Resilient Urban Infrastructure and Climate Change Adaptation in Megacities: *A Comparative Assessment of Cairo, London and New York*

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Abstract

Significant changes in climate are projected in the upcoming years combined with major impacts of frequent and extreme weather conditions affecting nations and major cities. In parallel, an increased urbanization is anticipated given that in decades the majority of the world's inhabitants are expected to be residing in cities. Therefore, ensuring adaptation remains an urgent matter for urban agglomerations since they are susceptible and vulnerable to climate change on one hand, and are exposing a large and an increased number of dwellers to major impacts on the other hand.

This research focuses on megacities, which are hosting and exposing millions of people to major impacts of global warming. The effects of this phenomenon are manifested in extreme weather events and natural disasters causing deteriorating damages to the environment and the social and physical infrastructure. The selected unit highlights the severity and magnitude of climate change in urbanized areas and develops a sense of urgency to act. Hence, questions are raised to deduce the way forward for climate adaptation in megacities.

This study adds to existing literature through identifying impacts of climate change on the urban infrastructure and creating empirical knowledge about adaptation strategies and environmental urban planning practices in place. For this purpose, a comparative research approach is adopted, focusing on three megacities: Cairo, London and New York. This approach sheds light on the various methods employed to understand the impacts, to develop strategies, to implement them and to address barriers to implementation. An 'Urban Resilience Index' is developed and applied, addressing a series of matters to assess the resilience of the infrastructure in megacities. This approach makes the resilience of the urban infrastructure quantifiable and tangible, which allows to deduce recommendations for climate change adaptation in megacities.

The results of the comparison reveal the importance of addressing climate change on a city scale. Firstly, through understanding the particular impacts on the urban physical infrastructure and their respective socio-economic implications. Secondly, through developing strategies and policies tailored to a particular context based on the understanding of the vulnerabilities. Thirdly, through implementing creative and innovative urban planning approaches to increase the city's resilience. Additionally, the results highlight the importance of keeping the developed strategies up-dated based on recent assessments as well as finding practical solutions to address barriers to implementation.

Keywords: *Impacts of Climate Change, Climate Change Adaptation, Environmental Urban Planning, Urban Management, Megacities, Urban Resilience Index, Resilient Infrastructure Indicators.*

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I hope that this research reaches a wide range of readers and contributes to raising awareness and making this world a better place through addressing a problem of global relevance on an urban level. With that being said, I hope you find pleasure going through the findings of this research as much as I found pleasure working on it.

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List of Acronyms and Abbreviations

BwN: Building with Nature

CRI: City Resilience Index

DEP: Department of Environmental Protection (in New York)

EEAA: Egyptian Environmental Affairs Agency

GCF: Green Climate Fund

GFDRR: The Global Facility for Disaster Reduction and Recovery

GHG: Greenhouse Gas

GLA: Greater London Authority

ICCCAD: International Center for Climate Change and Development

IIED: International Institute for Environment and Development

INDC: Intended Nationally Determined Contribution

ISO: International Organization for Standardization

IWRM: Integrated Water Resources Management

LCCP: London Climate Change Partnership

NAP: National Adaptation Program (the case of London)

NEEDS: Egypt National Environmental Economic and Development Study

NGO: Non-Governmental Organization

NPCC: New York City Panel on Climate Change

NYC: New York City

PDP: Participatory Development Program

SIRR: Special Initiative for Rebuilding and Resiliency

TE2100: Thames Estuary 2100

UHI: Urban Heat Island

UNDP: United Nations Development Programme

UNFCCC: United Nations Framework Convention on Climate Change

UNISDR: United Nations International Strategy for Disaster Reduction

Chapter 1: Introduction

The effects of climate change have started to come up to the surface with extreme weather conditions and with unusual and unprecedented meteorological events. As a case in point, at the end of February 2018, the Arctic's temperature marked 20 degrees higher than the usual and reached 6 degrees Celsius, whereas during the same period European cities witnessed freezing conditions and temperatures dropped to the lowest seen in centuries (Braun, 2018). Further extreme weather conditions could manifest and are foreseen in the light of climate change such as frequent and recurrent wildfires, stretched periods of heat waves and drought, intense storms and rainfalls, recurrent floods and a hastened sea-level rise. Since 1993, the sea elevation has been increasing on average of 3.2 millimeters per year (NASA, 2017). These extreme events have catastrophic consequences not only on uninhabited areas, agriculture, wildlife and biodiversity, but also on major cities and entire nations.

In its global risk report for 2018, the World Economic Forum classified 'extreme weather events', 'natural disasters', 'failure of climate change mitigation and adaptation' and 'water crises' respectively as the 2nd, 3rd, 4th and 5th global threat out of "Top 5 Global Risks in terms of Impact" (World Economic Forum, 2018). The world's biggest cities and wealthiest nations are not exempted from the consequences of climate change and will have to deal with magnified and significant impacts.

Since the effects of global warming have been coming to light, a sense of urgency to act has emerged. Climate change is a global problem which have received attention from international parties, especially after the momentous Paris Agreement in 2015. This agreement "aims to strengthen the global response to the threat of climate change" through not only acting to limit greenhouse gas (GHG) emissions, but also ensuring a climate-resilient approach and enhancing the capability to adapt to the unfavorable impacts of climate change (UNFCCC, 2015).

Cities are key players in the view of climate change impacts and adaptation. On one hand, large urban agglomerations have majorly contributed to climate change, since they account for around 80% of GHG emissions (The World Bank, 2010). On the other hand, these cities are likely to be most affected by the impacts and consequences of this global threat, since they are developed and constructed at the proximity of rivers and seas to allow for trading, transportation and connectivity which makes them today vulnerable to the rise of sea level, flooding and severe rainfalls and frequent storms. Extreme weather conditions put the urban infrastructure susceptible to major impacts. Examples are seen every year with urban hubs drowning following heavy rainfall or river flooding, destructing houses, damaging highways, cutting off roads and devastating entire cities. For instance, Hurricane Harvey affected 13 million people and have caused 125 billion dollars in damages (World Vision Staff, 2018).

Cities could also present an opportunity for innovation and creativity as well as the building capacity to adapt to climate change given that they have the power and the needed resources. Urban agglomerations present dynamic platforms for collaborative actions, as major stakeholders and key players are interested in offering a safe and healthy environment and a competitive economic setting. Partnerships and coalitions are allowing for cities to join forces and share best practices, such as C40, Urban Resilience Network, ICLEI and Urban Sustainability Officers Network (McCarthy, 2017). Urban governors and urban planners have been inciting and designing projects in support of sustainable developments and building resilience such as the expansion of urban green spaces as well as the improvement of the urban infrastructure. Adaptation initiatives are determined by the assessment and the understanding of impacts, the willingness of municipalities and city leaders to take action, the development of strategies, the availability of legal frameworks, the participation of various stakeholders, and the availability of financial and technical capacities. However, in terms of governance, one of the main challenges is the integration of climate issues into "non-environmental" urban policies, such as urban planning, which play a key role in shaping cities (Cassen, et al. 2015).

1.1 Problem Statement

Cities with a population exceeding 10 million residents (known as megacities) are the point of focus of this thesis and are selected as a research unit. These cities are more sensitive and vulnerable to climate change in comparison to small or medium sized cities as they expose a larger number of people as well as a greater number of infrastructures and constructions to impacts of climate change. Further factors could maximize the susceptibility of these cities, such as their location, rapid urbanization, and the existence of fragile and outdated infrastructures. "It is expected that 70% of the world population will be urban by 2050" (Population Reference Bureau, 2016). Thus, with a constant population growth and an increased urbanization, the number of the world's megacities is projected to increase. Given that these cities and large communities are vulnerable to environmental disruptions, a close attention needs to be paid to the adaptation of megacities and their infrastructure, as they are threatened by the consequences of climate change.

1.2 Research Objectives

The objectives of this thesis are as follows:

1- To improve the knowledge on the relationship between urban planning approaches that can be assessed and determined, and a range of environmental impacts and risks on the physical infrastructure in different megacities selected as cases.

2- To assess and quantify the resilience of the urban infrastructure in megacities through developing and applying an urban resilience index.

3- To contribute to the improvement of climate adaptation approaches in urban agglomerations through the:
    a- Inspection of governmental strategies and implemented urban planning approaches and planned urban infrastructure projects to adapt to climate change in selected megacities.
    b- Identification of opportunities and barriers in regard to climate adaptation in megacities

1.3 Research Questions

Main research question:

How should the urban infrastructure and urban planning approaches develop in mega-cities to build resilience and adapt to climate change?

The sub-questions below are formulated to help answer the main research question:

- What are the impacts of climate change on (mega)cities?
- What are the current strategies in place in support of environmental urban planning allowing to build resilience in each of these megacities?
- How resilient is the urban infrastructure in megacities to impacts of climate change?
- How could megacities adapt their urban infrastructure and be more resilient for climate change impacts that may occur in the future?

These sub-questions give a better insight on the topic, as it is first important to build an understanding on the current and potential impacts of global warming on megacities in general and on the selected cases in particular, namely Cairo, London, and New York[1]. Then it is vital to understand where these cities are standing in terms of climate change adaptation and to know more about the environmental urban projects in place to build resilience. Consequently, a better understanding is acquired on how resilient these cities are to overcome likely and unlikely impacts. Thus, the room for improvement is unveiled and one can develop an understanding on how these cities could be more resilient and better prepared to overcome future shocks and stresses in the light of climate change. This allows to reach a conclusion and recommendations answering the main research question.

[1] The rationale for the selection of these megacities as cases is explained and elaborated in Section 3.2.2

Chapter 2: Literature Review

In this chapter, the link between climate change and cities is further elaborated and emphasized. The chapter examines the consequences of rapid urbanization on climate change, and the impacts of climate change on cities in general and on megacities in particular. Moreover, it explores existing literature on climate adaptation efforts in megacities and urban projects to build resilience. The concept of resilience is further explained based on contemporary literature. This chapter sheds light on the role of urban planning in ensuring adaptation. Finally, it highlights potentials and limitations to adaptation as stated in existing research and studies.

2.1 Megacities' Development, Rapid Urbanization and Effects on Climate Change

Cities hosting more than 10 million inhabitants present a relatively new system of urban development as until the 1950s there were only two megacities: Tokyo and New York. In 2016, 31 megacities were recorded globally, and their number is expected to reach 41 by 2030 (Population Reference Bureau, 2016). These cities are growing in size and number and the results show no forecasts of slowing (United Nations, 2016).

The rapid urbanization and expansion to host more than 10 million residents and to be world economic centers turn these megacities into significant sources of pollutants that negatively affect the environment (Folberth, et al. 2014). As approximately 60% of people are living in cities today, these urban areas are considered major contributors of GHG emissions. Cities consume roughly 70 % of the energy produced worldwide as more energy services are required for commercial and industrial activities, transport, and households' demand (OECD, 2010). The GHG in cities are not only emitted due to the burning of fossil fuels but are also released due to changes of land-use and unorganized land management in the light of urbanization (Environmental Protection Agency, n.d.). Consequently, the release of the GHG in the atmosphere, traps the heat, warms the planet and leads to climate change.

Megacities prioritize economic competitiveness over environmental matters. The complexity of these cities make it hard to ensure a sustainable management and design approach in addition to achieving a balance between the three pillars of sustainability: economic competitiveness, quality of life (social aspect) and a protected environment. Thus, a balanced and integrated urban planning approach could be a way to reduce and limit the impacts of the cities' rapid development on the environment (GlobeScan, and MRC McLean Hazel, 2007).

2.2 Impacts of Climate Change on Megacities

Megacities are not only contributors to climate change, but they are quite vulnerable and most affected by the impacts and consequences of this global issue. According to the Cities Climate Leadership Group, nearly all cities are threatened by climate change, and roughly 70% are at the present dealing with the effects of this global issue. Cities of both developing and developed countries are vulnerable and susceptible and will have to deal with consequences of changing climate (Huq, 2018). Moreover, the majority of cities on this planet are jeopardized by the impacts of flooding due to sea level rise given that almost 90% of urban areas are situated at the coast (Cities Climate Leadership Group Website, n.d).

Megacities' infrastructure and urban dwellers are particularly sensitive to the impacts of climate change. For instance, concrete jungles captivate more heat throughout the day in comparison to rural areas or smaller cities, thus heat waves may be intensified. Furthermore, the population density in megacities is higher. Consequently, these cities are more vulnerable to the various impacts of climate change as it is likely to affect a greater number of people. The bigger the city, and the greater concentration of social and physical infrastructure, the higher the threat of exposure and the more vulnerable it is (GlobeScan, and MRC McLean Hazel, 2007; Dodman, 2018).

The effects of climate change on megacities will depend on the geographical location of these cities and will depend on the experienced changes of climate. For instance, coastal megacities could be mainly affected by storm surges and the rise of sea levels. Cities in hot climate zones could experience stretched periods of heat waves and drought and water shortage alongside with recurrent wildfires. Climate change could also intensify the frequency at which environmental hazards and natural risks occurs (The World Bank, 2011).

Extreme weather events could affect the quality of life of megacities' dwellers and their comfort and health. Moreover, urban residents are likely to be vulnerable to aging infrastructure, including the built environment, urban mobility systems, sewers, and drainage systems as well as existing storm and flood defense configurations (United States Environmental Protection Agency, 2017).

In addition to the physical impacts, climate change has significant and devastating financial effects. Additional expenditures on cities' accounts and substantial disruptions of business processes could result following unexpected extreme weather events such as flooding and heavy storms (Cities Climate Leadership Group Website, n.d). As an illustrative example, the American government has directly attributed over 350 billion US dollars over 10 years to overcome the damages climate change has caused. These costs are expected to exponentially increase over time to reach 100 billion US dollars per year by the end of the 21st century (Da Costa, 2017).

Being susceptible to climate change, efforts for adaptation are needed to be implemented in cities. However, adaptation in megacities can be quite challenging, not only due to their extended area and high density but also because these cities present a complex urban dynamic environment (GlobeScan, and MRC McLean Hazel, 2007).

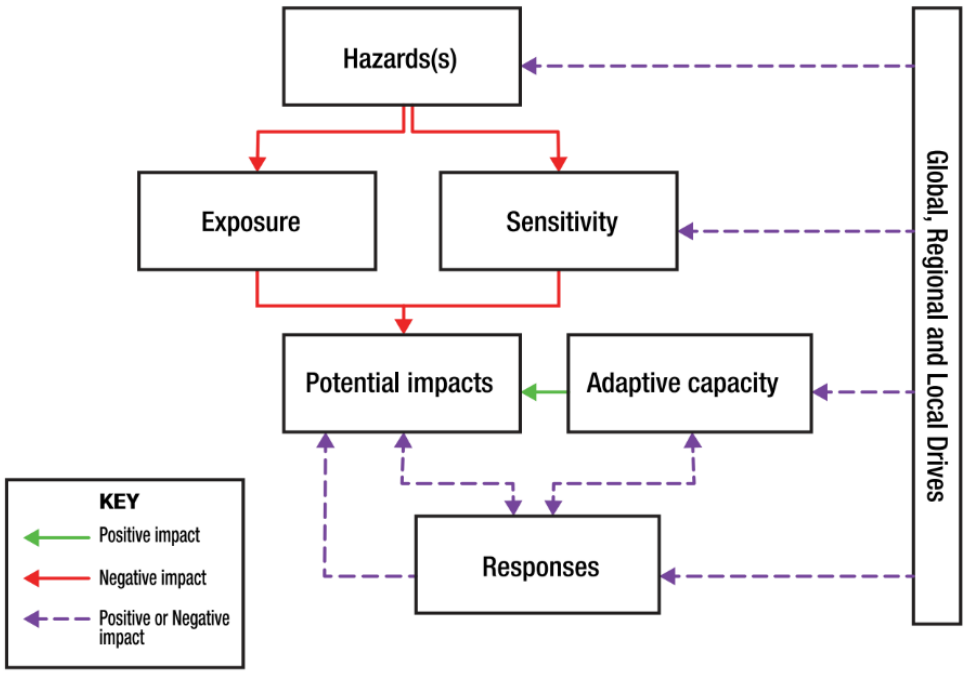

Figure 1 *A framework for understanding urban vulnerability to climate change. Source: UNEP, 2013*

Figure 1 above highlights the importance of climate change adaptation in hazardous environments. Climate change has negative impacts on sensitive and exposed environments, however, introducing the adaptive capacity could change the intensity and the response to these impacts.

