerability research (e.g., community-based adaptation) and planning research.
- Limited planning and design tools that exist to measure resilience and adaptive capacity to climate change. In most cases, planning and urban design guidelines for adapting to climate change are normative.
- Scales of adaptation interventions in planning discourse that often exclude the agendas of a local community and environment, and its unique exposure to climatic change and its adaptation options appropriate locally.

The ***second manuscript*** underscores primarily two major approaches–ecological design and ecosystem-based adaptation–and explores their theoretical overlaps while establishing links between climate change adaptation and planning literature. In other words, it investigates their advanced applications in relation to resilience and green infrastructure through design, and adapts a methodological tool for public participation (i.e., design charrettes) to bridge expert knowledge and community experience to facilitate adaptation actions at the community scale. Thus, the manuscript responds to *how the knowledge of green infrastructure and ecological design can be advanced to facilitate the design of human settlements while adapting to climate change*. The manuscript recommends a number of design strategies that primarily consider landscape ecological urbanism[15]. The approaches advocated here pay more attention to

[15] Landscape ecological urbanism represents a combination of landscape urbanism and urban ecology, and thus, offers potential strategies to bring their ideas together to reflect natural and cultural processes (Steiner, 2011).

ecological design in terms of landscape design and the use of geo-morphological components but less to urban forms in terms of urban morphological components – the physical domains of urban design. In other words, concepts such as reversibility, biodegrability, and flexibility and their potential in designing coastal infrastructure are discussed in depth. While developing possible planning and design actions for adaptation, these concepts consider climatic impacts only, experienced, observed, and/or predicted, given that the precise information on climate change impacts (extreme events in particular) at the local level and their impacts on urban built environments are still unavailable (Hunt & Watkiss, 2011). However, their roles and applications in designing and shaping urban form to cope with climate change and, most importantly, its unknown impacts or "uncertainty", remain less-explored.

In dealing with the uncertainty resulting from climate change, planning scholars consider "resilience" as a bridging concept between urban design and planning and climate change (Costa, et al., 2014; Davoudi, et al., 2012). Although the concept resilience is fairly new in planning discourse, particularly in the context of adaptation planning, the ***third manuscript*** aims to identify the scope of this concept to address the shortcomings identified in the second manuscript and to answer the research question of *how climate change adaptations can be advanced through integrating knowledge from urban planning and design and resilience*. This third manuscript reviews this socio-ecological concept, as discussed in climate change and planning literature. It is important to note here that although the term resilience and its applications in planning have emerged recently, its different analogous forms, for example flexibility and adaptability, have long been discussed in planning literature – since the early of last century. In the context of the human dimension of adaptation, these analogous forms can potentially increase a system's adaptive capacity to reduce its vulnerability and to cope with unknown changes. Reviewing these alternative forms in the planning discourse reveals the connections between resilience and design of the physical domain of a built environment. Building on these connections, this manuscript establishes the Urban Design Resilience Index (UDRI), a multidimensional theoretical framework for adaptation. The UDRI includes urban morphological components and their design potentials to increase resilience so as to better cope with uncertainty, whether or not posed by climate change. The framework encompasses a list of possible urban design indicators that can give researchers/design professionals a conceptual foundation that acts as a particular context for adaptation decision making. As well as dealing with the consequences of climate change, the framework focuses on the ever-changing urban environment and urban systems and optimizes resource use to promote environmentally-sensitive development. The manuscript considers adaptation as a part of sustainable development–a goal highlighted by several international agreements, from the Kyoto Protocol to the recent Paris agreement. However, all indicators along with their measures discussed in the manuscript are still generic, and their successful application depends on urban forms' physical characteristics in a given context and the types and degrees of vulnerability of that area. Thus, further work is needed to apply and test the UDRI in a context to support adaptation decision making.

Building on UDRI, the ***fourth manuscript*** aims to operationalize it in the context of Negril and to investigate how the design of urban forms can influence resilience to cope with climatic uncertainty. More especially, it investigates *what urban design tools are needed to measure and enhance the resilience of an existing settlement (i.e., Negril's) to climate change, and how*. In doing so, this manuscript classifies the impacts of climate change and associated uncertainty into two subsets: one resulting from rapid-onset climatic events (e.g., a hurricane) and the other from slow-onset ones (e.g., sea-level rise). This manuscript compares the concept "resilience" in planning literature and in socio-ecological literature managing urban areas and communities at risk. It pays more attention to bounce-forward resilience as this advanced model of resilience thinking advocates the long-term, incremental, and transforming ability of urban forms to cope with climate change. The IPCC's 5th assessment report also highlights such a model for climate change adaptation, particularly for urban areas (Pachauri, et al., 2014). Accordingly, the manuscript develops six design tools (i.e., ecological design, multi-functionality, polycentricism, redundancy, connectivity, and indeterminacy) to measure the current resilience of an existing built environment. These tools help explain the degree of resilience of an existing system as a bench mark and thereby precisely indicate an area/part of it to be improved and how. Thus, adaptation design solutions may vary by parcels and blocks or even a small area depending on their resilience. Each individual tool has an enormous opportunity to contribute to advancing resilience thinking through urban design and planning as well as showing trajectories of future planning and adaptation research. The first tool, ecological design, is one of the six tools, discussed intensively in manuscript II in relation to ecosystem-based adaptation and community-based adaptation (Figure 6.2).