2.3 Megacities' Adaptation to Climate Change

Two main pillars that support planning for climate change are identified: mitigation and adaptation. The mitigation approach is concerned with the limitation of GHG emissions trapping the heat and leading to global warming. Meanwhile, the adaptation process is concerned with adjusting the existing social, governmental and infrastructure systems in reaction to perceived and expected alteration in the weather conditions, thus is addressing the consequences of the problem (Bolich, 2013). Both approaches are equally important to limit damages from climate change and complement one another. However, as the impacts have started to come up to the surface and as cities are having to deal with both direct and indirect consequences of climate change, this thesis is focusing on adaptation approaches. This concept is further elaborated below

based on existing literature and on conducted interviews with experts in the field of climate change adaptation in an urban context.

Climate change adaptation is the preparation process to overcome negative impacts resulting from climate change and taking advantage and emphasizing opportunities that could arise (World Bank, 2011). Adaptation practices appropriate to local conditions are being developed to limit the risks and the impacts of climatic changes (Clark, 2012). The stepping stone for a successful urban management approach and the development of long-term resilience is to understand the exposure to the impacts of climate change. Following that, developing responsive projects and policies respective to possible impacts (The World Bank, 2011; Huq, 2018).

On one hand, urban climate change adaptation efforts could be manifested in built projects and large-scale infrastructure erected to protect cities from the harsh weather conditions resulting from global warming, such as building dams and dikes, reducing paved areas and increasing drainage ability. On the other hand, enhancing adaptive capability could also be manifested in behavioral modifications such as putting new frameworks in place, changing policies and governance systems as well as raising awareness among citizens (Clark, 2012). Both approaches, developing the physical and the social infrastructure complement one another and are important to ensure building resilience. However, in megacities which are already built and have a little room for retrofitting, investing in developing social capacity and raising awareness is predominantly crucial to prepare citizens to overcome extreme weather events and impacts of climate change (Huq, 2018).

Cities around the world have been more and more aware about the importance of planning for climate change and developing impact adaptation strategies through projects, policies or future plans. Investing in adaptation plans will cut the economic burdens resulting from climate impacts (The World Bank, 2011). This thesis emphasizes the role of adequate planning and suitable urban design approaches in building adaptation.

2.4 Building Resilience in Megacities

Climate change adaptation ensures the resilience of a city, or in other terms, its readiness to overcome existing and future potential climate impacts through limiting their harshness and magnitude. Following the occurrence of an impact, resilient cities are able to rapidly and efficiently respond. Increasing resilience, could also improve the city's competitiveness and its attractiveness for investors (The World Bank, 2011).

Billions are being spent on recovering from disasters rather than investing in projects for prevention and preparedness. However, to build resilience, the focus should be on protective measures to allow for fast recovery. Given that man can't forecast and avoid every disruption, building resilience is a tool to prevent likely and unlikely disruptions from becoming a catastrophe and causing distresses. Building resilience finds stresses and crisis as an opportunity or as a way to rebuild more adaptively and efficiently. Cities should not only focus on previous

crisis to frame policies but should also focus on building capacity for events that might occur in the future through fortifying social, soft and physical infrastructures. Urban centers are rapidly growing and expanding, besides, new megacities are emerging needing the construction of an estimate of 40% of new infrastructure (Rodin, 2015). Therefore, the way forward in planning and building those investments is crucial to ensure more resilient cities.

However, developing the physical infrastructure is only a part of building resilience; it is also important to develop the social infrastructure through making people aware and capacitated to know what to do in times of emergency given that one can't prevent an event from happening but can be better prepared for it. "People better prepared, in my definition of resilience, are more resilient" (Huq, 2018).

According to the 100 Resilient Cities' organization forum, resilient cities manifest seven features which make them ready to endure, react and adapt to unexpected stresses. These qualities are "reflective, resourceful, robust, redundant, flexible, inclusive and integrated". In other terms, resilient cities are cities that understand past experience and use it to advise future decisions. They resort to creative and unconventional ways to use resources. These cities adapt a well-apprehended and a well-rounded management system and have a superfluous capacity which is purposively spared to come in hand in cases of extreme pressures. Resilient cities are flexible in the sense that they have the promptness and the capacity to implement different and various strategies in cases of unusual circumstances or unexpected emergencies. Lastly, these cities are inclusive and integrated as they adapt a comprehensive governance-system and cooperative leadership and ensures the implementation of appropriate actions and projects. "Cities must take the lead to become more resilient, this involves rethinking the way they design their infrastructure (energy, water, waste and transport) to rethinking their business model and policies." (Lam, 2011).

Building resilience requires the cooperation and the efforts of both the private and the public sector, along with policy makers, environmentalists and urban planners. "Building resilience in a city is the work of a generation. It takes time and requires forward-thinking investment" (Sharma, 2018).

The ISET diagram presented in the figure below (Figure 2) emphasizes the relationship between understanding vulnerability and building resilience. It also highlights that to build urban resilience the stakeholders, organizations and built systems should comprehend the local context and the vulnerability to climate exposure. Furthermore, they should come together, learn from each other and apply the scientific knowledge to identify the actions that need to be taken, prioritize these actions, design projects and policies, implement them and, finally, monitor them to identify potentials for improvement and prioritize actions.

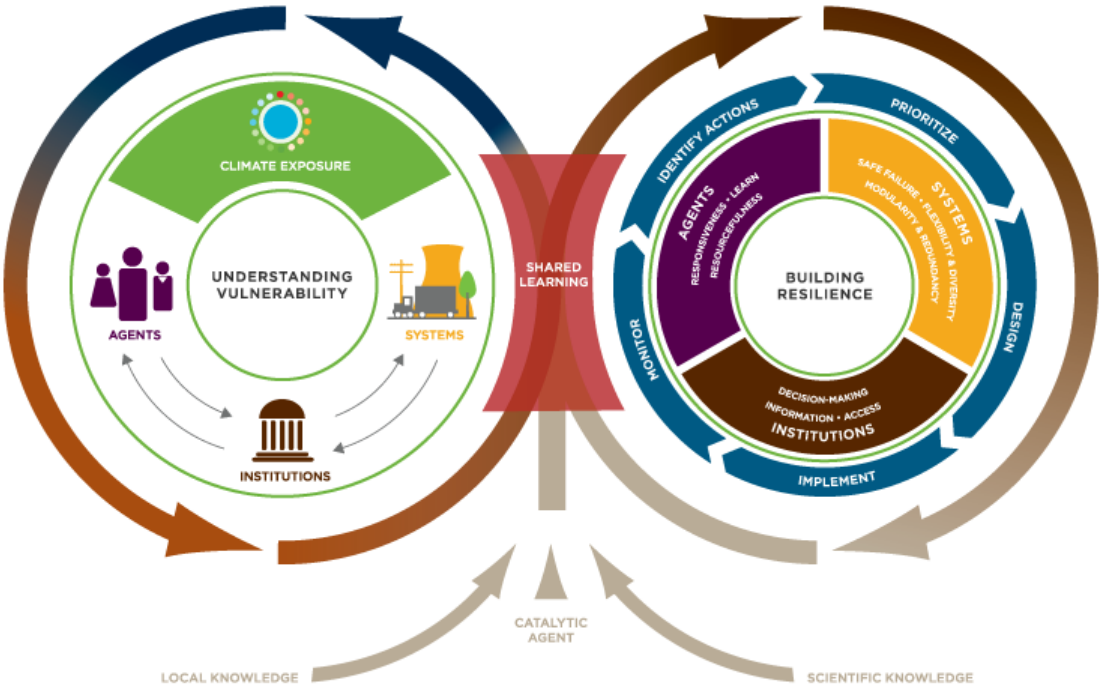

Figure 2 *Climate Resilience Framework. Source: ISET, 2014*

2.5 Role of Urban Planning in Climate Change Adaptation

Urbanization is increasing the pressure on the environment as it is causing cities to expand and to grow in an unprecedented way, increasing investments in built-infrastructure, construction and urban developments. Therefore, a comprehensive urban planning approach ensures a healthy development and growth of these cities. The design of constantly growing cities and urban structures should be flexible and must integrate environmental concerns as well as adaptive measures. For instance, the metro project in Manila-Philippines, built in an area prone to environmental hazards, was designed with climate adaptation considerations (UNEP, 2013).

In an interview with Mr. David Dodman, the Director of human settlements at the IIED, he highlighted that a well-rounded urban planning approach is an important tool for addressing the topic of climate change in urban centers. On one hand, it is an essential instrument for mitigation, as it could reduce energy emissions of vehicles through ensuring the proximity of services and a better connectivity between urban nodes. On the other hand, it is a creative tool for shaping exposure to impacts of climate change in urban centers. For instance, urban planning can encourage the expansion of the city in areas and discourage it in others. Also, it allows for the development of creative adaptation solutions such as using flood plains for recreational areas and turning them into spaces of important value in the urban settings, this way people wouldn't be living there and wouldn't be much affected following the occurrence of environmental events (Dodman, 2018).

Environmental urban planning presents an opportunity to reduce the impacts of climate change. Some urban 'green interventions' can be intertwined with the built environment in deltas and coastal cities to reduce urban heats and flood risks while sustaining biodiversity such as urban parks, green corridors and bed reeds. This innovative concept was introduced as the 'Building with Nature' (BwN) concept, through emphasizing the importance of creating flexible, integrated and climate proof solutions (De Vriend and Van Koningsveld, 2012).

China also adopted the concept of 'sponge cities' to increase water absorption in cities and combat flooding. This approach is simple yet effective, "replacing concrete pavements with wetlands, green rooftops and rain gardens means storm water is absorbed back into the land, making water work for the city instead of against it" (Roxburgh, 2017). However, the integration of these urban interventions is more challenging in megacities, "old districts" and cities that are already built in comparison to newly developing cities and emerging expansions of urban agglomerations (Huq, 2018).

"Action taken in towns and cities is essential for addressing global environmental problems" (Dodman et al., 2013). Climate change adaptation in cities could be realized by addressing fundamental improvements to the infrastructure deficits. The integration of adaptation approaches into urban planning and management principles present a noteworthy potential for tackling the issues. The susceptibility of cities and their occupants to the impacts of climate change is not only molded by their exposure to certain hazards, but also by the vulnerability and the capacity of economic, social and environmental systems to adapt. For Instance, increasing the share of green areas in a city could make residents more resilient to stress and could increase social activities and communication. Moreover, environmental re-integration can improve the quality of the environment while decreasing costs of air decontamination and water treatment (UNEP, 2013).

2.6 Potentials and Limitations to Climate Change Adaptation in Cities

Diverse cities have different abilities to manage the impacts of climate change. Cities in developing countries face more challenges coping with impacts, as these cities could have constricted financial assets to cope with changes or respond to emergency cases such as evacuation or relocation (United States Environmental Protection Agency, 2017). Nonetheless, with in interview with Mr. Huq, the Director of the ICCCAD, he highlighted that developing cities could be more resilient as the citizens are used to deal with various problems. He also underlined that the poor residents of both developing and developed countries are usually the ones with less access to services, thus more vulnerable to impacts. However, public awareness and social cohesion are important factors that affect the ability of cities to deal with the impacts and that is not a function whether these cities are rich or poor (Huq, 2018).

Fortunately, megacities present an opportunity to adapt to climate change, having concentrated resources and the means to develop resilience (Dodman, 2018). Cities have a powerful impact as throughout the years they proved to be centers of businesses, culture and creativity and attracted the settlement of a vast number of people. Urban centers have been the birthplace of innovations. The complex urban structure of cities and its concentrated density present an opportunity to improve the quality of life and ensure safe and resilient cities through well-organized and smart infrastructure and planning (Cities Climate Leadership Group Website, n.d.). Moreover, the development of large scale adaptation initiatives could present cost effectives solutions. For instance, it is cheaper to develop adaptation projects for people living in a concentrated area, than to implement measures for the same number of people residing in more dispersed settlements (Dodman, 2018).

To ensure the adaptation of cities to climate change, gaps in various issues should be addressed:

Firstly, cities need to better **comprehend climate interactions** with existing infrastructure, in terms of building materials and urban morphology, as well as with human activities. Understanding these interactions helps assess atmospheric circulation, thus the likelihood of heat waves, floods and erosions of infrastructure as well as other vulnerabilities. A better understanding of natural hazards resulting from global warming ensures a better preparedness for prospective impacts (Bai, 2018; Huq, 2018).

Secondly, cities need to ensure **enhanced quality and reliability of data-collection**, the data is essential to monitor dense cities; therefore, the standardization of reporting is crucial. Data on informal settlements should be available, as well as reliable records of GHG emitted. Information and maps of infrastructure networks are fundamental to be prepared for extreme weather events. Records are essential for cities to build resilience as they reduce uncertainties and risks; thus, increase the ability of urban agglomerations to overcome impacts of climate change (Bai, 2018).

Thirdly, to ensure the development of climate resilient cities, **the involvement of various stakeholders** is a key element. Policy makers, researchers, city planners, architects, environmentalist along with other urban stakeholders should strengthen their partnership and share knowledge. Cities are quite dynamic and complex; therefore, various aspects and disciplines need to be taken into consideration (Bai, 2018).

Existing literature highlights the relationship between climate change and cities in general, however, finding existing literature emphasizing the impacts of climate change on megacities in particular is challenging. This thesis aims at addressing how megacities should develop their urban planning strategies and practices to build resilience and overcome probable consequences and adapt to climate change given that this field is yet under-explored.

Chapter 3: Research Approach

This chapter clarifies the methodology used for the selection, the collection and the analysis of data in order to ensure achieving the research objectives highlighted in the first chapter and to answer the main research question. The thesis is of a qualitative nature, given that urban agglomerations and megacities present a complex dynamic context. The research approach thus follows an in-context observational and interpretive pattern. This scientific study explores the topic of climate change adaptation in the particular context of megacities.

3.1 Research Framework

This research adds to existing literature on climate change adaptation through analyzing the impacts, the development and the implementation of strategies as well as potentials and limitations to climate adaptation in megacities. The objective is to reach a recommendation of favored approaches for these cities to implement to build resilience and to adapt to changes of climate.

The study is based on the 'principle of confrontation' to draw conclusions (Verschuren and Doorewaard, 2010); as throughout this research the adaptation practices of three Mega-cities, selected as case studies, are compared and contrasted with one another: Cairo, London, and New York

The research resorts mainly to primary data through undertaking interviews with experts in the field of climate change adaptation and urban environmental management. Moreover, interviews are conducted with various interviewees representing the perspectives of different stakeholders, including the government, the local community and environmental experts. A list of questions used as a basis for the conducted interviews can be found in Appendix A. In addition, a desk research approach is adopted, as the thesis also builds on secondary data from previous studies, including the review of institutional and political frameworks as well as developed environmental impact assessments and adaptation strategies, in each of the selected cases.

The case study approach allows to deduct theories or a set of relations from a real-life contemporary phenomenon. However, it is important to highlight that the findings based on the selected cities and cases offers no grounds for generalizing the findings. Yet, these megacities offer concrete examples highlighting the importance of climate change adaptation in a built and constantly expanding dense urban context and help reach conclusions and recommendations on the direction forward for cities to build resilience.