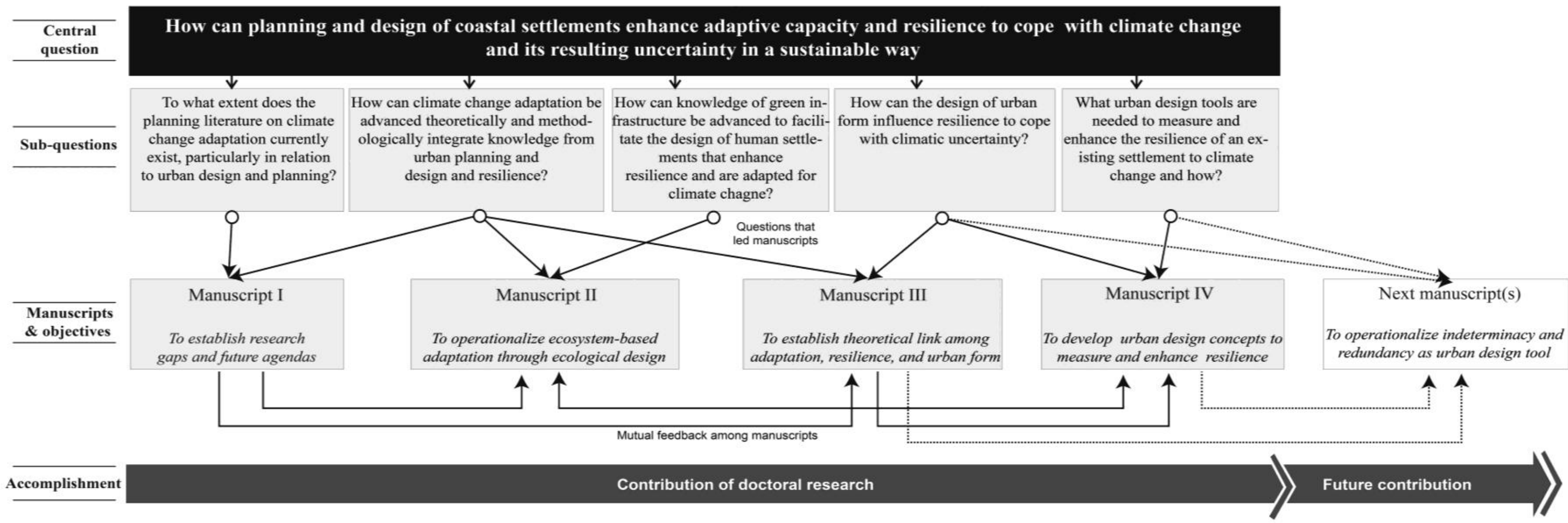


Figure 6.2 The framework of this dissertation to address search questions

6.4 Key lesson learned and research contribution

6.4.1 Contribution to knowledge: a global perspective

Climate change research still lacks precise information on climatic impacts at the local level, and different climate models, with their approximations and inadequacy, often result in uncertainty (Collins, et al., 2012). Perhaps, at the local level, this lack hinders transferring knowledge from normative adaptation policies to specific implementable adaptations, i.e., adaptation actions – one of the least explored areas of adaptation research until 2011 (Berrang-Ford, et al., 2011). Likewise, design literature, including planning, urban and landscape design, and architecture, in relation to adaptation has generally failed to integrate the domains of theory and practice. The former, often guided by multidisciplinary scholars, tends to frame climate change adaptation and considers normative adaptation strategies primarily at macro scale. The latter focuses on implementing adaptations (i.e., adaption actions) without due consideration of adaptation (or resilience) theories and literature. Indeed, few such actions have appeared, and those only since of the middle of last decade. One valid reason for this omission is the lack and inaccessible formats of climate change data. These problems challenge planning scholars wanting to use these data in adaptation planning. Hence, until the middle of last decade, scholarship other than planners led adaptation studies in the mainstream of planning literature, as Pizarro, et al. (2006) noted. The findings of this dissertation show that planners' awareness of adaptation has significantly increased since 2006-07, and thus eventually about 39% of contributors are now from planning or closely related fields (Figure 6.3). However, the use of different planning theories or models and their potentials to link climate change adaptation or resilience remain rare.

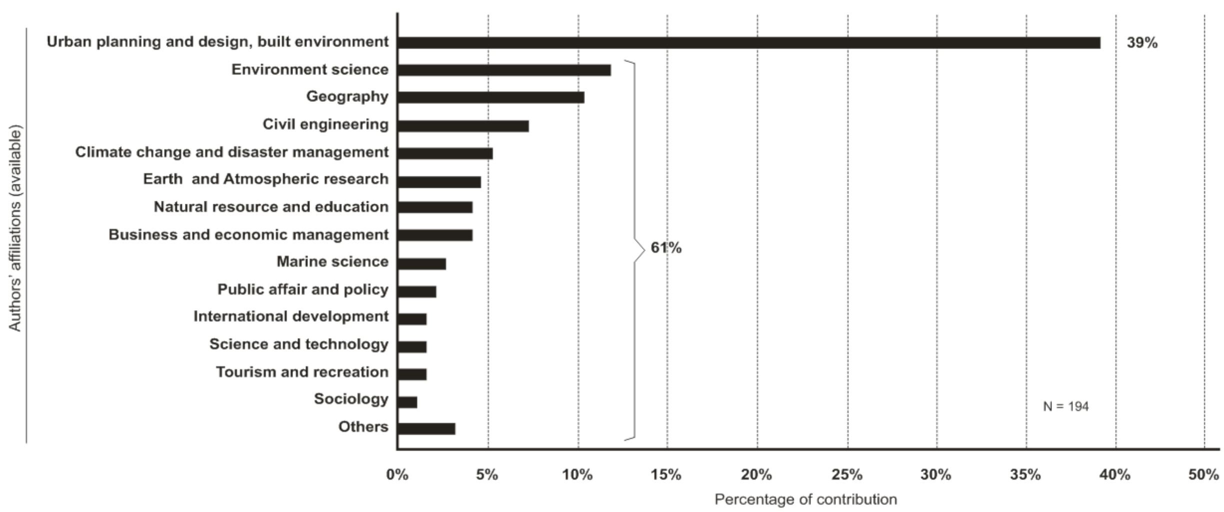


Figure 6.3 Planners' contribution to adaptation studies in the leading planning journals published from 2000 to 2013.

Accordingly, this dissertation addresses the above shortcomings and investigates theoretical and methodological similarities among three concepts–planning, adaptation, and resilience–to link them. The following lessons learned from this dissertation can be applied for advancing planning and adaptation research.

Strengthening public participation in adaptation decision making

Local and autonomous approaches are always recommended for climate change adaptation: "adaptation must be context specific ...[and] rooted in the local environment and culture" (Berger & Ensor, 2014, p. 9). Thus, adaptation studies in relation to the human dimension often recommend public participation to ensure the input of local communities (IPCC., 2014; Reid & Schipper, 2014). The success of community-based adaptation (CBA) lies in engaging local people, particularly those who are at risk, and their active roles in adaptation decision making. Public participation has existed in planning discourse over decades. However, the contemporary forms of public participation in planning seem to be limited to public hearings, rather than being openings for discussion and negotiation between stakeholders, and they often over-emphasize interdependence to trap people into ineffective participation (Forester, 2012). Perhaps that is why public participation often fails to engage people, the most-disadvantaged ones in particular, and makes them unlikely to attend public meetings. In the context of adaptation, most documented efforts, similar to rational comprehensive planning approaches, are guided by experts and exclude local people. Thus, focusing on the human dimension, many scholars consider transactive and collaborative planning as ideal models, because both have the potential to offer multiple forms of discussion that empower and encourage people to participate (Hudson, et al., 1979). With regard to empowering people, these models of planning and CBA seem to be similar.

In particular, this dissertation adapts the design charrette, as such a transactive tool, to involve people in a series of activities and encourage them to provide information and thus facilitate CBA. Any such advanced participatory tool can certainly help identify and prioritize local adaptation strategies and preferences and, most importantly, facilitate the ongoing process of adaptation. For example, focus groups and in-depth interviews may also facilitate public participation, depending on the context. Figure 6.4 illustrates the success of public-participation strategies–e.g., design charrettes (Dhar & Khirfan, 2016) and ethnographic approaches(Hogarth, Campbell, & Wandel, 2014), essentially planning models (transactive and collaborative), in engaging vulnerable communities so as to inform community-based adaptation and facilitate local adaptation decision making. Clearly, it is now important to build a community's adaptive capacity, not only reducing its vulnerability to climate change and ensuring better disaster preparedness, but also encouraging locals to participate in supporting the adaptation process. This capacity also enables community members to respond to the ongoing challenges and to make decisions for their lives and livelihoods in the age of climate change (Ensor, 2011).

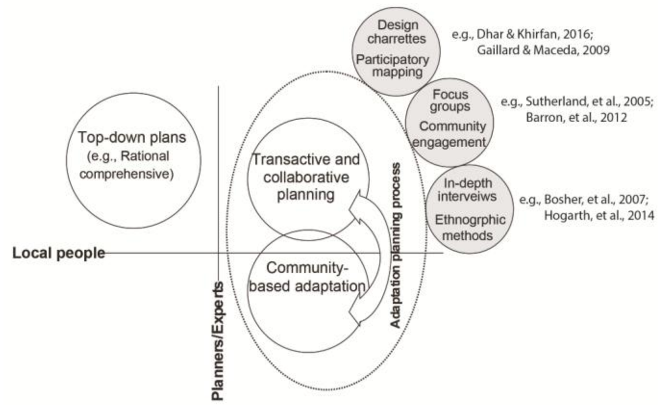


Figure 6.4. A public participation model supporting adaptation decision making

<u>*Promoting soft and ecosystem-based adaptation first*</u>

Every area is unique in terms of its geographical, environmental, socio-economic and cultural features as well as its exposure to climate change. The physical planning and design of human settlements of such an area must adhere to the potential of local features and ecologies, and also accelerate and strengthen such potential in advancing adaptation. Ecological design, including its many contemporary branches (e.g., landscape urbanism), always advocates a fusion between natural and human systems. As McHarg (1969) wrote, a city is "a form, derived in the first instance from geological and biological evolution, existing as a sum of natural processes and adapted by man". Soft ecosystem-based adaptations highlight such natural processes and use them to adapt to climate change and preserve the ecosystems of a particular area. The advantages of preserving natural ecosystems and green infrastructure include several cultural, social and economic benefits, e.g., recreation, ecotourism, intellectual inspiration, and scientific discovery (Steiner, 2014). Most importantly, recently, advanced applications of urban ecological design have advocated incorporating the concept of resilience while prioritizing climate change adaptation (Larco, 2016; Wu & Wu, 2013). A successful application that combines EbA, ecological design, and urban green infrastructure would also be an approach for no-regret adaptation. It would thus follow the bounce-or transform forward resilience approach and exploit other benefits of adaptation, such as promoting sustainability.

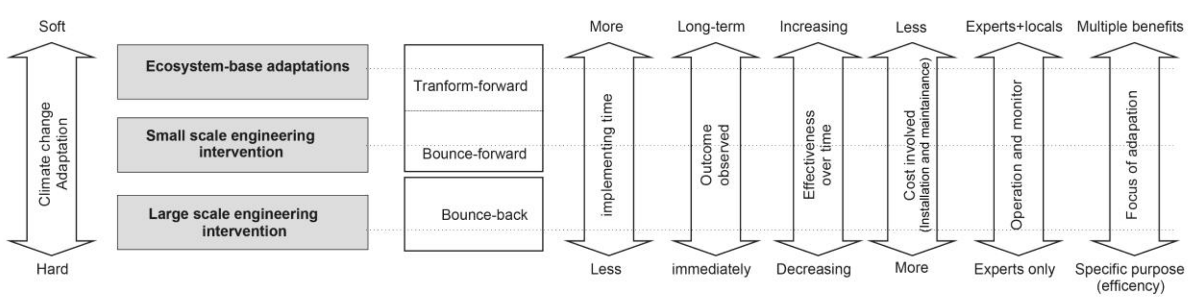


Figure 6.5. The benefits of soft adaptation interventions

In contrast, there are hard or large scale engineering adaptation interventions, which might also be necessary in adapting a particular area to specific climatic threats. These goal-oriented approaches are often kept in place based on their efficiency and performance, for a limited period of time (depending on a project's lifetime), and thus, strictly follow a bounce-back resilience model. Empirical evidence and other insights also confirm awareness of the possible negative impacts of these approaches on local environments and ecosystems. Soft ecology-based adaptations require a relatively long-term plan, unlike hard ones. Figure 6.5 presents a comparison among these approaches based on several measures, such as the time and operational cost needed. Yet, the first preference in prioritizing adaptation options should be soft interventions; they could be stand-alone – or integrated with other hard interventions if any urgent remedy is necessary. Most importantly, hard strategies must also entail the enhancement of soft ones, as these can take control later on.

6.4.2 Contribution to Caribbean planning and design: a local perspective

Current threats, resilience, and adaptive capacity of Negril's built environment

Negril's current vulnerability and climate change problems are complex and often interrelated with anthropogenic actions, such as water pollution and illegal farming in the wetland (the Great Morass). Beach erosion is the key threat to Negril, and Long Bay has experienced a higher rate of beach erosion (at between 1 to 2 m/year) than neighbouring bays. As a result, Negril's tourism industry, Jamaica's third largest, which generates over 5% of the national GDP, is at risk too. In addition to anthropogenic actions, the impacts from both rapid-onset climatic events (e.g., storm surges) and slow-onset ones (e.g., sea-level rise) are equally responsible for increasing Long Bay's erosion. However, most public agents involved in Jamaica's planning and development focus primarily on rapid-onset events and their impacts on coastal settlements. Less attention is paid to the impacts from the slow-onset events. As a result, the breakwater project–a mega-engineering submerged project–is now underway, and is intended to cut wave energy so as to stabilize Long Bay's shore line. However, local communities and agencies, including the Negril Area Environmental Protection Trust (NEPT) and Jamaica Hotel and Tourism Association (Negril Chapter), are concerned about the negative impacts of the project on marine ecosystems. Thus, to protect their beach, they would prefer ecology-friendly approaches, particularly, beach nourishment and restoration of coral reefs and seagrass, rather than large-scale engineering adaptations. The reaction against the latter approaches is somewhat similar to that argued by Michelle Mycoo, a Caribbean planner and adaptation scholar. Her recent experience on coastal zone management in Barbados revealed that such hard and large-scale engineering interventions would not only adversely impact local ecosystems but also reduce coastal communities' resilience to climate change (Mycoo & Chadwick, 2012).