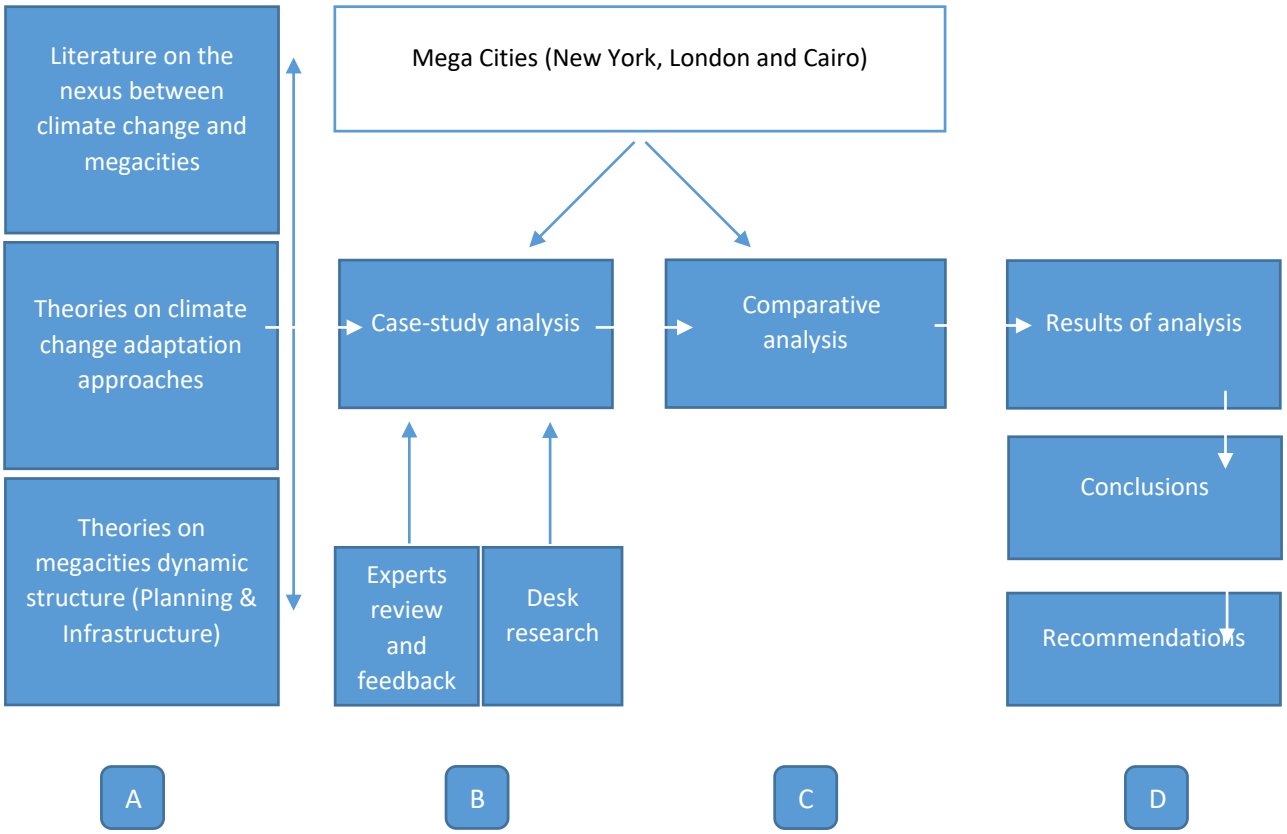

Figure 3 *Developed Research Framework*

As visualized in Figure 3, this research framework is conveyed as follows:

A: This step addresses the sources from which the study is developed, based on available scientific literature highlighting the nexus between climate change and large urban agglomerations, as well as theories on climate change adaptation and on urban planning in the dynamic context of megacities.

B: At this step, a case study analysis is conducted in each of the 3 megacities selected as cases: Cairo, London and New York. Interviews are essential for primary data collection, and desk research is important to support these cases using existing literature.

C: This step involves the confrontation of the results of the 3 megacities selected as case studies. The comparative analysis allows for the deduction of results allowing for the development of conclusions and recommendations

D: This step highlights the results of analysis and the comparative study contrasting the 3 megacities. The assessment is followed by a conclusion and recommendations for developing a resilient city capable to adapt to and overcome the impacts of climate change.

3.2 Research Strategy

Since megacities present a dynamic and a complex environment and that the issue of climate-change adaptation is of contemporary concern, the research adopts the case study approach. This qualitative approach develops an understanding of a situation in a complex setting through investigating cases of similar conditions and examining real-life contemporary situations. Relying on the case study method gives "a profound insight into the way various processes take place" (Verschuren and Doorewaard, 2010). A desk research approach is also fundamental as this study relies on professional and scientific publications in order to collect relevant secondary data in support of the thesis topic and the selected case studies.

3.2.1 Research Unit

Cities are major contributors to GHG emissions, are vulnerable to impacts of climate, present an opportunity, and have the resources and means to overcome these consequences. Therefore, this thesis tackles this global problem from an urban perspective. The research focuses on megacities in particular, i.e., cities that have a population exceeding 10 million inhabitants. This focus is justified by the facts that those cities are home to over billions of people around the world, are major attractions and economic hubs, are already built and constantly expanding, are quite complex and present a real environmental and sustainable management challenge. Furthermore, an attention is given to the urban infrastructure projects and the role of city planners beside other stakeholders in planning and designing for adaptation.

3.2.2 Selection of Cases

To draw a comparison between different cases, megacities of both developing and developed countries are selected, i.e. Cairo, London and New York. This allows to compare and contrast adaptation approaches between a developing and a developed city, and between two developed countries, in order to deduce the way forward in adapting the physical infrastructure to climate change. These three cities have different capacities and means to build resilience, all three cities are financial centers, and are prone and threatened by various natural disasters in the light of climate change. Furthermore, these cities have different governance systems and approaches to urban development and are at different levels of readiness to withstand natural disasters and combat climate change and lastly all three regions have different geographic and climate conditions. Focusing on these megacities highlights the urgency of climate change on an urban scale and gives different perspectives on approaches, measures and innovations allowing for cities to endure negative impacts.

Adopting a case study approach enables for a close examination of the situation within megacities. This approach allows for the investigation of the contribution of megacities to climate change, the impact of this world problem on an urban level, as well as the opportunities that they hold to adapt to climate change and build a resilient urban infrastructure.

Rank	City, Country	Population in 2016 (thousands)	City, Country	Population in 2030 (thousands)
1	Tokyo, Japan	38 140	Tokyo, Japan	37 190
2	Delhi, India	26 454	Delhi, India	36 060
3	Shanghai, China	24 484	Shanghai, China	30 751
4	Mumbai (Bombay), India	21 357	Mumbai (Bombay), India	27 797
5	São Paulo, Brazil	21 297	Beijing, China	27 706
6	Beijing, China	21 240	Dhaka, Bangladesh	27 374
7	Ciudad de México (Mexico City), Mexico	21 157	Karachi, Pakistan	24 838
8	Kinki M.M.A. (Osaka), Japan	20 337	Al-Qahirah (Cairo), Egypt	24 502
9	Al-Qahirah (Cairo), Egypt	19 128	Lagos, Nigeria	24 239
10	New York-Newark, USA	18 604	Ciudad de México (Mexico City), Mexico	23 865
11	Dhaka, Bangladesh	18 237	São Paulo, Brazil	23 444
12	Karachi, Pakistan	17 121	Kinshasa, Democratic Republic of the Congo	19 996
13	Buenos Aires, Argentina	15 334	Kinki M.M.A. (Osaka), Japan	19 976
14	Kolkata (Calcutta), India	14 980	New York-Newark, USA	19 885
15	Istanbul, Turkey	14 365	Kolkata (Calcutta), India	19 092
16	Chongqing, China	13 744	Guangzhou, Guangdong, China	17 574
17	Lagos, Nigeria	13 661	Chongqing, China	17 380
18	Manila, Philippines	13 131	Buenos Aires, Argentina	16 956
19	Guangzhou, Guangdong, China	13 070	Manila, Philippines	16 756
20	Rio de Janeiro, Brazil	12 981	Istanbul, Turkey	16 694
21	Los Angeles-Long Beach-Santa Ana, USA	12 317	Bangalore, India	14 762
22	Moskva (Moscow), Russian Federation	12 260	Tianjin, China	14 655
23	Kinshasa, Democratic Republic of the Congo	12 071	Rio de Janeiro, Brazil	14 174
24	Tianjin, China	11 558	Chennai (Madras), India	13 921
25	Paris, France	10 925	Jakarta, Indonesia	13 812
26	Shenzhen, China	10 828	Los Angeles-Long Beach-Santa Ana, USA	13 257
27	Jakarta, Indonesia	10 483	Lahore, Pakistan	13 033
28	Bangalore, India	10 456	Hyderabad, India	12 774
29	London, United Kingdom	10 434	Shenzhen, China	12 673
30	Chennai (Madras), India	10 163	Lima, Peru	12 221
31	Lima, Peru	10 072	Moskva (Moscow), Russian Federation	12 200
32			Bogotá, Colombia	11 966
33			Paris, France	11 803
34			Johannesburg, South Africa	11 573
35			Krung Thep (Bangkok), Thailand	11 528
36			London, United Kingdom	11 467
37			Dar es Salaam, United Republic of Tanzania	10 760
38			Ahmadabad, India	10 527
39			Luanda, Angola	10 429
40			Thành Pho Ho Chí Minh (Ho Chi Minh City), Viet Nam	10 200
41			Chengdu, China	10 104

Table 1 *Rank of World's Megacities according to population in 2016, and anticipations for 2030, Source: United Nations, 2016*

Table 1 puts the selected cities in perspective with other megacities around the world. All three cities are among the biggest cities in the world in terms of population and are expected to grow bigger by 2030.

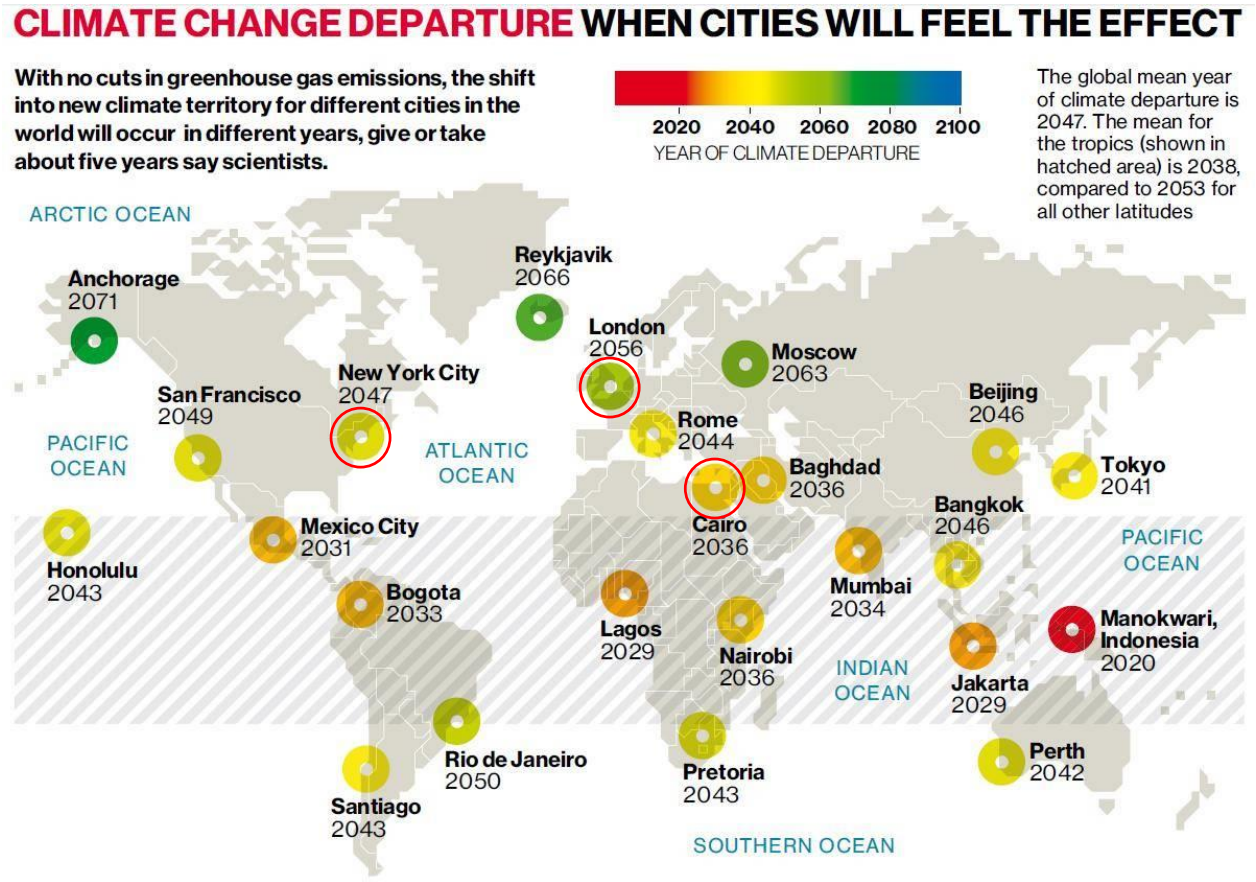

Figure 4 *Predictions of years in which major cities around the world will feel intensified impacts of climate change. Source: Connor, 2013*

Figure 4 highlights that the selected case studies are all prone to experiencing impacts of climate change in the near future. The given dates are predictions, they would vary according to the actions taken to mitigate the global issue. Cairo is expected to feel intensified effects of climate change around year 2036, whereas New York is expected to deal with major consequences of extreme weather conditions around year 2047, and London will be dealing with increased impacts around year 2056 (Connor, 2013).

3.3 Conceptual Model

To be able to address the impacts of climate change on the urban infrastructure and to build an understanding of the adaptation approaches in each of the selected megacities, this thesis follows a conceptual model, which is shown in Figure 5. Using the elements of this model to compare and contrast the selected cases allows to better understand the differences as well as the similarities of building resilience in different urban contexts. While many research projects focus on national level or on one case study at a local level, there is a need for more comparative approaches in order to highlight key success factors for urban adaptation and to gain an in-depth understanding of the interactions between players at different levels (Coenen et al. 2012).

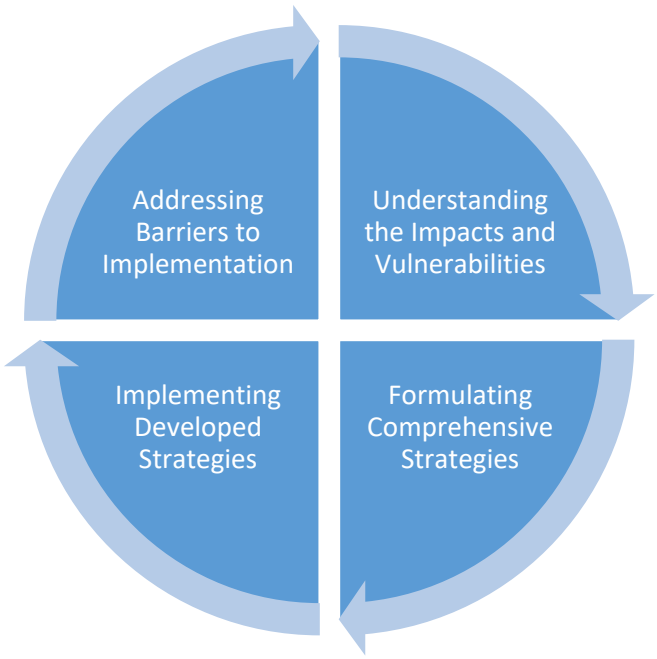

Figure 5 *Conceptual model*

The conceptual model builds on ideologies and concepts highlighted in the World Bank's "Guide to Climate Change Adaptation in Cities" developed in 2011 and the Climate Resilience Framework developed by the ISET in 2014. Based on the elements of the model, four areas of focus are addressed in each of the selected cases:

1. Understanding the impacts and vulnerabilities
2. Formulating comprehensive strategies
3. Implementing developed strategies
4. Addressing barriers to implementation

To ensure a proper adaptation of cities, understanding the impacts in a particular context is crucial (World Bank, 2011). The developed model focuses on the role of the local and the national government along with urban planners and other key stakeholders in the development of plans, policies and comprehensive adaptation strategies. The direct connection between governments and the responsibility to increase the resilience of the urban physical and the social infrastructure is clear (McArdle, 2014). This model considers the implementation as essential to transform the drafted strategies into reality. "Implementing action through a combination of traditional, city government-led initiatives (e.g. policy/regulation) alongside other enabling activities (e.g. with private sector partners) is more effective for delivering climate action than either policy/regulation or partnerships on their own" (Arup and C40 Cities, 2015). The developed conceptual model also emphasizes the importance of addressing barriers to implementation. Adaptation is not on a single time project implementation, but rather dynamic and ongoing process (World Bank, 2011). Indicators are essential to communicate the barriers to implementation in order to improve decision-making and boost adaptation opportunities (Suárez

et al., 2016). They are also an important tool for the evaluation and the prioritization of adaptation actions.

3.4 Defining Concepts

To ensure the development of a focused thesis, defining key concepts within the context of the conducted research is important.

Mega-cities: As previously mentioned in this thesis, Mega-cities refer to metropolitan areas hosting more than 10 million inhabitants. According to the United Nations' "The World's Cities in 2016" Data booklet, 31 megacities exist today and 41 megacities are expected to exist in 2030.

Urban Resilience: Refers to building the capacity of cities to adjust and transform in the face of both expected and unexpected events. This research adopts the "100 Resilient Cities" concept is defined as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience" (100 Resilient Cities, n.d.).