Discussion with local professionals and planners, particularly public agents, reveals that that they are not against soft approaches at all; rather they favour them. Thus, recent Planning Orders include several options for promoting them. However, the agents remain reluctant to prioritize these approaches and incorporate them into planning and development. Apart from very general guidelines for a few ecosystem-based adaptations (setbacks, reefs and mangrove installation), which climate change literature always recommends, no planning action is scheduled for implementation in the near future.

In addition, Negril's planning heavily focuses on centralized systems, for example, central energy infrastructure and waste management units, and even the ongoing breakwater project itself. Apart from possible negative impacts (if any), the performance of all these systems might require regular maintenance and up-grading and skilled personnel and expert knowledge. No alternative plans are available if any of these systems fails, or does not act as desired or is affected by climatic or non-climatic events. In other words, there is no formal integrated planning that can combine these hard and goal-oriented adaptations with the soft ones locally preferred and practiced. Moreover, this efficiency-focused adaptation and infrastructure planning indeed follow a bounce-back model of resilience. The current Negril planning and development have already started considering the cumulative performances of these actions to contribute to economic development. One such example is the recent approval of higher density by adding one additional floor to buildings in the Negril area. However, these centralized initiatives i) shows a severely lack of well documented integration with soft-hard adaptation, ii) focus only on eliminating climatic problems, mostly from rapid-onset events, iii) put less effort into controlling anthropogenic pollution affecting the marine environment, and iv) ignore Negril's people and their preference and knowledge for adaptation decision (e.g., indigenous adaptation). An integrated approach is needed if Negril's built environment is to meet its climate change challenges, one that combines hard and soft approaches to addressing rapid and slow onset climatic events and their impacts, and that uses planning and land use policies to control anthropogenic activities that reduce the area's resilience.

Future urban design and planning approaches to enhance resilience of Negril's coastal built environments

The findings of this study reveal that Negril's resilience capacity, based on six urban design tools, is still limited, particularly in implementing ecological design and tackling the situation during and right after an extreme event. Manuscript 2 discusses the former in depth with a set of physical planning and design recommendations (Table 6.1), and Manuscript 4 explores the latter and includes several urban morphological design strategies that also have potential to inform local planning's capacity to deal with slow-onset events.

Table 6.1 combines a number of recommendations drawn from the manuscripts, made based on empirical evidence that could potentially highlight ways to increase the resilience of Negril's built environments. The primary objectives of current and proposed adaptation planning are to deal with extreme climatic events and their impacts. One example of such adaptation is the breakwater project. Another is the ongoing Community Disaster Plan for Negril by the Office of

Disaster Preparedness and Emergency Management (ODPEM) that will include emergency evacuation and recovery actions.

Table 6.1 *Negril's current resilience and the potential scope of enhancing it through urban (ecological) design.*

Concepts (Manuscript-IV)	Brief objectives	Resilience		Design and planning strategies for adaptation
		Current level	Potential scope	
Ecological sensitivity	To ensure a balance between human and natural systems	↓↓	↑↑	Enhancing bio-degradability and reversibility Adopting situation-based land use planning Promoting eco-infrastructure Integrating coastal adaptation strategies (adapted from Manuscript-II)
Connectivity	To enhance accessibility and permeability across the area	↓↓	↑	
Multi-functionality	To highlight a system's innate potential to accommodate diverse functions	↓	↑↑	Generating alternative economic activities (e.g., eco- or cultural tourism) Encouraging decentralized systems (adapted from Manuscript-II)
Redundancy	To have back-ups and/or alternatives for essential services	↓↓	↑	
Polycentricism	To distribute basic systems or their parts and to spread out risk	↓	↑	
Indeterminacy	To make a system open for coping with the unknown	↓	↑	Promoting small building-footprints and low-rise development, and innate design potential to change (adapted from Manuscript III & IV)

Note: ↓↓=very poor, ↓= poor, ↑= to some extent, ↑↑=adequate

Most documented recommendations for Negril (e.g., Town and Country Planning Development Order for Negril) focus on enhancing the long-term coping ability of Negril's built environment – in other words, adhering to ecological and revolutionary forms of resilience. However, the prevailing practice predominantly includes hard adaptation interventions. Instead of providing a specific solution to a specific problem (e.g., beach erosion, the utmost challenge of Negril) as most hard adaptation interventions do, this research presents a comprehensive approach of adaptation planning that integrates other approaches in a sustainable manner for human well-being. Nevertheless, this comprehensive approach is prejudiced toward exploring soft approaches more than hard ones and favorability considers slow-impacts events and/or long-term solutions of rapid-impact events through planning and design.

6.5 Future Research

This study provides a comprehensive review of the growing research on climate change adaptation in planning literature since the early part of this century, with a particular focus on urban resilience. Based on this synthesis, it is evident that the state of adaptation has improved markedly since about 2005. The catastrophic impacts of extreme events, particularly hurricane Katrina in 2005 on New Orleans, and soon after the bestowal of the 2007 Nobel Peace prize on IPCC's 4th assessment report, have increased the awareness of adaptation, particularly in the human dimension, among planning scholars. However, these studies predominantly focused on vulnerability assessment and urban governance, and encompass primarily qualitative techniques. This dissertation investigates the advances, both theoretical and methodological, in understanding among interdisciplinary concepts over recent decades. This thesis investigates the gap between planning and adaptation and identifies what new tools, techniques, or concepts are available. With its tight focus, this research is able to provide a strong foundation for moving planning research toward advancing climate change adaptation. However, several areas still remain under-investigated and would benefit from greater study.

6.5.1 Advancing methodological approaches

The empirical research presented here advances methodological approaches, e.g., transactive planning, and understanding of the current adaptive capacity of human settlements while bridging experiential and expert knowledge. Methodologically, this research adopts diversified methods, but primarily qualitative approaches, to understand, compare, measure, and improve the physiognomy of human settlements and their design. These qualitative techniques are common in urban design and planning research. Moudon (2015) argues that they fall under a humanities-inspired model and suggests instead a science-based pedagogic model, an alternative that includes quantitative approaches for advancing urban design and planning research. This alternative offers researchers more opportunities for collaborative and interdisciplinary research, which is especially required for climate change adaptation research (IPCC., 2014). However, it requires precise scientific information of a city: physical morphological data of its urban form and detailed climatic change information. For example, detailed GIS data/maps can quantify and analyse such information to advance urban design research. To this purpose, the availability of climate projection data and climatic impacts at the neighbourhood level for a given context are essential, given that the impacts of climatic extreme events particularly in urban areas, are still rare. In addition, applying this approach to many developing cities is hardly possible because of the unavailability of scientific information. Once data are available, future urban design research could follow Moudon's alternative model. However, a combined tool using humanities-inspired and science-based models would widen the range in opportunities of urban design research that deals with the human dimension of climate change.

6.5.2 Shifting predict-and-prevent approaches to uncertainty-oriented planning

Determining appropriate adaptation planning and policies often relies on climatic data – current and future – as the basis for reducing or exploiting climate change impacts (Tyler & Moench, 2012). This predict-and-prevent approach is somewhat similar to the type of adaptation framework advocated in climate change literature (B. Smit & Wandel, 2006; Sutherland, Smit, Wulf, & Nakalevu, 2005) (Figure 6.6, part A). However, in reality, the unavailability and approximation of climatic information and models make such an approach very challenging, particularly at the local level. In addition, by their very nature, these models cannot capture all factors of a natural system, and those they do capture are often incompletely understood (Collins, et al., 2012). Also, the climatic models available have limited capacity to project the unknown in relation to the human dimension of climate change. The scope of the predict-and-prevent approach, even if resulting from collaborative research, is limited because only projected regional climatic changes are considered to determine their effects on human system. In reality, the effects on human-systems "often depend more on the relative resilience of a given society than on the magnitude of environmental change" (Maslin & Austin, 2012, p. 183). Thus, with regard to the interrelation between human-natural systems, uncertainty does exist at the local level. Urban design and planning professionals often have difficulties in identifying likely climatic impacts, in dealing with this uncertainty, and in setting appropriate ways of acting (Milly et al., 2008).

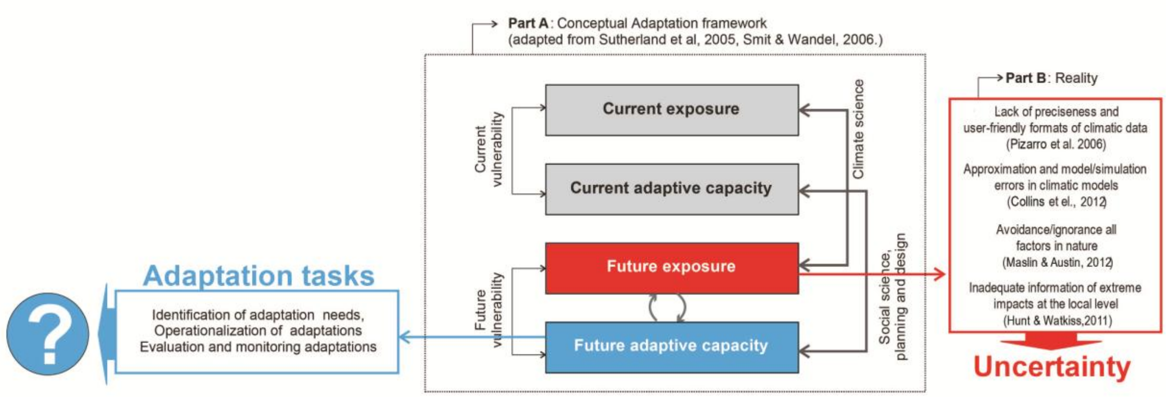


Figure 6.6 Adaptation framework in climate change literature and its limitation

Instead of this limitation of climatic information, planning professionals use this predict-and-prevent approach and marry historical climatic data and future predictions to justify their approach to preventing climatic impacts. Such predict-and-prevent approaches are criticized because of their limited capabilities: first, to deal with surprises (Wardekker, de Jong, Knoop, & van der Sluijs, 2010, p. 988); second, to consider indirect climatic impacts and their resulting uncertainty (Jabareen, 2015; Tyler & Moench, 2012); and last, to exploit opportunities for climate change adaptation (Berrang-Ford, et al., 2011). Jabareen (2015) suggested a need to shift this conventional mentality toward uncertainty-oriented planning that might be able to combine the climatic data still available and an evolutionary resilience of planning. Figure 6.6 validates the reasoning behind the need for uncertainty-oriented planning. Accordingly, this new planning model would be more responsive to unknown future circumstances and be better able to make urban areas less vulnerable and more adaptive.

6.5.3 Passive survivability, critical issues of emergency responses

The key features of adaptation often highlight situations that are highly related to variability and extremes, not simply changed average conditions. Smit et al. (1999) used a metaphor of "dangerous" as an essential element to determine adaptation. The extent to which natural ecosystems and sustainable development are in danger depends partly on the ability of an impacted area or system to adapt and partly on the nature of the climatic variability of that area. The severity of the latter is directly related to failure of mitigation. The objectives of various international agreements (including the Kyoto protocol, sustainable development goal, and recently the Paris agreement) since the 1980s have raised global awareness about mitigation. Decades of waiting would be required to see the result of these agreements (if implemented successfully). Climatic variability along with rapid-onset climatic events will continue, and thus the need for adaptation is obvious. Given that, mitigation has global benefits but needs international commitment. Planners have little control over the climatic variability of a particular area, and can only to enhance resilience of the built environment through planning and designing pre-emptively.

During and immediately after extreme events, people, particularly in urban areas, have to face the most critical period to survive passively, perhaps without basic city amenities, e.g., power, heating fuel, or water supply. For example, in Chicago, a 1995 heat wave killed more than 700 people who lacked air conditioning (Klinenberg, 2002), and in eastern Canada, a massive 1998 ice storm left 4 million people without power and forced over 600,000 from their homes (Kibert, 2013). More recently, 150,000 people in New York City were without power because of Winter Storm *Jonas* (Hanna, Botelho, & Gray, 2016). Hence, Alex Wilson (2006) has coined the term "passive survivability", which refers to the ability of the built environment to offer critical life-support conditions for its users without such city amenities until rescue is available. This critical survival stage, depending on resilience of a building and city's infrastructure, may last for an extended period–up to 2 to 3 days (Jabareen, 2015; Vale & Campanella, 2005). Pre-emptive planning and design strategies, as reactive adaptation, are thus essential. Urban resilience literature includes aspects, such as disaster risk management and long-term coping strategies; however, passive survivability has been overlooked.