Climate Change: This study adapts the "United Nations Framework Convention on Climate Change" (UNFCC) definition of climate change which refers to the alteration of the global atmospheric composition as a result of the direct or indirect human activity.

Impacts of Climate Change: The impacts of climate change in this research refer to the negative impacts of global warming as such as the rise of sea level, and increased frequency of extreme weather conditions exposing communities to high levels of threats.

Climate Change Adaptation: This research adopts the definition the World Bank's Guide to "Climate Change Adaptation in Cities" for climate change adaptation which refers to the preparation process to overcome negative consequences resulting from the alteration of climate while benefiting from opportunities that could arise (World Bank, 2011).

Urban Environmental Management: A combined planning and management strategy limiting unfavorable environmental impacts and supporting economic profits in an urban context and an overlay of three dimensions constituting the urban environment: natural environment, socio-economic environment and the built environment. (GDRC, n.d.)

Physical Infrastructure: Defined as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions." (Fulmer, 2009). The physical infrastructure includes various systems, such as transportation, water supply, sewage, energy grids, waste collection, health, etc. However, this research focuses on the green and built infrastructure including constructed projects and natural environments in urban contexts, and not on waste and energy management due to time limitations.

Urban heat island (UHI) effect: The UHI effect is prompted by the construction materials used in urban context which have different thermal properties than a green environment. UHI is a key

aspect of urban climate, since "the urban geometry of a city can increase surface temperatures as well by obstructing air flow and preventing cooling by convection" (Saab and Tolba, 2009).

3.5 Research Limitation

Due to time limitations, this research restricts its focus to:

A. **Climate change impacts in urban settings** in general; knowing that the alteration of climate patterns could also have major consequences on forests, agriculture, ecosystems as well as other sectors.
B. **Megacities** in particular, knowing that urban settings involve cities of all sizes or classes which could be differently affected by climate change.
C. **Adaptation approaches** in particular given that planning for climate change in urban settings could also involve mitigation approaches and measures to reduce the pressure on the environment.
D. **Adaptation of the urban infrastructure**, to provide a focused research since megacities present a very dynamic and complex environment. Given that adaptation could be concerned with social, physical and governmental reforms, this research will focus on the physical infrastructure (as defined in section 3.3) including constructed projects and natural environments in urban contexts.
E. **Case studies**: 3 megacities which help draw conclusions since they represent different climate conditions thus different impacts of climate change as well as different management approaches of both developing and developed countries.

3.6 Data Collection Methods

Research questions	Data required to answer the question	Source of data	Method to access the data
What are the impacts of Climate Change in (mega)cities?	- Identified impacts of climate change in each of Cairo, London and New York	-Published literature (i.e. environmental impact assessments, articles etc.) -Transcripts of interviews based on exploration of each case	-Desk research -Meeting/Interview in person or via Skype
What are the current environmental urban planning strategies implemented to build resilience in each of these mega cities?	-Identified strategies and plans in place in Cairo, London and New York	-Published literature (i.e. adaptation strategies, policies, master plans etc.) -Transcripts of interviews based on exploration of each case	-Desk research -Examination of Urban Planning and infrastructure projects -Meeting/Interview in person of via Skype

How prepared are megacities for impacts of climate change?	-Assessment and criteria for preparedness level	-Published literature -Transcripts of interviews based on exploration of each case	-Desk Research -Meeting/Interview in person or via Skype
How could megacities be better prepared for climate change impacts that may occur in the future?	-Identification of gaps in each case -Identification of potentials for improvements	-Published literature - Transcripts of interviews based on merging ideas of environmental experts and urban planners	-Desk Research -Meeting/Interview in person or via skype

Table 2 *Research questions, required data, sources and methods of access to data*

This section conveys the materials needed to answer the main research questions. It brings to light the sub-questions and identifies the required data. Furthermore, it recognizes the source of these data and the method of access to the necessary information.

As previously mentioned, this research looks in depth in each of the selected megacities as case studies, thus each of the sub-questions is answered in each of the selected context.

As highlighted in Figure 3, the research framework depicts the impacts of climate change in each city to better understand how they are affected and what climate change impacts they are exposed to. Desk research is used to get access to data available in scientific literature, databases and other accessible literature and documents. Impacts and vulnerability assessments developed by the local and/or the national government are examined along with news articles highlighting the damages caused following an extreme weather event (flooding, droughts etc.). The research focuses on impacts of changes of climate patterns since the beginning of the 21st century, starting with the year 2000.

Following the identification of impacts, the study examines the contemporary urban planning and the developed management strategies (on a local and/or a national level) adopted since year 2000 in each of the selected cases to build resilience. Documents published by these cities are used as a basis to identify current efforts in place ensuring the adaptation of susceptible urban infrastructure to probable impacts. Additionally, interviews with key-players, such as urban planners and city representatives, are important to know more about the efforts each of these cities are putting to adapt the urban infrastructure to climate change.

After consideration of the impacts, and the actions undertaken by the selected megacities to adapt to climate change, indicators and criteria are set to identify the resilience and the ability of cities to overcome expected and unexpected stresses. These criteria are based on the capacity of economic, social and environmental and governmental systems to adapt. The developed criteria to assess the urban resilience is further elaborated in section 3.8 Desk research as well as interviews with city leaders, urban coalitions and environmentalist and external organizations

and parties (such as C40, The Urban Resilience Network, and Urban Sustainability Officers Network, 100RC…) are important to get access to the necessary data.

Finally, following the identification of impacts, management approaches to build a resilient urban infrastructure and the level of readiness these cities are at, gaps and room for improvement can be determined. Conclusions are thus made based on critical analysis supported with desk research and the input of experts answering the main research question (Figure 3).

3.7 Interview Guide and Ethical Conduct

Conducting interviews is one of the approaches adopted for data collection (Figure 3), in parallel to desk research, in order to answer the main research question and the relevant sub-questions. For this research of contemporary concern, interviews are crucial as they are resource intensive. The interviewees, with their knowledge and expertise, help achieve an in-depth and thorough information acquisition on the topic (Kvale, 2003).

Therefore, it is important to highlight that this thesis is responsibly written respecting general ethical principles. The research is of educational relevance and scientific validity. The ideas or texts not originated by the author are thus identified and referenced. Furthermore, any conducted interview during the course of research respects the rights of the participant. As sources of primary data, interviewees are notified that the information they are giving is used and referenced in this literature if they agree upon it. If they wish to remain anonymous, this research preserves their confidentiality and recognizes their privacy matters. To ensure the participants in the aforementioned privacy rights, each interview starts with a brief summary of the research topic and is followed by a clear question addressed to interviewees to assert whether they could be identified in the referencing or whether they prefer to remain anonymous (*Please refer to Appendix A for the design of the interviews*).

Conducting interviews in support of the case studies has been challenging as it involves interviewees from different parts of the world. Nonetheless, a total of 9 interviews are conducted involving at least one actor representing the government's perspective in each selected case. This allowed for providing insights on how the national or the local government is approaching the topic of climate change adaptation. Moreover, interviews are also conducted with environmentalists and experts who have worked on the topic of climate change adaptation in an urban context. Their perspective on the topic is valuable as they have a wide experience working on the topic.

The table below highlights the interviewees who participated and supported the development of this research project.

Case	Expert	Title and Role	Affiliation	Type of Interview
Developing Cities	**Saleemul Huq**	Director	International Center for Climate Change and Development (ICCCAD)	Skype Interview
Cairo	**Saber Osman**	Adaptation Director	Egyptian Environmental Affairs Agency (EEAA)	Skype Interview
	Rawad Rizk	Sustainable Energy Specialist	Regional Center for Renewable Energy and Energy Efficiency (RCREEE)	Skype Interview
	Interviewee 1	Urban Planner	-	Phone Interview
London	**Gemma Holmes**	Senior Analyst	Committee on Climate Change in London	Written Interview
	Interviewee 2	Policy Advisor	-	Skype Interview
	David Dodman	Director: Human Settlements Group	International Institute for Environment and Development (IIED)	Skype Interview
New York	**Gary Yohe**	Professor of Economics and Environmental Studies Member of the New York (City) Panel on Climate Change (NPCC)	Wesleyan University and NPCC	Phone Interview
	Interviewee 3	Consultant	-	Phone Interview

Table 3 *List of Interviewees*

3.8 Data Analysis: Urban Resilience Index

This section elaborates on the methodology used to assess and measure urban resilience in the selected cases. An urban resilience index is developed to give a single-weighted value assessing the resilience level of megacities. It is an important tool to make the concept of resilience palpable and perceptible. There is no universal assessment tool adopted to measure urban resilience. Assessing whether a megacity have a resilient urban infrastructure or not could therefore be perplexing. International agencies and NGOs have been developing tools, indicators and standards to make the concept of urban resilience reckonable. As a case in point, the "International Organization for Standardization" (ISO) issued the ISO 37120 standard as an "indicator for city services and quality of life" to be used in assessing the resilience of a city (UN Habitat, 2017). Moreover, Arup[2], with the provision of the Rockefeller Foundation, have developed the City Resilience Index (CRI) as a tool to better understand and quantify resilience (The Rockefeller Foundation and Arup, 2016). The CRI provides a stimulating and a comprehensive approach to quantify resilience on an urban level. It offers a multi-layered approach integrating various dimensions such as health and wellbeing, economy and society, infrastructure and ecosystems and leadership and strategy. However, due to the research limitation mentioned in section 3.5 and the focus of this research on the physical infrastructure in particular, a corresponding resilience index is developed to assess the resilience of the urban infrastructure of each of the selected megacities.

3.8.1 Assessment Questions

30 questions are addressed in the four areas identified in the developed conceptual model (*Section 3.3)*: Understanding the Impacts, Formulating Comprehensive Strategies, Implementing Developed Strategies and Addressing Problems. Literature review is used as a foundation to formulate a set of questions in each area defined in the conceptual model (Figure 5), as further explained below.

Understanding the Impacts and Vulnerabilities

"The starting point in managing risks and building long-term resilience is for a city to understand its exposure and sensitivity to a given set of impacts" (World Bank, 2011). The first step to addressing the problem is the ability of the different stakeholders, including the mayor, the city planner and the citizens, to understand the problem. Once an acknowledgement and an understanding of the issue has been established, they have to think about possible solutions and required actions (Huq, 2018). Therefore, a comprehension of local vulnerabilities is key to adaptation. The World Bank's guide to adaptation highlights the fact that various approaches are used to assess the impacts i.e. some assessments focus on environmental effects on particular economic sector or in a particular geographic location. However improved recent assessments

[2] Arup is a multinational design consultancy firm based in the UK.

are ones that not only focus on physical dimensions but incorporate economic and social implications related to the sensitivity of affected regions. (World Bank, 2011).

The questions below are addressed to assess whether the selected megacities have developed an understanding of impacts and vulnerabilities.

1. Is there a national vulnerability assessment of Impacts of climate change?
2. Is there a local vulnerability assessment of Impacts of climate change particular to a specific urban setting?
3. Is there an understanding of indirect socio-economic implications of climate change on the city?
4. Is there a mapping of climate impacts based on data collection and monitoring?
5. Are changes in climate patterns projected and anticipated?
6. Is the national government inciting research and studies in the field of climate change adaptation?

Formulating Comprehensive Strategies

Various factors come in play allowing for the formulation of a well-rounded strategy. First, national support is important in addressing the topic as a countrywide priority. Moreover, the World's Bank guide to adaptation highlights the role that the city government plays in ensuring adaptation through presenting a high degree of commitment. Social collisions are acknowledging the importance of the commitment of local governments to design a comprehensive strategy allowing for a sustainable development of urban centers. As a case in point, ICLEI is working on engaging with city leaders and strengthening their actions to allow for a sustainable future (Huq, 2018). Furthermore, the involvement of external actors with scientific competencies or expertise is essential for the development of a sound strategy based on the comprehension of impacts. The engagement of the local community with the formal authority is also crucial for the development of a resilient robust strategy ensuring a 'safety net' for vulnerable citizens (World Bank, 2011). Urgent actions should be addressed first, therefore the prioritization of actions through developing short, medium and long term plans is key. "Because cities are dynamic systems that face unique climate impacts, their adaptation must be location specific and tailored to local circumstances" (World Bank, 2011).

Based on the literature review, the questions below are addressed to assess whether the selected megacities have formulated well-rounded strategies to address impacts and vulnerabilities.

7. Is there a national political support to adaptation to climate change?
8. Is the local government committed to climate change adaptation?
9. Is there a clear determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate change?
10. Is the strategy "tailored" to the assessed local impacts on the urban infrastructure?
11. Is the strategy coordinated with scientific experts (including environmentalists, city planners, climate experts etc.)

12. Is the strategy coordinated with the local community (including NGO's, cultural forums, civil societies and non-political councils)?
13. Is the adaptation strategy addressing and prioritizing urgent matters?
14. Is there an urban master-plan ensuring the adaptive development of the city?

Implementing Developed Strategies

The implementation of a developed strategy is when policies, aims and visions are turned into a reality. In order to ensure the adaptation of developed strategies, financial and technical resources should be available. Implementation is crucial to know whether the strategy works or not, this can't be identified in advance since "adaptation to climate change is a learning by doing process, you have to do something and see if it works or not. And once you test it, you do more, you replicate or you scale up what works and you discard what doesn't work." (Huq, 2018). The government's commitment is crucial to ensure a long-term implementation of adaptation projects. However, "many cities face significant obstacles in fulfilling their functions because of long-standing problems with governance, such as corruption, lack of transparency, and weak administration". Community and non-governmental corps play a role in enhancing the government's role in ensuring an adaptive urban infrastructure (World Bank, 2011).

The questions below measure the implementation of adaptation at the level of urban infrastructure, which refers to houses and infrastructures, such as electricity, water and communication systems, as well as urban green infrastructure (Suárez, et al. 2016).

15. Are short terms adaptation initiative being implemented?
16. Is funding made available for the adaptation of the urban infrastructure?
17. Is the local community playing a role in enhancing the implementation of adaptation project?
18. Is the local government transparent in the implementation of adaptation projects? (preventing corruption)
19. Are houses built to ensure the safety of their inhabitants and withstand extreme weather events?
20. Is there a defensive flood protection system in place to protect the city?
21. Are initiatives for greening cities being implemented to reduce the effects of UHI?
22. Is there an efficient drainage system preventing from flooding in cases of cloudburst?
23. Do citizens have access to fresh water?
24. Is the transportation system resilient to extreme weather events?
25. Is there a secure energy supply?

Addressing Problems

A resilient city is a city that keeps on improving its understanding to impacts of climate change and keeps on improving adaptation strategy and looks forward to addressing long term implementation projects. Adaptation "is a dynamic process, and one that should be revised over time based on new information" (World Bank, 2011). Cities learn from the implementation of

the project, as following the occurrence of an event, gaps are revealed and allows for a better preparation for future events. It is possible that the efforts the city is undertaking are making it more vulnerable and not less susceptible, this is known as "Maladaptation". Therefore, "once you realize there is a problem, you have to look at your own current plans, and see whether your current plans are going to make your problem worse or better" (Huq, 2018).

26. Are impacts recently updated integrating new findings (after 2015)?
27. Is the strategy recently updated integrating recent impacts assessment (after 2015)?
28. Are the barriers impeding the implementation of adaptation initiatives identified?
29. Are long term adaptation (Year 2050-2100) initiatives and projects being developed?
30. Are there any emergency plans to act in cases of occurrence of extreme devastating environmental events?

3.8.2 Quantification of the Assessment Results

The questions above present a desired situation based on existing literature identifying approaches to resilience. Therefore, each positive answer (*Yes*) accounts for 1 point as it identifies the application of resilient approaches as defined by existing literature. Each negative answer (*No*), accounts for no points, as it presents the lack of implementation of measures that enhances the resilience of the urban infrastructure. Each answer highlighting a situation where resilient approaches are currently being addressed yet not fully implemented is signaled by (+/-) and accounts for 0.5 points. The sum of the answers to all questions ($\sum_1^{30} p$) give a numerical value which is to be divided by 3 to equate to (i). The result is thus calculated over 10, a maximum which represents a high level of resilience and readiness to overcome climate change; 0 being a level of total unpreparedness and non-consideration for climate change adaptation.

$$\boldsymbol{i = \frac{\sum_1^{30} p}{3}}$$

Since resilience is not a static characteristic and cannot be directly measured (Suárez, et al. 2016), the obtained value (i) can change overtime and only assesses the resilience of the urban infrastructure of the selected megacities at the time when this research is conducted.

Intervals between 0 and 10 are identified to clarify the meaning of the total numerical value obtained in each of the cases.

- **$0 < i \leq 2$: Non-existent to Weak Resilience**: Meaning the urban infrastructure is not well adapted and not adequate to changes of the climate and could present itself with weak resilience. The infrastructure can be majorly impacted in the light of extreme weather events or other consequences of climate change due to a lack or a poor understanding of impacts which is a stepping stone in insurance climate resilient (World Bank, 2011; Huq, 2018). A poor understanding of the impacts could weaken the process of developing and implementing strategies.
- **$2 < i \leq 4$: Weak to Moderate Resilience:** Meaning that there is a fragile approach to developing strategies and building adaptation based on a weak understanding of

impacts of climate change. Further factors could maximize the susceptibility of these cities like their location, rapid urbanization, and the presence of fragile and outdated infrastructures (Mungo, 2017).

- **$4 < i \leq 6$: Moderate Resilience:** Meaning that adaptation concerns have emerged, yet the megacity is still trying to boost its resilience through implementing adaptation initiatives based on a basic understanding of impacts of climate change. With a moderate resilience, the country acknowledges the importance of adaptation but could lack an administrative commitment and/or technical and financial resources (World Bank, 2011).
- **$6 < i \leq 8$: Moderate to High Resilience:** The megacities have built an understanding of impacts and is experimenting in addressing the topic. These "Lab-cities" are aware of the importance of climate change adaptation and the physical infrastructure in place is somehow resilient due to various adaptation initiatives in place. However further investments, research, resources and governmental support is needed to increase the resilience since the main components of a well-rounded adaptation approach include involving various stakeholders, boosting the capacity of learning, being flexible and being innovative (Suárez, et al., 2016).
- **$8 < i \leq 10$: High Resilience:** The megacities are leading climate change adaptation and setting an example to other cities through adopting "best practices" based on a thorough understanding of the impacts of climate change, major support from local and national governments and the availability of technical and financial resources. Nonetheless, these could still be vulnerable to severe impacts and need to constantly update their strategies and address the barriers to the implementation of adaptation approaches, given that adaptation is "a continuous process towards a desirable state in response to the constant internal and external urban pressures" (Suárez, et al., 2016).

Chapter 4: Results and Discussion

This chapter further elaborates on impacts of climate change on large urban agglomerations as well as adaptation plans in place to build resilience and overcome these consequences. This section particularly examines the cases of Cairo, London and New York.

4.1 Impacts of Climate Change on the Urban Infrastructure

As mentioned in the literature review, various cities and metropolitan areas have been suffering the consequences of natural events. The impacts of extreme weather events vary from one context to another, and depend on various factors such as the geographical location, the social and the economic capacity of the country, the implemented management strategies in place to build resilience and the level of readiness of these cities to overcome these impacts (United States Environmental Protection Agency, 2017). Some aspects could increase the vulnerability of an area or of certain communities, for instance, "the poor citizens, whether in developing or developed countries, are the ones who have the least access to services and have the least protection from impacts of climate change." (Huq, 2018). The situation makes them physically more vulnerable to impacts. However, by enabling them to understand the problem and prepare for it, they can actually deal with it when it happens and they will overcome the problem if they are better organized (Huq, 2018).

These hazards are attributed to the alteration of climate conditions over the past decades. For instance, floods result from the rise of surface water levels and from heavy rainfalls. Heat-waves, long drought periods and major wildfires are subsequent to the increase of temperatures. Extreme weather conditions have been causing the destruction or the disruption of urban infrastructure systems. These disturbances extend beyond the direct consequences, which are felt and observed, to further repercussions on societies, economies, environments and entire systems. These impacts threaten large cities in particular given that urban contexts present complex societal and economic systems. Cascading impacts can directly disturb facilities and services in urban centers such as practicality, comfort, mobility, health, economic activity, access to energy and water, security and the over-all quality of life of the residents. Weather events and hazards resulting from climate change could disrupt accessibility within and to a megacity. Given that the urban infrastructure system is intertwined, the disruption of the transportation system restricts access to work, education, healthcare as well as other services. Moreover, in the light of an extreme weather events, power disruptions are probable limiting the access to heating, cooling and lighting. Solid waste collection could be disrupted reducing the level of comfort, livability and health of residents. Moreover, access to drinking and clean water can also be limited (Wilbanks and Fernandez, 2013).

These damages could disrupt the day-to-day economic and social activities and even endangers lives. On one hand cities expenditures on reparations could result in unaccounted-for costs. On the second hand, disruption of the pattern of daily activities could pull the economy of cities down. Businesses will not be able to operate, their sales and profits will decrease conceivably leading to loss of wages. The economic consequences on urban inhabitants could lead to the displacement of people. The situation could cause an increase of social inequalities and increased level of legal violations or crime as well as other social problems.

The disruption of the urban infrastructure leads to a "snowball" effect hindering the social and economic activity on a regional level and possibly on a national level. I.e., some cities which rely on the tourism and services sector as a major economic source are majorly affected on the economic front by repercussions of climate change.

4.2 The Case of Cairo, Egypt

4.2.1 Understanding the Impacts and Vulnerabilities in the City of Cairo

Cairo, the Egyptian capital, is located in North-East Africa and has an arid climate. This metropolitan area is the biggest in the Middle-East region and Africa and the 9th biggest in the world with more than 19 million inhabitants. The city's population is expected to reach more than 24 million in 2030 in the light of colossal urbanization (United Nations, 2016). This case is an example of a megacity in a developing country dealing with impacts of both urban sprawl and climate change. Cairo presents an interesting case, not only due to its important social and economic position in the middle-east, but also because it is of important historic and cultural value. Cairo has started to experience some impacts of global warming. Those effects are expected to be amplified in less than 20 years, putting the life of millions of people at risk, if no serious adaptation or mitigation have been adopted (Connor, 2013).

It is estimated that 65 % of Cairo population live in informal settlements. These dwellers are particularly prone to adverse impacts of extreme weather conditions. With its urban slums, Cairo presents a susceptible environment as these settlements are often in poor conditions and lack maintenance, exposing their inhabitants to risks. In the light of environmental or natural hazards, these structures are at a high jeopardy of being damaged and destructed, making it difficult to limit the economic and social ramifications of environmental impacts (World Bank, 2011). Interviewee 1 highlighted that Cairo residents are sensing the consequences but are not aware that these impacts are emerging because of changes in climate patterns and are not aware of their respective socio-economic ramifications. He elaborated that following the occurrence of an environmental event, the survival instinct lead residents to try to increase their resilience and find small-scale solutions to deal with the consequences. Due to the lack of knowledge, the solutions the residents come up with are not always sustainable or appropriate, and they tend to mal-adapt which weakens their resilience instead: "People complain when their properties are affected in

the light of extreme weather events, but continue to build the same way they have always been building." (Interviewee 1, 2018).

An initial 'National Communication on Climate Change' was in 1999 introducing vulnerabilities of Egypt to the changes of climate. Updated versions were published in 2010 and 2016 respectively integrating new vulnerabilities which haven't been addressed before such as impacts on 'urban systems'. However, conducting impact assessment is challenging in Egypt in general, and Cairo in particular. "There is a lack of basic information, such as meteorological data" (UNDP and Egyptian Cabinet Information and Decision Support Center, 2011). The released communication reports focus on a national level. No assessment of direct or indirect impacts of climate change have been developed to address the vulnerabilities in Cairo. The Adaptation Director at the Egyptian Environmental Affairs Agency (EEAA) highlighted that the understanding of the vulnerabilities and impacts on the urban population should be improved, and attributed the deficiency in data collection to a deficiency of monitoring stations and the lack of expertise in data collection and monitoring (Osman, 2018).
Cairo is experiencing many effects of climate change, and the situation is expected to worsen, as projections for 2030, 2050 and 2100 have shown major changes in temperature and precipitation patterns (OECD, 2004). Sections below elaborates on the impacts of climate change on this megacity based on existing literatures, desk research and interviews.

4.2.1.1 Urban Heat Island Effect and Heat waves

Cairo was developed at the juxtaposition of the Nile River and have experienced a rapid growth since the 1960s. The rapid, unplanned and unprecedented development and expansion of the city have exerted a huge pressure on the environment. The extensive urbanization, limiting green spaces, have reinforced the UHI effect in the city. "Cairo shows a significant rise in surface temperature with a general trend of warmer urban areas versus cooler surrounding cultivated land" (Saab and Tolba, 2009).

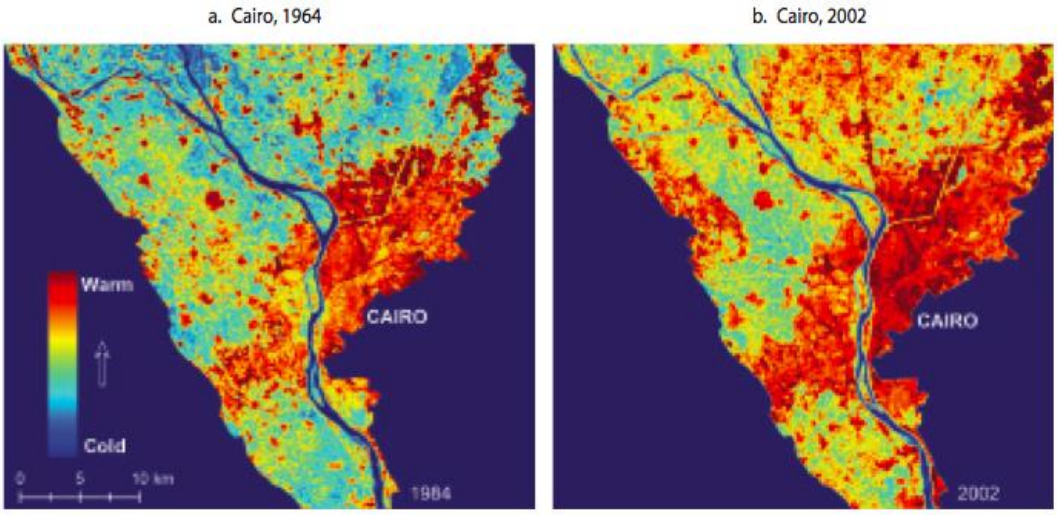

Figure 6 *UHI: Rise in Cairo's Surface Temperature between 1964 and 2002, Source: Ghoneim, 2009*

As shown in Figure 6, the UHI has spread through the delta area between 1964 and 2002 with the extensive development of the city. With the continuous increased and unplanned urbanization, the UHI effect is projected to be amplified particularly that urban planning in Cairo is still underdeveloped: there's not enough greening, asphalt is covering the surfaces limiting their permeability and buildings and their roofs are not well maintained and taken care of (Osman, 2018).

An increase in temperature degrees and the reoccurrence of heat-waves will become unbearable and uninhabitable in some locations leading for the dislocation of people; particularly in Cairo which is vulnerable to heat waves, especially that there are no big water surfaces or elevated areas which can help limit the UHI effect and sooth the climate (Osman, 2018). The internal migration is expected to increase social instabilities and inequalities in the country as more people are expected to be living in informal slums with no access to basic infrastructure (Barron, 2018). In extreme cases, heat waves could result in significant health issues and in the increase of death rate.

4.2.1.2 Droughts and Desertification

Cairo has a water shortage problem, as it receives slightly more than one centimeter of rainfall per year (GEF, et al., 2016). In the events of climate change, water shortages are expected to intensify in the city due to changes in weather patterns and anticipated reduced precipitation (Jenison, 2016). The situation could lead to issues on various levels. On an economic level, the scarcity of freshwater increases the costs of access and causes financial burdens on the inhabitants. Health wise, the limited access to clean water could result in the spreading of viruses and diseases. Additionally, desertification and the attenuation of water resources in the Nile area could affect the quality of agricultural crops. As an example, finding it hard to have access to clean water, with the shortage of government's supply of irrigation water, Egyptian farmers are using untreated water in agriculture. A report published by Al Jazeera (2009), interviewing local farmers, affirms that more than 250 acres of land are irrigated by sewage water. This has caused the spread of diseases leaving hospitals filled with patients suffering from illnesses related to food poisoning (Al Jazeera English, 2009).

4.2.1.3 Flooding & Rise of Sea Level

Recurrent flooding due to the change in the precipitation patterns and unusual rainfalls are becoming a threat to Cairo (Osman, 2018). Consequently, the urban physical infrastructure will have to deal with amplified impacts, particularly in poor neighborhoods and developed informal settlements (World Bank, 2011). The situation could lead to economic losses and the disturbance of daily activities. In April 2018, heavy rainfalls have caused the flooding of roads as water level rose to reach over one meter, submerging cars and causing unbearable traffic. Additionally, the events have caused further property damages, such as the distortion of buildings' roofs, and power outage (Ahram, 2018; Rizk, 2018). This flooding was attributed to the failure of water draining systems: "The accumulated water exceeded the capacity of some public sewers in the city, causing heavy damage in the drainage system" (Ismail, 2018; Interviewee 1, 2018).

Likewise, in October 2016, the Egyptian delta area was inundated by water, which caused damages to the built infrastructure, electric power cuts, economic losses, and the displacement of hundreds of people as well as fatalities. The situation provoked the military to take action in order to aid affected families (Fox News, 2016; Rizk, 2018). The Head of the UNISDR in the Arab World asserted "Flood risk is a reality in the Arab region and it is very important that governments invest in flood prevention measures and an adequate land use planning"; in a context where urban flooding "is becoming more dangerous and costly because of the increasing population exposed within urban settlements" (Acero, 2014). An interview with Mr. Rizk, a sustainable energy specialist at Regional Center for Renewable Energy and Energy Efficiency (RCREEE), highlighted the importance of building resilience and adapting to changes of climate as extreme weather events and floods could directly and indirectly impact the security of energy supply, affect the transmission of energy and cause power outages.

Besides flooding due to cloudbursts, Cairo is indirectly threatened by the rise of sea level as Egyptian coastal cities and parts of the Nile delta area "will be swamped by the intruding Mediterranean" (National Geographic, 2013). Consequently, residents of directly impacted coastal cities, such as Alexandria, are likely to relocate to other urban hubs, such as Cairo. The internal migration and the dislocation of people is likely to increase the pressure on the capital and the expansion of informal settlements.

4.2.2 Formulating Strategies to Build Resilience in Cairo

Egypt was among the first Arab countries to have signed the international initiatives on climate change. The country indorsed the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. At the national level, as a result of the improved scientific evidence on climate change and its impacts on Egypt, the National Committee on Climate Change has been established in 2007 (GEF, et al., 2016). This committee is concerned with developing adaptation and mitigation strategies and it allows for the collaboration among various ministries and organizations. Nonetheless, adaptation efforts lag behind mitigation actions in Egypt. Awareness has increased in the area of mitigation and GHG emissions, and the government and private companies are collaborating to develop renewable energy resources. However, as far as adaptation is concerned, people in Egypt, and particularly in Cairo, don't have the same level of awareness yet (Osman, 2018; Rizk, 2018). Climate change adaptation is not given sufficient attention in the national priority list of decision-makers as the country is prioritizing other political and socio-economic problems (Al Genzoura, 2012). Moreover, the lack of institutional systems required to monitor, build data basis, analyze data and advise decision makers concerning adaptation and follow up implementation to face climate changes constitute a major problem (GEF, et al., 2016).

Nonetheless, to address the challenges, in 2011 the country developed the National Strategy for Adaptation to Climate Change and Disaster Risk Reduction. The national strategy is a top-down approach supported by a panel of experts (UNDP, and Egyptian Cabinet Information and Decision Support Center, 2011; Osman, 2018). The comprehensive national program aims to

strengthen the institutional system for coping with climate change and help the country put climate change within the priorities of the government. The national strategy is focusing particularly on three areas, the rise of sea level and its impact on the delta region, the lack of water resources, and the impacts on the agricultural sector. Nonetheless, extreme weather events are not taken into consideration in the areas of focus (Osman, 2018).

Moreover, the country's 'Intended Nationally Determined Contribution' (INDC) highlights the aim to adapt to the predicted issues of water scarcity through up-surging the water storage capacity, improving drainage, rain water harvesting and irrigation systems (Arab Republic of Egypt, 2015).Additionally, Egypt is aiming at raising public awareness as well as supporting research in the field of planning for climate change. The country intends to encourage the exchange of information and the cooperation between universities and research institutes in areas related to understanding impacts and developing adaptation responses. The national strategy highlights the importance of the participation of local communities in decision making, however recognizes that the role of civil society is weak (UNDP, and Egyptian Cabinet Information and Decision Support Center, 2011). Egypt's government is aware that, in order to turn these intentions into reality, the implementation of the INDC requires involving various stakeholders, such as city planners, environmental experts and various NGOs. It also entails the backing of international parties through financial and technical support to allow the country to build capacity and to transfer the technology to a relevant local context (Arab Republic of Egypt, 2015).