6.5.4 Balancing adaptation and mitigation to achieve the goal of sustainable development

Planning scholars have already paid much attention to reducing GHG emissions; however, they have yet to cover climate change adaptation. This thesis indicates a number of parallel concepts existing in planning and design and adaptation literature – hitherto unrevealed – to link them. The potential planning strategies that promote resilience, for instance, can facilitate adaptation. Successful adaptation lies in an integrated approach not an isolated attempt. Although growing awareness exists among planning scholars to investigate adaptation, in most cases, these adaptations seem to be isolated from other planning strategies that could facilitate mitigation or sustainable development. This integration is particularly important in reducing the chance of maladaptation, which is the unconscious result of stand-alone adaptation actions. One such action may reduce the impacts of climate change but at the same time increase the sources for greenhouse gas emissions. Hamin and Gurran's (2009) study on land use planning at the municipality level in Australia and the US discovered that about 22 out of 50 projects have conflicts between mitigation and adaptation. Mitigation and sustainable development share many underlying principles. For example, "combating climate change and its impacts" is a prioritized goal adopted in the recent 2015 United Nations Sustainable Development Summit in New York. Fields's (2009) study is one example that involves both the technical application of smart growth, a movement from urban sprawl to compact sustainable form to reduce the dependency on automobiles (Boeing, Church, Hubbard, Mickens, & Rudis, 2014), and hazard alleviation approaches in the context of post-Katrina. Hence, the challenges for further researcher are to integrate climate change (adaptation and mitigation) and sustainable urbanism even through in a larger scale such integration, particularly in the trans-boundary solutions of sustainable development, is difficult. For example, through the adaptation of the binational desalination planning in the U.S.–Mexico region, the U.S. is perhaps able to reduce the vulnerability with regard to water supply in the South-West of U.S. while simultaneously increasing environmental vulnerability in Mexico (Wilder et al., 2010). Nevertheless, as Garschagen & Romero-Lankao (2015) warned, balance in terms of examining and acknowledging the possible pathways of dealing with vulnerability in association with contemporary urbanization across scales is essential.

6.6 Conclusions

Susan Fainstein (2012) argues that, very often, "good planning" is believed to be simultaneously in the general interest and guided by "experts". In advancing climate change adaptation research, this thesis first facilitates understanding of the complex relationship between different interdisciplinary concepts and their links from empirical evidence. In doing so, it explores indigenous and planned adaptation strategies through the active engagement of local communities. It also devises context-specific design and planning guidelines i) to understand climate change threats, ii) to measure the adaptive capacity and the resilience of local built environments, and thus ii) to develop urban design strategies as a means of anticipatory adaptation. This research finds that interrelationships between the climate change threats/hazards and the characteristics of built environments and physical infrastructure define an area's vulnerability, which is unique and may even vary from its neighbours'. For example, in Jamaica, beach erosion is the utmost threat to Long Bay, but certainly not the same to its neighbour West End. Because of high tourism and economic prospects, Negril's government, consulting with experts and local people, adopted many strategies, soft to hard, to reduce beach erosion. However, the central adaptations often reflect an ignorance of i) the integration of these approaches, ii) the consent of local people and their preferences, iii) ecological potential, iv) the benefits of adaptation proposals, and v) the area's current carrying capacity, which is needed to decide whether or not Negril needs further development. In particular, adaptation planning also considers the current capacity of settlements as a benchmark, based on which future plan should be considered. Adaptation is a context-specific concept and could vary spatially and temporarily. Thus, designing for adaptation should address the above shortcomings in ways that also promote urban resilience and sustainable development.

Finally, this dissertation concludes by answering Smit et al.'s (1999) three popular questions for measuring successful adaptation and poses a new question (i.e., the 4th).

1. Adaptation to "what" (e.g., the climate related stimuli, experiences of impact)?
    - Answer: The impacts of climate change experienced and predicted coupled with complexity of human settlements
2. "Who" or "what" adapts (e.g., the system, the barriers of adaptation)?
    - Answer: Built environment and infrastructure, as asset-based adaptation that protects people and properties in a sustainable manner
3. "How" does adaptation occur (e.g., types, process and expected outcome of certain adaptations)?
    - Answer: Through enhancing long-term resilience through design that respects indigenous strategies and knowledge of adaptation and local ecosystems
4. "What" if no impact occurs as predicted (dealing with uncertainty)
    - Answer: Adaptation actions, if integrated with long-term planning processes, enhance urban resilience and thus are able to deal with other challenges and

> uncertainty. Consequently, they can exploit other benefits of an urban system while coping with changes and achieving sustainable development. It does not matter how much a system is affected by climate change.

Overall, the successful adaptation of a system lies in the process: “climate change adaptation should not be an explosive sprint, rather a progressive marathon” (Costa, et al., 2014, p. 89). Adaptive urban design and planning should facilitate this process and highlight incremental transformation of the urban form over time, while simultaneously promoting sustainable development. Interdisciplinary scholarship is thus imperative to advance our understanding of climate change and its resulting multifaceted challenges for human-natural systems.