In parallel to the national strategy, the Ministry of Environment have started in 2013 to cooperate with GIZ (German International Cooperation) on a project about the adaptation of climate change in the Greater Cairo region. The main focus is to develop a climate change vulnerability assessment for the adaptation strategy of urban informal areas, given that the most vulnerable groups in the region are the people living in urban slums. (Osman, 2018). Moreover, the governor of Cairo have committed to collaborate with 'C40 Cities' to address the subject of climate change and to make the city resilient. The local government plans to improve mass transportation systems and the livability of the city (C40 Cities, July 2015). However, the city's governorate haven't to date developed its own strategy to address building resilience.

4.2.3 Implementing the Developed Strategies to Build Resilience in Cairo

Finding implemented large-scale adaptation projects supported by a clear and a primary climate change motivation to build resilience have been challenging in the case of Cairo. "Specific climate change adaptation activities in Egypt have been limited mostly to studies and planning." (OECD, 2004). Interviewee 1 highlighted that in theory and on paper, the efforts the government is putting look great, but in reality, the corruption co-tangled with short-sighted planning have caused adaptation efforts to lag behind. Moreover, there is a lack of indicators allowing to evaluate and monitor the implementation and the progress of the programs and policies highlighted in the strategy (Osman, 2018). Nevertheless, several small-scale initiatives have been implemented to approach the problem of the unsustainable development of the city, remarked by

informal settlements, environmental deterioration, congestions and economic disparity. Ensuring a sustainable growth of Cairo could limit the impacts of climate change and ensure a resilient development of the city.

The most remarkable large-scale urban project is the capital development announced in 2015. The project is under construction and expected to be completed and delivered between 2020 and 2022. It consists of 70 thousand acres built from scratch and aims to provide a clean environment, gardens, job opportunities as well as housing. The project adopts technologies and strategies enhancing resilience to changes of climate (The Capital Cairo, 2015). The Egyptian government and the developers of the project are positive that it will put an end to the unplanned expansion of the capital and informal settlements, increasing the resilience of the city. Building new cities offer the opportunity for environmental urban planning. However, the fast development of a mega-urban planning project creates tradeoffs between planning for climate change and building resilience on one hand and economic and financial choices on the other. The development of a new city gets the attention of real estate developers, who often do not prioritize environmental concerns. These developments are usually seen as investment opportunities rather than an opportunity to address environmental issues. Sustainability is often used as a marketing strategy and a selling point rather than a primary focus (Interviewee 1, 2018). Furthermore, new estate developments could foster social inequalities as they are often unaffordable for a majority of the citizens (Monks, 2016). Hence it doesn't help in limiting the expansion of informal settlements and it increases the carbon footprint weakening the resilience of a city (Interviewee 1, 2018). These new developments remain unpopulated due to the lack of reliability of the existing transportation system. Leaving residence obligated to have their own car to commute to the center where services are concentrated.

Given that the lack of funding has been one of the country's main barrier to implementation, areas of priorities and their associated costs have been identified in the "Egypt National Environmental Economic and Development Study" (NEEDS) for climate change. Nonetheless, international projects and funding have been playing a major role to support Cairo respond to impacts of climate change. For example, the Green Climate Fund (GCF) approved the funding of "USD 31.39 million for the Enhancing Climate Change Adaptation in the North Coast and Nile Delta Regions in Egypt"(Twining-Ward, 2017).

Moreover, the UNESCO and the UNDP have launched "Climate Change Risk Management" project in cooperation with the Egyptian Ministry of Irrigation and Water Resources. Various components were developed addressing both mitigation and adaptation initiatives. The project includes the implementation of flood forecasts, Integrated Water Resources Management (IWRM) and the adaptation of agriculture (GEF, et al., 2016).

The Global Facility for Disaster Reduction and Recovery (GFDRR) have also supported Egypt in various projects to increase its resilience through adaptation, mitigation and risk reduction measures (GFDRR Official Website, n.d.).

Furthermore, projects funded by the EU have been developed, such as the participatory development program (PDP[3]). This PDP focuses on adaptation measures strengthening the capacity of local urban communities to withstand probable impacts and build resilience, particularly in the slums and informal settlements of the Great Cairo region (PDP, 2018). The objective of the PDP is to implement small-scale adaptation measures in urban slums in cooperation with the urban population and civil society in order to enhance resilience. The initiative also strengthens the development of official policies, strategies and plans. Furthermore, the project aims at improving the situation of the built environment through rehabilitation in order to reduce the impacts of UHI. The PDP also works on raising awareness and facilitating the exchange of experiences among experts and parties involved in climate change adaptation programs, urban development and environmental planning. Overall, the project intends to integrate adaptation measures into urban development methodologies at all levels as well as to align climate change adaptation objectives with national policies and plans (PDP, 2018).

Small urban agriculture projects have been implemented to address the topic of extreme heat waves and their impacts on food security, such as "Greener Cairo: Sustainability through Urban Agriculture". The project started in 2010 with the planting of rooftop gardens, wall gardens and roof-farms. The gardens have mainly esthetic, environmental, and insulation purposes, meanwhile the farms' main goal is to ensure food security. The project was primarily developed in underprivileged areas in close collaboration with communities. Trainings and quality control were important to ensure the healthy growth of crops and herbs. The initiative also helps these communities to build financial capacities, therefore the crops are not only grown for subsistence but also to be sold on the market. In 2015, 200 people were trained and around 120 rooftop farms were installed. The project has faced some opposition at first, as people were not familiar with urban gardening (Parietti, 2015).

The adaptation director at the EEAA, highlighted that many projects, measure and initiatives are being implemented, however since the country has had an accumulation of previous problems the results of implementations take a longer time to manifest (Osman, 2018).

4.2.4 Addressing Barriers to Implementation

Despite participating in international environmental agreements and developing national adaptive strategies promoting resilience, such as the INDC program, the actual implementation of climate change adaptation is still insubstantial in Egypt. The government is dealing with other pressing priorities, climate change adaptation is not yet a primary motivation for national decision-makers (Interviewee 1, 2018). Most implemented projects are in place to address social, economic or political problems rather than to prepare for impacts of climate change. In addition, the implemented projects consist of small scale initiatives rather than long-term or big scale

[3] "The PDP is an Egyptian-German development measure implemented by the Ministry of Planning and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). It is funded by the BMZ, the European Union (EU) & the Bill and Melinda Gates Foundation with a total EUR 49 million" (ESeed official website, 2018)

adaptation projects. Moreover, it is believed that corruption has played its role in impeding the implementation of various projects: “One of the key obstacles that continue to face Egypt’s development process is the lack of well-coordinated and transparent decision-making” (GEF, et al., 2016). Furthermore, no clear long-term adaptation approaches, initiatives or projects have been announced to ensure the commitment of the government to improving the resilience of the urban infrastructure in Cairo. The 3rd national communication on climate change identified barriers impeding the implementation of adaptive measures which include lack of database and monitoring, lack of financial resources and uncoordinated institutional activities.

However, impacts of climate change have been recently assessed integrating new findings and results. In 2016, the country has released the “Third National Communication on Climate Change” integrating new vulnerabilities which haven’t been addressed in the first and second publication released respectively in 1999 and 2010. Furthermore, a new strategy is currently being developed and expected to be published in a couple of years, addressing the barriers and gaps which came to the surface after the release of the first adaptation strategy in 2011 (Osman, 2018). The new strategy is expected to be published by 2021 and aims at considering adaptation measures, which can be developed to overcome extreme weather events, not only in the greater Cairo region, but also in all parts of the country (Osman, 2018).

The ministry of environment aims at increasing and improving data collection and monitoring as well as the processing of this data. Furthermore, whenever an environmental problem occurs, it is seen as an opportunity to learn and to adapt to reduce the risk of it happening another time (Osman, 2018). Bridging the gaps and learning from weaknesses is crucial, however, adopting a reactive approach to adapt to climate change instead of a proactive approach could weaken the country’s resilience in the face of unexpected environmental hazards. Hence, the GFDRR have worked along with the government between 2014 and 2017 and offered financial and technical support to for the development of warning systems and management capacity (GFDRR Official Website, n.d.).

International support is given from various countries, parties and NGOs for the development of initiatives and projects to ensure the resilience of Cairo in the light of climate change. Therefore, the question that remains unanswered is: Do these efforts and initiatives ensure an adequate adaptation of the urban infrastructure? To answer this question assessment criteria are developed to evaluate the level of preparedness of Cairo to overcome direct as well as indirect consequences.

4.2.5 Measuring Urban Resilience in Cairo

The methodology used to measure resilience and provide a weighted average over 10 is elaborated in Section 3.8.

The criteria set to measure urban resilience in Cairo reflects that the megacity is not yet well prepared to overcome impacts of climate change. The national government is starting to understand the importance of addressing this world problem on an urban level. However, the

problem lies in the weak comprehension of vulnerabilities particular to this context due to the lack of data collection and monitoring and due to the limited consideration of further socio-economic repercussions of climate change. Moreover, the assessment shows that the strategy is rather general as no strategy is "tailor-made" to address the problems particular to Cairo, and that the participation of the civil society on a strategic level is still weak. In addition to that, the evaluation depicts that the implementation of the developed strategy is infirm reflected through fragile and non-shielding physical infrastructure, mal-functioning in cases of environmental events. The situation appears to be the result of lack of financial and technical resources co-tangled with governmental corruption. Nonetheless, the problems in understanding impacts, formulating strategies and implementing projects are currently being addressed with the support of the government and international corps. Cairo has rather a reactive approach to climate change adaptation, and is trying to bridge the gaps and is still learning from experience.

The score below is based on evidence from document reviews as highlighted in Appendix B.

	Questions	**Yes/No**	**Score**
Understanding Impacts and Vulnerabilities	Is there a national vulnerability assessment of Impacts of climate change?	Yes	1
	Is there a local vulnerability assessment of Impacts of climate change (addressing impacts on Cairo)?	No	0
	Is there an understanding of indirect socio-economic implications of climate change on Cairo?	No	0
	Is there a mapping of climate impacts based on data collection and monitoring?	No	0
	Are changes in climate patterns projected and anticipated?	Yes	1
	Is the national government inciting research and studies in the field of climate change adaptation?	Yes	1
Formulating Comprehensive Strategies	Is there a national political support to adaptation to climate change?	+/-	0.5
	Is the local government (Cairo governorate) committed to climate change adaptation?	+/-	0.5
	Is there a clear determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate change?	No	0
	Is the strategy "tailored" to the assessed local impacts on the urban infrastructure?	No	0
	Is the strategy coordinated with scientific experts?	Yes	1
	Is the strategy coordinated with the local community (including NGO's, cultural forums, civil societies and non-political councils)?	No	0
	Is the adaptation strategy addressing and prioritizing urgent matters?	+/-	0.5
	Is there a land use and zoning addressing adaptive measures?	+/-	0.5

Implementing Developed Strategies	Are short terms adaptation initiative being implemented?	Yes	1
	Is funding made available for the adaptation of the urban infrastructure?	+/-	0.5
	Is the local community playing a role in enhancing the implementation of adaptation project?	Yes	1
	Is the local government transparent in the implementation of adaptation projects? (preventing corruption)	No	0
	Are houses built to ensure the safety of their inhabitants and withstand extreme weather events?	No	0
	Are initiatives for greening Cairo being implemented to reduce the effects of UHI?	+/-	0.5
Implementing Developed Strategies	Is there a defensive flood protection system in place to protect Cairo?	No	0
	Is there an efficient drainage system preventing from flooding in cases of cloudburst?	No	0
	Do citizens have access to fresh water?	No	0
	Is the transportation system resilient to extreme weather events?	+/-	0.5
	Is there a secure energy supply?	Yes	1
Addressing Barriers	Are impacts recently updated integrating new findings (after 2015)?	Yes	1
	Is the strategy recently updated integrating recent impacts assessment (after 2015)?	+/-	0.5
	Are the barriers impeding the implementation of adaptation initiatives identified?	Yes	1
	Are long term adaptation (Year 2050-2100) initiatives and projects being developed?	No	0
	Are there any emergency plans to act in cases of occurrence of extreme devastating environmental events?	Yes	1
Total (Over 10) $i = \frac{\sum_1^{30} p}{3}$			4.67

Table 4 *Urban Resilience Index Measuring the Resiliance of the Physical Infrastructure in Cairo to Overcome Impacts of Climate Change.*

4.3 The Case of London, United Kingdom

4.3.1 Understanding the Impacts and Vulnerabilities in London

London, the capital of both England and the UK, is the largest and most populated city in the kingdom and one of the biggest urban areas in Europe. It is amongst the oldest of the world's great cities with a history dating back to Roman times. London started developing at the banks of River Thames and expanded to cover an area of more than 1500 square kilometers, which most of it was developed over the last century (Hudson and Roumpani, 2014). The city is the country's cultural and economic hub hosting more than one hundred of the EU's best 500 largest businesses (Briney, 2017). For these reasons, this capital has attracted over 10 million inhabitants, and is expected to become the home for around 11 million people in 2030 (United Nations, 2016).

As a highly populated and constantly expanding city, London faces a growing pressure on the physical infrastructure and on the environment. The changes in climate patterns are expected to further intensify these prevailing pressures. The city has an oceanic climate with relatively cool summers and cold winters, however its climate is changing as it has been experiencing warmer and drier summer as well as wetter winters in the past decades (Official website of Mayor of London, n.d.). London is expected to be dealing with intensified impacts in the year 2056, leaving it with less than 40 years to build resilience and an adaptive environment capable to overcome the consequences of climate change (Connor, 2013).

The impacts of global warming on the UK have been assessed in 2012 and updated in 2017 after a Climate Change Act was developed in 2008 requiring the government to assess the risks and opportunities the country will face from climate change on a five-yearly basis and use it as a foundation for the development of adaptation programs (Holmes, 2018). Moreover, vulnerabilities addressing particular impacts on London City have been identified. A London Climate Change Partnership (LCCP) was founded with the collaboration of main partners including the city's council, the mayor of London, universities and scholars, as well as governmental and non-governmental agencies interested in ensuring a resilient development of their city. The LCCP released a report in 2002 "London's warming: A Climate Change Impacts in London Evaluation Study". The assessment elaborated on the indirect impacts and socio-economic implications of climate change on the city. Technical assessments are based on mapping of climate impacts grounded on data collection and monitoring. Moreover, a "Climate change risk assessment for London" was published by the LCCP in 2012. These valuation also include projection predicting impacts based on various emissions scenarios. The local government is also inciting the development of further research and studies addressing the topic of climate change. To reach a wide range of recipients, environmental facts and maps are made available to the public on the Environment Agency's website. However, one of the key informants interviewed, who preferred to remain anonymous, highlighted that even with making the information available online, many still don't understand the consequences of climate change

on London since the only clearly sensed impact is heat-wave. Climate change is not a primary concern for many local residents as they tend to think either that they are not affected or that adapting to the issue is beyond their capacities. A vast majority of citizens consider increasing resilience of the urban infrastructure is the sole responsibility of the government (Interviewee 2, 2018).

This section further elaborates and focuses on the impacts of climate change on the urban infrastructure in London and give illustrative examples based on governmental publications as well as other literature sources.

4.3.1.1 The Urban Heat Island Effect and Heat-waves

London is predominantly sensitive to the rise of temperature degrees due to the intensification of the UHI effect. The city has faced a series of extreme and unusual warm temperatures after the year 2000. The extreme heat, not only causes discomfort to people but also leads to the disruption of transport system and daily activities. Dealing with heat waves results in additional expenses due to a higher electricity demand thus people living in poverty are more susceptible to extreme weather events and could feel an intensified social exclusion. In addition to that, increased temperature degrees could amplify health problems such as vector borne diseases and in severe cases lead to death. London is not very prepared for heat-waves (Interviewee 2, 2018). For instance, in April 2017, snow and hail hit the city just few weeks after the temperature has unusually reached 22 degrees Celsius (Parker, 2017). The same year, London experienced its longest heat wave in over 20 years and its hottest June day in 40 years where the temperature reached 34.5 degrees Celsius. The event has caused the death of three people at least, who drowned trying to cool off the heat (Siddique and Taylor, 2017). Extreme hot weather conditions were also experienced in 2003 in London to which the death of more than 600 people in the city is attributed (London Assembly Environment Committee, 2015). During those events, the transportation system got disrupted as the city's underground metro became unbearably hot and as low-river heights prevented some ferries from sailing (Met Official Website, 2015). The series of extreme heat waves is expected to be more frequent and recurrent in the coming years. "By 2050, what we in this country think of as being a heat wave of the kind experienced in the summer of 2003 may well be the norm" (Official website of Mayor of London, n.d.).

4.3.1.2 Heavy Rainfalls and Flooding

With increased temperatures, the level of water vapor in the atmosphere rises, increasing the likelihood of heavy rainfalls. According to the UKCIP02 report, cloudbursts in London could increase "between 10 to 20% by the 2050s and up to 30% by the 2080s", alongside, "Heavy winter rainfall could occur twice as frequently by the 2080s" (Hulme et al., 2002). Therefore, the city will have to deal with a larger volume of rainwater. Addressing this problem is crucial as the harm resulting from cloudbursts could escalate to disrupt daily activities, transportation and cause damages to the built environment; especially, that the Victorian drainage system wasn't aimed to cope with the stresses of the current and future population which leaves the city at risk of flooding (Mayor Khan, 2017). As a case in point, in 2000, England and Wales have witnessed

the wettest fall season since year 1766, resulting in damages adding up to more than 1 billion pounds (the World Bank, 2012). Moreover, in February 2014, South East England received 268% of the average precipitation (Cowling, 2014). The Thames River as well as water reservoirs were thus saturated with the great volume of precipitation leading to a massive flood. Approximately 1000 homes along the river had to be evacuated, and hundreds of people were rescued. The flooding not only traumatized the inhabitants of the area, but also resulted in physical damages adding up to almost 500 million British Pound (Cowling, 2014).

In addition to floods due to cloudbursts, London is particularly vulnerable to being inundated by the Thames River due to the rise of surface water levels accentuated by climate changed. Figure 7 highlights the different areas likely to be affected. The impacts have already been coming to the surface, as in January 2018 the banks of River Thames were flooded due to high-tides, triggered by storm Eleanor, causing traffic chaos and locking people in their cars. The events prompted the closure of the Thames Barrier[4] built to protect the city from being flooded (Robinson, 2018). Weather due to heavy rainfalls, the fail of water reservoirs or due to the rise of sea level, flooding is menacing the city. "The impact of a major flood in London would be significant because it is heavily urbanized and 15 per cent of the city's surface area lies on the floodplains of London's rivers" (Mayor Johnson, 2011).

Figure 7 *Flooding Risks from Rise of River/Sea level. Source: Environment Agency Official Website, n.d.*

4.3.1.3 Droughts and Water Scarcity

Despite heavy rainfalls, flooding and having to deal with an excess of water, London is astoundingly threatened with droughts and water scarcity. The constantly growing population, co-tangled with unbearable heat waves, and changes in the patterns of precipitation puts the city at jeopardy of not being able to meet its citizen's water demand. Drought periods are likely to

[4] The Thames Barrier has been operating since 1982 (Environment Agency Official Website, n.d.).

appear when consecutive winters do not meet precipitation average such as years 2003- 2005, 2008-2009 and 2012-2013 (London Weather Website, n.d.). For example, during the 2003 heat wave, the UK recorded its driest period between February and October since 1921. The effects of the drought were relatively limited in London, it particularly impacted farming communities in other parts of the UK. However, the reoccurrence of drought periods accompanied with no serious water management approaches or adaptation measures could lead to an increase of water price, considering it a scarce matter. This could further affect the prices of other goods and services leading to a snowball effect. Moreover, the demand could surpass the supply, leaving water authorities in crisis to find solution to bridge the gap.

4.3.2 Formulating Strategies to Build Resilience in London

"In the UK as a whole, climate change is becoming more perceived as a priority" (Interviewee 2, 2018). The national government adopts an active stand against climate change as it ratified various international initiatives. The country has signed the UNFCCC in 1992 and ratified it in 93, it also enacted the Paris agreement in 2016. Before Brexit, the UK collaborated with its associates in the European Union developing the European Climate Change Program in 2000 and the EU Emission Trading Scheme. However, the government stated that their "statutory commitments under the Climate Change Act 2008 are unaffected by the decision to leave the EU" (HM Government, 2017). Moreover, the UK developed national approaches to address the issue such as the United Kingdom's Climate Change Program. (Committee on Climate Change Official Website, n.d.). As required in the Climate Change Act, the UK government must produce a report (the National Adaptation Programme), following the development of risk assessment once every five years which sets out the objectives of the government with regard to adaptation. The report presents the government's strategies and policies for meeting those objectives as well as the time-scales for the implementation of respective adaptation measures. The Act specifies that the developed policies and proposals must address the risks identified in the most recent conducted risk assessment (Holmes, 2018). The NAP was published in 2013, looking at various topics including: infrastructure, the built environment, businesses and local government, natural Environment, healthy and resilient communities and agriculture and forestry.

Mayor Khan of London asserts that planning for climate change is an important matter not only on a national level but also on a local scale. Consequently, he has addressed adaptation measures to reduce flood risks, cope with droughts and reduce heat risks (Official website of Mayor of London, n.d.). In an attempt to protect London from the effects of climate change and to build resilience, the city council has launched an adaptation strategy and a roadmap to resilience in a publication in 2011 (Mayor Johnson, 2011). The strategy defines priorities and actions to build resilience and manage climate related impacts based on the identification of risk hotspots in collaboration with researchers. The plan aims first at developing a further understanding of impacts and opportunities, second, at identifying options to cope with the impacts and third at developing actions supporting the management of both impacts and opportunities.

A new “London Environment Strategy” is currently being developed, based on updated environmental data, re-affirming the city’s commitment to planning for climate change. The Greater London Authority (GLA) ran a series of workshops allowing for stakeholder engagement, including businesses, NGOs and local communities (Interviewee 2, 2018). Moreover, the strategy’s draft was shared in 2017 for public consultation. The finalized plan is set to be published in 2018 highlighting both adaptation and mitigation approaches, setting out a vision and an inspiration for London in 2050. The newly developed strategy builds on the initial one released in 2011 while focusing on the role of technology in sustainable urban developments (Smart Cities) and on developing an approach to healthy streets (Mayor Khan, 2017).

The developed adaptation strategy is key to ensure London is well prepared for the impacts of climate change. It is tailored to the assessed local vulnerabilities on the urban level and focused on strengthening communities through increasing the share of green areas in the city (I,e: Urban parks, street vegetation, green-roofs and green walls). The strategy perceives greeneries as an opportunity for the city to limit the UHI effect and to provide a filtering layer protecting from flooding. “However, as the GLA is not a major landowner, the Mayor does not have any significant responsibility for the day-to-day management of parks and green spaces in London.” (Mayor Khan, 2017). Therefore, the mayor finds it important to develop policies that will incite the private community to increase the share of green spaces. The adaptation strategy sets out actions to empower local initiatives to develop solutions and supports the private sector, businesses and other institutions to prepare for various challenges (Mayor Johnson, 2011).

The city’s government recognizes the importance of adopting proactive approaches rather than developing reactive approaches. Nevertheless, the adaptation strategy develops a holistic perspective integrating both proactive and reactive measures. Developing preventive measures including mechanical processes and improved zoning and regulations is seen as important in order to address and prepare for long-term impacts. Likewise, ensuring the preparedness of the city through public awareness, vulnerability assessments and supportive insurance policies is crucial. Furthermore, the strategy doesn’t underestimate the significance of developing responses to recover from disasters occurring in the light of extreme weather events such as emergency plans and programs to support the defeated population following unfortunate weather events.

To address the problem of overheating, the city aims at designing new projects and retro-fitting existing ones to limit the need for cooling and ventilation. The strategy aims at ensuring the use low-carbon methods in situations where cooling can’t be avoided. Moreover, the city-government plans to identify the parts of the city with an intensified UHI effect co-tangled with social deprivation, in order to prioritize their actions and adaptation plans. The integration and use of new and smart technologies is seen as important to make well-rounded, environmentally-sound decisions. “A smart digital London” could allow for a more efficient use of the urban infrastructure such as energy and water (Mayor Khan, 2017).

The GLA developed a strategy to manage and overcome the flooding of surface water. The plan consists of three timeframes: short term (2012-2035), medium term (2035-2070) and long term (2070-2100). It suggests developing new spatial planning approaches and local resilience processes, as well as continuously maintaining, enhancing and improving the flood management systems in place. The strategy recognizes the importance and incites the development of emergency planning activities while enduring flood forecasting. It supports monitoring and collecting data, building partnerships, developing frameworks, mapping and identifying 'critical areas', developing management plan, prioritizing projects and funding these projects (Greater London Authority, 2017).

The Thames Water corporate strategy extends to cover both demand-side and supply-side measures to address the problem of drought in London. The demand-side measures focus on consumers' behavior through enhanced media campaigns, leakage reduction, ban of sprinklers and unattended hosepipes. The supply side-measures aim to optimize existing sources and to re-commission sources which are generally not fully utilized as their operation proved to be not cost-effective or as they do not meet certain water quality criteria (Thames Water Utilities LTD, 2016).

These various approaches are supported by the LCCP and constitute the direction and the strategy the city is developing to address the impacts of climate change on various levels. The designed strategy and intended actions allow for the participation of the community through an online discussion platform "Talk London" allowing for Londoners to have a say in environmental issues and proposed adaptive projects. London's adaptation strategy looks promising however, it is important to examine the status of project implementation in the city and the executed measures to build resilience.

4.3.3 Implementing the Developed Strategies to Build Resilience in London

In 2007, legislative changes have shifted the responsibility to plan for climate change from the central government to the GLA. This have put the mayor of London in a powerful position to ensure the implementation of climate change adaptation projects. The role of the national government is sure important in the implementation of adaptation strategies, however local authorities have a critical role in conveying adaptation approaches addressing the specific needs of a particular context. "Local authorities hold important policy levers, such as local spatial planning and the enforcement of building regulations, and are responsible for the delivery of a range of relevant services such as local flood risk management, public health and social care, and emergency planning." (Holmes, 2018).

To ensure a healthy growth of the city, increasing efficiency and resilience is one of the main priorities. The mayor acknowledges the importance of involving citizens in climate change adaptation in order to build a resilient city. Therefore, awareness campaigns have had their share on the city's government agenda. The city's primary concern is to adapt to storms, river floods and to heat-waves. Adjusting to the sea level rise and drought is also on the governor's program however more urgent matters need to be addressed first (Official website of Mayor of London,

n.d.).

In the recent years, there has been a loss of green areas, gardens and open spaces due to new developments in London. Moreover, half of the city's residents have a meagre access to parks (Mayor Khan, 2017). Yet, the city proves to have a green cover of more than 30% (World Cities Forum, 2017). Parks and green spaces have been given a significant attention in the development of London, as the current mayor is looking forward to increase the share of green areas to 50% and make the city a National Park City. The project is a long-term vision for the city which not only increase the resilience and the adaptation of the city through reducing the UHI effect, but also through creating a stronger connection between the residents and the environment and through increasing the walkability and the use of bicycles in the city. This could limit the use of the current transportation system in place which is primarily fuel-based and reduce the pressure on the physical infrastructure. The project's target is to make more than half of the city's area green by 2050. To ensure that, financial subsidies of approximately 9 million pounds are to be awarded in several rounds for the implementation of large scale green infrastructure projects. Also, these subsidies aim to incite community tree planting and the conduction of studies and research to suggest new approaches to plantation and to develop records about London's vegetation cover (Official website of Mayor of London, n.d.). Nonetheless, it takes time to identify the actual progress in the implementation of these goals and to recognize whether the desired results are noticeable and perceptible (Interviewee 2, 2018).

In response, the public sector in collaboration with the cross river partnership have supported local businesses and landowners to increase the share of green areas in the city through planting rain gardens, pocket parks, green roofs and walls. The "Greening London" project was a successful initiative to green the capital, offering more than one hundred green infrastructure projects, increasing the city's biodiversity and improving the air quality. This project, developed in 2010, aims to portray that businesses and the environment don't have to be unharmonious, and that a healthy environment is necessary to the growth of thriving economy. The Greenwood theater pocket park is an example of a small scale park which not only adds to the aesthetics of the city but also contributes to improving biodiversity and reducing the UHI effect (*Figure 8*).

Figure 8 *Greenwood Before and After the Implementation of the Pocket Park Project.*
Source: Team London Bridge, 2014(picture to the left); City Scape Organization Official Website, 2018 (picture to the right)

Groundwork, an environmental organization, have also supported the emergence of green spaces in London through offering financial and technical support to locals. For instance, it is working along with local citizens to design and implement adaptation measures on housing estates such as integrating green roofs and incorporating 'Sustainable Urban Drainage Systems' (SUDS)[5]. These systems are considered a solution for both flooding due to heavy rainfalls and to water scarcity, as excess water is filtered through permeable surfaces and drainages to underground systems offering filtering and storage. Furthermore, Groundwork developed the 'Energy Garden Project; which converted over thirty over-ground stations and platforms into gardens offering plots for food plantation. Furthermore, these green spaces are used for the installation of solar panels, providing energy for small scale facilities on the station. (Groundwork Official Website, n.d.).

The Environment Agency committed to financing new major research on sea level rise, fluvial currents and sea storm floods. More than 300 studies on the topic of flood hazards in the Thames estuary in a context where flood defense mechanisms are ageing and population growth is exerting additional pressure on floodplains. These studies concluded that no major changes to the defense structures in place are required in the coming 25 years (Thames Estuary Partnership Official Website, n.d.).

The city's assembly environment committee developed a flood prevention plan to cover approximately around 40% of the houses (10,000 approx.) at risk of flooding. The scheme requires a budget of around 100 million pounds over the course of 10 years, half of this funding might be covered by central government grants. However, 60% of the houses (14,000 approx.) would still be susceptible to significant risk even if the proposed planned is completely implemented. Nevertheless, the assembly members have ensured that other measures will be implemented to protect the floodplain for at least the coming 20 years (UK Government, 2014). The Environment Agency developed the Thames Estuary 2100 (TE2100) project which protects the city and the inhabitants of the Thames Estuary from future flooding. The budget allocated for this project is of 196 million pounds. The TE2100 is based on current patterns of climate change, however is flexible to incorporate adaptation and updates over the rest of the century to match future weather conditions. "Estimates predict a relative sea level rise of 90 cm by 2100 but the TE2100 Plan is adaptable to differing rates of sea level rise up to 2.7m, and an increase of 40% in peak river flood flows." (Thames Estuary Partnership Official Website, n.d.).

Moreover, the government has developed an online platform to allow residents to know if they are at risk of flooding. Dwellers can sign up for flood warning's service for free to detect whether their property is threatened. The online tool increases the resilience as it warns for immediate risks through indicating river and sea levels, it also alerts for the threats on the short and the long run. Furthermore, lodgers can have access to the environment agency's registers to identify the submerging history of a certain property. The platform provides guidelines to

[5] "SUDS aim to mimic within urban areas the way rainfall drains in natural systems", SUDS include: permeable surfaces and filter drains, bio-rentention areas and green roofs, infiltration structures, basins and ponds and underground storage (Anglian Water Services Ltd, n.d.).

prepare people to protect themselves from prospective flooding. It also offers road travel information following the occurrence of a swamping incident. Additionally, a 'floodline' is made available to allow for people to report flooding or related impacts. All of these measures ensure a better preparedness of Londeners and their city in cases of heavy rainfalls (UK Government Official Website, n.d.).

As the responsibility to implement adaptation projects have shifted from the national to the local government, the latter was left with the issue of the local budget for planning for climate change being cut. Local authorities are being left to implement different strategies developed on a national level without receiving any additional funding (interviewee 2, 2018).

4.3.4 Addressing Barriers to Implementation in London

The Stern Review also known as "The Economics of Climate Change" (a long report released in 2006 for the national government of the UK) highlights the barriers to adaptation, including: ambiguity and lacking information, misaligned and missing markets and financial constraints.

"With some exceptions, despite progress with NAP actions, in many areas the vulnerability to climate change is not reducing and in some it has increased. It is therefore timely for the National Adaptation Programme to be refreshed and updated." (Holmes, 2018). Hence, an updated program, including more ambitious proposals, is expected to be published in 2018, reducing the country's vulnerability to changes of climate.