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Appendices

Appendix A: Different adaptation strategy

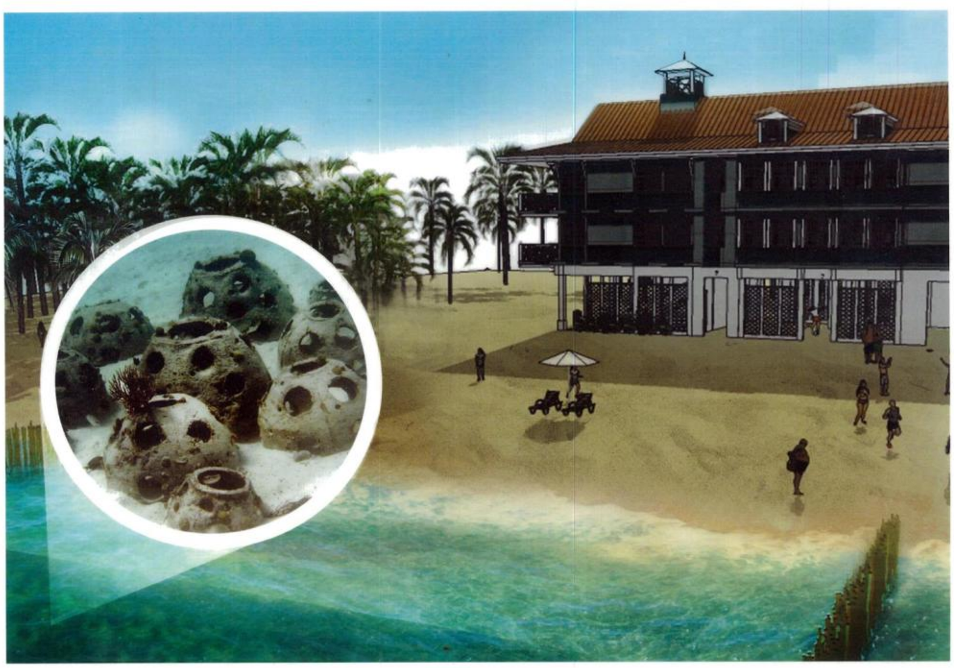
A1. Accommodation adaptation strategy

Accommodation 1: Hard Engineering-based Adaptation Intervention

Accommodation 2: Soft Ecosystem-based Adaptation Intervention

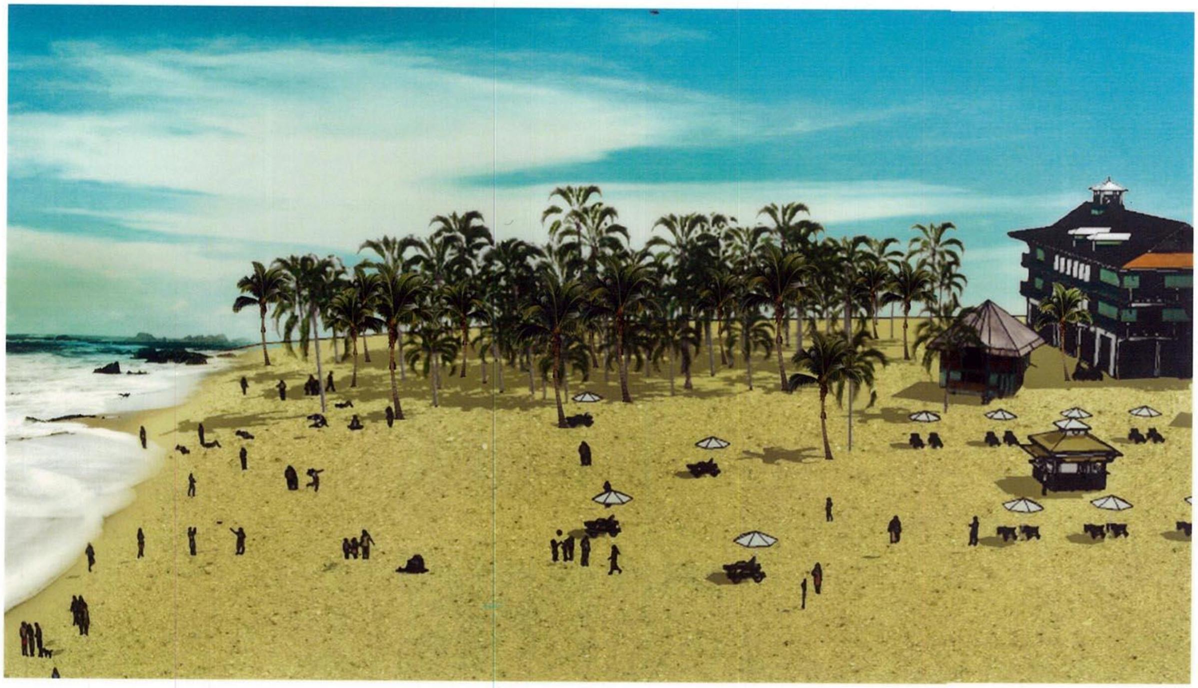
A2. Protection adaptation strategy

Protection 1: Hard Engineering-based Adaptation Intervention



Protection 2: Soft Ecosystem-based Adaptation Intervention

A3. Retreat adaptation strategy



Retreat

Appendix B: Interview protocol form

Toward measuring resiliece and adaptive capacity of coastal settlements: a case study of Negril

Interview

Questions

Objective:

To develop a design and planning framework that can measure resilience and adaptive capacity of coastal settlements in terms of design while providing guidelines for improving resilience to climate change.

Date: _ _/ _ _/ _ _ Code: _ _ _ _ _

Participant's designation/profession (professional group, e.g., a planner or an environmentalist):

Licensed professional (Planner/urban designer/architect/land developer/other): yes/no

Years of experience: _ _ _ _ _ _ and at the scale: National/regional/district/project

A. Understanding climate change problems

Q.A1. what are the major threats to coastal settlements with natural beaches in Jamaica and in Negril (Long Bay) in particular?

Q.A2. what causes these events/threats? [e.g., rising sea-level and temperature (slow-onset events) or hurricanes and surges (rapid-onset events)]

B. Investigating adaptation planning and design approaches to reduce the impacts

General:

Q.B1. How better physical planning and design of built environments can reduce these impacts? (e.g., how streets should be designed and connected, how buildings should be arranged within a plot, the amount of how much impervious/paved surface allowed in a plot?) [Adaptive capacity/resilience]

Q.B2. Are such planning/design measures or similar already implemented/proposed in Jamaica (particularly at local level)? How can they be done (if not yet done)? How can we measure progress in doing such actions [seeking indicators]?

Q.B3. Vision 2030 of Jamaica, under the goal 3, the sector "Plan safer, fairer cities", recommends to

Plan and implement drainage and flood control measures (2010-2025) (p.36)

Ensure emergency plans and disaster mitigation plans are in place (2014-2030) (p.36-37)

Q.B4. From your experience, can you give a couple examples of such flood control measures (e.g., hard/soft/incremental) usually recommended by the Vision 2030 or other documents (e.g., Disaster act 1997)? How the existing (or proposed) planning has addressed these measures (if any)?

Local level (Negril):
Q.B5. To what extent local planning and design recommendations (e.g., coastal setback 45 m recommended by the Town and Country Planning Development Order 2013 for Negril area) are followed/practiced by local builders/communities? Why?

Q. B6. What better physical planning and design strategies (long-term preparedness) that you would like to see in Negril, particularly in Long Bay? [e.g., setbacks, break waters (hard measures), street networks/building patterns-large or small footprint, building density, zoning, environment or ecology friendly, etc]

C. Measuring adaptive capacity/resilience of Long Bay's built environments
Please give your opinions on the following aspects of physical planning and design of Long Bay's built environment.

Q.C1. Ecological design (use of ecosystem services)/integration:

What are ecologically potentials to reduce the major threats [which we talked about at the beginning]? How can Long Bay's built environments use these potentials though design [at the local scale]?

Please evaluate this statement:
"Long Bay's existing built environments adequately integrate local ecosystems to reduce the threats."

Strongly agree – agree – neither agree nor disagree – disagree – strongly disagree

Q.C2. Mixed use/multi-functionality/polyvalent spaces:
Do you agree that Long Bay's current activities/land use might need to be adjusted over time to cope with climatic threats? [e.g., resort to commercial, residential, or mixed –short or long-term]

Please evaluate this statement:
"The existing trend of Long Bay's development has potential enough for incorporating multiple functions and land uses if needed over time."

Strongly agree – agree – neither agree nor disagree – disagree – strongly disagree

Q.C3. Modularity/poly centricity/distributed system:

A module/cluster represents a small group/part of area designed in a way that can reduce its dependency on others and particularly, on the centralize system in terms of, e.g., physical infrastructures, electricity, water, waste disposal

systems, etc [house hold energy unit vs. central energy grid, plot/community level waste management vs. centrally managed system, depending on a single streets vs. different alternatives].
Do you agree that such distributed system can reduce climate risks of the Long Bay area?

Please evaluate this statement:
"Long Bay's physical planning and design exhibits similar modular/distributed systems"

Strongly agree – agree – neither agree nor disagree – disagree – strongly disagree

C4. Redundancy/ diversity (coastal defence, streets and infrastructure, and amenity services):
Redundancy occurs when more than one system serve the same purpose so that the whole system can still run when parts of it collapse. Have you experienced any such redundancy in terms of street networks, land uses, and amenity services in Long Bay?

Please evaluate this statement:
"There is sufficient redundancy in Long Bay's current built environment."

Strongly agree – agree – neither agree nor disagree – disagree – strongly disagree

C5. Connectivity/permeability and block size:
How well are the existing streets (major and minor) of Long Bay connected? Are different points of interest (e.g., public streets and beaches) well accessible (visually and physically)? [e.g., shorter blocks increase connectivity and permeability more than what superblocks do]

Please evaluate this statement:
"Long Bay's built infrastructure and points of interest are publicly well accessible"

Strongly agree – agree – neither agree nor disagree – disagree – strongly disagree

C6. Indeterminacy/half-determined systems (openness) or the ability to change/serve other unknown purposes:
What are the emergency planning actions (e.g., for piling up debris/sea grass after the hurricane Ivan or accommodating temporary emergency shelters) that Negril required while recovering from a disaster? What are the other planning needs (short term and long term) that are not still experienced but should be considered?

Please evaluate this statement:
"Long Bay's built infrastructure holds enough potential to be changed and to accommodate unknown functions"

Strongly agree – agree – neither agree nor disagree – disagree – strongly disagree

D. **Additional comments:**

Glossary

Adaptive capacity

Adaptive capacity refers to "the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change" (Smit et al. 2001, p.881).

Bioswales

Bioswales refer to areas designed to act miniature wetlands "to collect and treat water from an impermeable surface, such as a parking lot" (CWC, 1996, p. 8). They "capture sediments, absorb nutrients and degrade petroleum hydrocarbons" and thus function biologically, chemically, and hydrologically (R. Alexander, 1999, p. 46). They are increasingly being used to mange storm-water and limit flooding as well as to improve aesthetics of urban areas. For example, bioswales adjacent to sidewalk in Portland, Oregon, represent about 77% of the city's green-street facilities, which are parts of urban green infrastructure (Netusil, Levin, Shandas, & Hart, 2014)**.**

Built environment

Built environment refers to "human-built structures, from large-scale civic buildings to personal dwellings, the space in between such structures and their spatial arrangement on the landscape" (Thom et al., 2009, p. 15).

Climate change

According to the IPCC, climate change can be referred to as "any change in climate over time due to natural variability or as a result of human activity" (IPCC, 2007, p. 6). The United Nations Framework Convention on Climate Change (UNFCCC) (1992, ar.3) defines it as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". This thesis primarily follows the IPCC's definition regardless of the cause of climate change, whether attributed to natural variability or to human activity.

Climate change adaptation

Climate change adaptation is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"(IPCC, 2001b).

Climate change mitigation

This term refers to "an anthropogenic intervention [that seeks] to reduce the source or enhance the sinks of greenhouse gases" (IPCC, 2001b, p. 379).

Ecological planning and design

Ecological planning refers to a “biophysical and social process comprehensible through the operation of laws and time”, whereas ecological design includes “the subject of form”‒in term of locations, processes, and appropriate materials‒while following ecological planning (McHarg, 1997, p.321).

Green Infrastructure

Green Infrastructure represents “an interconnected network of natural areas and other open spaces that conserve natural ecosystem values and functions” (Benedict & McMahon, 2006, p. 6). This integrated network includes “natural and semi-natural areas, features and green spaces in rural and urban, and terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services” (Naumann, Davis, Kaphengst, Pieterse, & Rayment, 2011, p. 14). Thus, the elements of green infrastructure are those that contribute to “preserving and enhancing diversity within ecosystems in terms of habitats, species and genes"(2007, p. 170).

Maladaptation

The conflict between mitigation and adaptation results in maladaptation. Barnett and O’Neill (210, p.211) define maladaptation as “action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups”.

Resilience

Resilience determines “the persistence of relationships within a system and is a measure of the ability of the system to absorb changes of state variables, driving variables, and parameters, and still persist” (Holling, 1973, p. 17). Thus, resilience refers to a system’s capacity “to absorb disturbance and reorganize while undergoing change” (Adger et al., 2011, p.758)

Sustainable development

Sustainable development, according to the Brundtland Commission, refers to the “development that meets the present needs without compromising the ability of the future generation to meet their own needs” (WCED, 1987, p. 8). Many use “sustainable development” interchangeably with “environmentally sound development” or “ecologically sustainable” (Lele, 1991, p. 608). Sustainable development underscores the dynamics of environment-development transformation, in other worlds, “the long-term ability of a system to reproduce” (S. Campbell, 1996, p. 306). The debate on sustainable development triggered ecological awareness, with concerns from environmental (ecological) degradation combined with a balance between social and economic aspects.

Urban form and morphology

In general, urban form refers to “the physical environment” of a city that includes the spatial pattern of its permanent and inert physical objects such as hills, rivers, streets, buildings, utilities, and trees (Lynch, 1981). In particular, it encompasses the unique morphological characteristics of a town, i.e., its “physiognomy or townscape”, which combines the town plan, the pattern of building forms, and the pattern of land use (Conzen,1969, p. 3). The town plan itself includes street networks, blocks, and building footprints. In particular, urban morphology, a study of urban form, highlights the physical dimension of urban design.

Vulnerability

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate viability and extremes. It is “a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system” (IPCC, 2007, p. 6).