The impacts of climate change on the city of London were updated in 2017 in the "UK Climate Change Risk Assessment 2017 Synthesis report: priorities for the next five years". A new strategy is currently being developed in response to the updated impacts. The plan also addresses the barriers impeding the implementation of adaptation initiatives. Lastly, London is developing long term initiatives and strategies to confirm its continuous commitment to climate change adaptation such as the TE2100 initiative managing water resources on the long run.

Moreover, in order to prepare for projected risks and to address barriers to climate adaptation, the UK is currently developing and implementing an Emergency Services Network (ESN) across the country, the ESN's application in London is more complex and challenging as this service requires to be effective and to work in the underground. The project is seen as essential for the country's national infrastructure. The ESN aims at keeping Londoners safe and to increase the city's resilience through establishing a connection between citizens and emergency service departments (i.e police, ambulances, firefighters etc.) (UK Government, 2018).

4.3.5 Measuring Urban Resilience in London

The methodology used to measure resilience and provide a weighted average over 10 is elaborated in Section 3.8.

The criteria set to measure urban resilience in London reflect that both the national and the local government is actively addressing the importance of climate change adaptation. A clear understanding of both direct and indirect impacts and vulnerabilities in London have been made.

Information are made accessible to public increasing their awareness, yet many Londoners are still not aware of the consequences of this global issue on their city. Moreover, a responsive up-to-date strategy is in place, addressing adaptation based on the assessed impacts. However, some of the developed strategies haven't been implemented yet but building resilience is an ongoing-process and doesn't happen over-night and requires persistent efforts (UN habitat, 2017). Additionally, London's government is actively addressing the barriers impeding the implementation of adaptation initiatives through identifying these obstacles and developing plans to act in cases of emergency as well as long-term plans.

The score below is based on evidence from document reviews as highlighted in Appendix B.

	Questions	**Yes/No**	**Score**
Understanding Impacts and Vulnerabilities	Is there a national vulnerability assessment of Impacts of climate change?	Yes	1
	Is there a local vulnerability assessment of Impacts of climate change (addressing impacts on London City)?	Yes	1
	Is there an understanding of indirect socio-economic implications of climate change on London?	+/-	0.5
	Is there a mapping of climate impacts based on data collection and monitoring?	Yes	1
	Are changes in climate patterns projected and anticipated?	Yes	1
	Is the national/local government inciting research and studies in the field of climate change adaptation?	Yes	1
Formulating Comprehensive Strategies	Is there a national political support to adaptation to climate change?	Yes	1
	Is the local government (London governorate) committed to climate change adaptation?	Yes	1
	Is there a clear determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate change?	Yes	1
	Is the strategy "tailored" to the assessed local impacts on the urban infrastructure?	Yes	1
	Is the strategy coordinated with scientific experts?	Yes	1
	Is the strategy coordinated with the local community (including NGO's, cultural forums, civil societies and non-political councils)?	Yes	1
	Is the adaptation strategy addressing and prioritizing urgent matters?	Yes	1
	Is there a land use and zoning addressing adaptive measures?	Yes	1
	Are short terms adaptation initiative being implemented?	Yes	1

Implementing Developed Strategies	Is funding made available for the adaptation of the urban infrastructure?	+/-	0.5
	Is the local community playing a role in enhancing the implementation of adaptation project?	Yes	1
	Is the local government transparent in the implementation of adaptation projects? (preventing corruption)	Yes	1
	Are houses built to ensure the safety of their inhabitants and withstand extreme weather events?	+/-	0.5
	Are initiatives for greening London being implemented to reduce the effects of UHI?	+/-	0.5
	Is there a defensive flood protection system in place to protect London?	Yes	1
	Is there an efficient drainage system preventing from flooding in cases of cloudburst?	+/-	0.5
	Do citizens have access to fresh water?	Yes	1
	Is the transportation system resilient to extreme weather events?	No	0
	Is there a secure energy supply?	Yes	1
Addressing Barriers	Are impacts recently updated integrating new findings (after 2015)?	Yes	1
	Is the strategy recently updated integrating recent impacts assessment (after 2015)?	+/-	0.5
	Are the barriers impeding the implementation of adaptation initiatives identified?	Yes	1
Addressing Barriers	Are long term adaptation (Year 2050-2100) initiatives and projects being developed?	Yes	1
	Are there any emergency plans to act in cases of occurrence of extreme devastating environmental events?	Yes	1
Total (Over 10) $i = \frac{\sum_1^{30} p}{3}$			8.67

Table 5 *Urban Resilience Index Measuring the Resilience of the Physical Infrastructure in London to Overcome Impacts of Climate Change.*

4.4 The Case of New York City, the United States

4.4.1 Understanding the Impacts and Vulnerabilities in New York

New York City (NYC) is located on the North-East coast of the United States. It consists of 5 boroughs, and is the country's largest urban agglomeration and one of the world's greatest cities. NYC lies in a "humid subtropical climate" zone with cold and snowy winters and warm summers. Its location, at the outlet of the Hudson River feeding into the Atlantic Ocean, has converted the city into a significant trading port and into an important world's economic, financial and cultural center. Founded in the 1600s, the city witnessed a very fast urban development throughout 400 years, making it home for over 18 million inhabitants. This megacity is expected to further grow to reach at least 19 million residents in 2030 (United Nations, 2016).

Nonetheless, the city's location makes it also vulnerable to changes of climate and the rise of sea level. This megacity is seriously threatened by global warming, exposing millions of people to severe impacts. NYC has already faced a series of extreme weather events over the past 18 years including heat waves, droughts, severe storms and hurricanes (NCEI, 2018). These events have shaken the city and traumatized its inhabitant causing fatalities and significant financial losses.

One of the informants who preferred to remain anonymous highlighted that the city is expanding. However, with the high value of real-estate in New York, more people are living in low-income areas. These people are the ones who are particularly sensitive to the issue of climate change as the infrastructure of their houses and of the areas they live in is weak. Also, the city hosts many homeless people, living with no shelters, these people's lives are also threatened following the occurrence of environmental event (Interviewee 3, 2018).

A series of four US National Climate assessments have been carried out since the beginning of the 21st century, released respectively in 2000, 2009, 2014 and 2017. These valuations have been the results of the efforts of the collaboration among a team of 300 experts and reviewed by the public and professionals including associates from the National Academy of Sciences. The state of New York has also assessed the impacts particular to its regional context in its ClimAID reports released in order to allow the state to respond to the changes of climate.

Local vulnerabilities, particular to NYC, have further been evaluated by the Department of Environmental Protection (DEP) and a 'New York City Panel on Climate Change' (NPCC). The panel, which consists of academics, scientists and practitioners from the private sector, was founded in 2008 to build an understanding of climate science projections and to improve data collection and monitoring. The NPCC addresses the vulnerability of the infrastructure on the short, medium, and long term. Furthermore, it develops methodologies for planning for climate change and works closely with cities (Yohe, 2018). The panel also produced the report 'Climate Risk Information' and released it in 2009, highlighting climate projections particular to NYC. Moreover, updated information was published in the "Climate Risk Information 2013:

Observations, Climate Change Projections, and Maps". These impacts have been underlined and are presented in the PlaNYC report "A Stronger, More Resilient New York" published in 2013 following Hurricane Sandy. The report stresses on both the direct and observable impacts of climate change on the city as well as their ramification of a socio-economic level.

This section further explores the impacts of climate change on this megacity and its implications on its physical infrastructure based on official reports, existing literature, recently published articles highlighting the severity of natural events in NYC due to climate change and interviews.

4.4.1.1 The Urban Heat Island Effect and Heat waves

The condensed urban fabric and lofty skyscrapers, defining NYC's skyline, trap the summer heat and make the city's climate hotter than the surrounding and in some cases unbearable. Heat waves are usually common in summer; they are becoming more severe due intensified UHI effect resulting from the augmented population density exerting an increased pressure on the environment. In an interview with Prof. Gary Yohe, a member of the NYC Panel on Climate Change, he highlighted that for more than a decade, the city has been experiencing an increase in the frequency of very intense heat events, "not necessarily warmer or hotter heat waves but longer than it used to be" (Yohe, 2016). Furthermore, a steep increase in the frequency of heat waves is projected in the city, with anticipations to reach triple today's rate by 2080(s) (NPCC, 2015). The situation is thus distressing given that heat waves are considered "one of the leading weather-related causes of death in the Unites States" (United States Environmental Protection Agency Official Website, n.d.). On average, each year hundreds of people get admitted to the emergency department at hospitals due to heat waves. Additionally, a dozen of people pass away due to heat stroke and around a hundred person die due to heat-related illnesses (Wolfe, 2017). According to NYC's susceptibility assessment, "this vulnerability is expected to worsen with climate change". As a case in point, in July 2013, a heat wave flounced across NYC, causing the death of four elderlies and an excessive use of energy reaching new records. In July 2011, temperatures broke new records reaching as high as 40 degrees Celsius, leading to the death of around thirty people due to heat strokes. In July 2006, a long heat waves caused the death of at least 100 persons and an increase of 8% in the overall death-rate in the city. In 2002, two different waves, each lasting for at least a week, have devastated the city and have caused the death of at least 17 people (Choudhury, 2016).

It is projected that global warming will increase the frequency and the intensity of heat waves translating into the death of hundreds yearly in the city of New York (Daily Climate, 2013). Moreover, higher summer temperatures and heat-wave would increase the stress on electricity demand which could lead to electricity reliability issues (Center for Climate and Energy Solutions, n.d.). Therefore, the present situation renders this impact among the most pressuring and prominent issues that need to be addressed in the city in the light of climate change.

4.4.1.2 Rise of Sea Level, Flooding and Intense Coastal Storms

NYC's coastline of over 830 km and its location bordering the Atlantic Ocean makes it vulnerable to impacts of sea-level rise. Since 1990, the sea level has risen on average around 0.3 cm each year in New York, which is almost twice as the global rate. Projections foresee the flooding of various areas along coastline on the short, medium and long run in the light of sea level rise (NPCC, 2015). The situation is distressing since these areas host a large number of people, iconic natural cultural and economic resources as well as critical infrastructures. Coastal flooding due to tropical storms, hurricanes and nor'easters could be particularly dreadful and devastating in these areas given that the effects would be intensified with the rise of sea level. As a case in point, Hurricane Sandy which hit hard in 2012, has resulted in severe damages to the urban infrastructure, direct financial losses, fatalities and caused the city's stock exchange to shut down for two sequential business days. It is estimated that the floods caused by this severe coastal storm have cost the city more than 70 billion US dollars and the life of 159 people (NCEI, 2018). The storm resulted in disruptions to the urban infrastructure, as mass transit systems were shut (including the city's underground subway network, and roadway tunnels). Furthermore, water and electrical services were interrupted, and hundreds of thousands houses and properties were damaged. Alarmingly, New York could be swamped by sandy-level flooding as frequently as once every 23 years by the end of the 21st century (Milman, 2016).

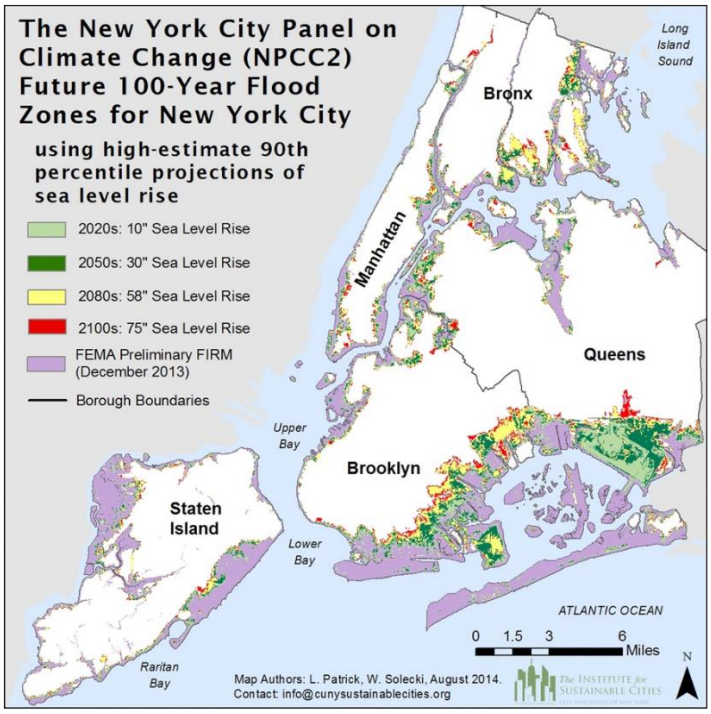

Figure 9 *NPCC2 Future 100-Year Flood Zones for NYC. Source: NPCC, 2015*

Figure 9 shows the areas which are susceptible to being flooded with the increase of sea-water levels. The sea level is expected to keep on rising and more areas are prone to be swamped.

Projections show that the situation will keep on aggravating and getting worse thus requires to be taken seriously and addressed urgently.

Moreover, aside from coastal storms, the city of New York has been experiencing frequent extreme precipitation events and heavy rains which have caused the flooding of roads, the flooding of subways, and nuisance flooding on some of the major arteries around the southern part of Manhattan. Yohe asserted that, in 1990s the subway used to experience minor floods around once a month, however in this century the flooding became much more frequent, to the point that it is causing disruptions to the subway system each week (Yohe, 2018).

4.4.1.3 Droughts and Water Scarcity

The rise of sea level not only increases the impacts of flooding in the light of severe storms, but also affects the quality of fresh water due to saltwater intrusion. This could increase the stress on water availability and the ability of the city to meet increasing water demand in the light of anticipated population growth.

The most worrying impacts of climate change on NYC are heat-waves and flooding due to the rise of sea levels and to heavy rainfalls. However, the city is not exempted from facing drought periods, as well as various different impacts, which have faced New Yorkers in previous years. The Northeast drought in 2016 is one example, which developed in various cities including NYC due to stressed water supplies. As well as drought periods which occurred in 2012, 2007 and 2002 (NCEI, 2018). Therefore, various adaptation strategies have been developed. The following section thus further elaborates on the plans adopted to limit the impacts of climate change on the city and its inhabitants and to build resilience.

4.4.2 Formulating Strategies to Build Resilience in New York

New York City has faced a series of environmental impacts throughout the years, and is expecting to face emerging challenges in the light of the rapid change of climate co-tangled with an increase in the city's urban population. Therefore, the NPCC have developed various studies to assist and support adaptation in NYC. These studies include the identification and projection of changes in climate and the "Adaptation Assessment Guidebook" which provides processes to detect the infrastructure at risk, which allows the development of appropriate adaptation strategy (NRDC, 2011; Yohe, 2018).

A PlaNYC released in 2007 by Mayor Bloomberg and entitled "A Greener, Greater New York", was the city's first developed sustainability strategy, focusing on population growth and on the urban infrastructure. The plan concentrated on improving the livability of the city through supporting the development of parks and addressing problems of aging infrastructure. An updated version was released in 2011, highlighting the city's pledge to environmental stability.

After Hurricane Sandy shook the city, a "Special Initiative for Rebuilding and Resiliency" (SIRR) was developed under the title "A Stronger, More Resilient New York". The SIRR involved the engagement and the participation of city leaders, elected officials, organizations and

the general public. The issued report includes guidelines to re-building the communities and areas impacted by the traumatizing storm on one hand, and recommendations to increase the over-all resilience of buildings and infrastructure on the second hand. To this end, the government intends to address the problem of extreme heat waves which is particularly risking the lives of kids, elderlies, people with chronic illnesses and people with no access to proper ventilation and air-conditioning (The City of New York, 2013). The approach focuses on updating UHI maps and models to allow for the development of better adaptation strategies. Moreover, the identification of vulnerable populations in high-risk neighborhoods is highlighted as crucial. The governor's strategy includes the engagement with specialized agencies and with the community to develop heat-warning systems and to expand the access to ventilated spaces during heat-waves. The adaptation of parks and the expansion of green infrastructure is one of the tools suggested to project communities from effects of severe weather events; as well as the retrofitting of existing park facilities to increase their resilience. Additionally, the strategy focuses on raising awareness and informing the city's residents about ways to ensure their safety.

Furthermore, other strategies are developed to address the problem of flooding and sea-level rise including improving and updating of the flood-mapping process supported by regular coastal-analysis. The city plans to work on improving the public's access and understanding of flood-maps, which could take the shape of an interactive communication platform allowing residents and property owners to better understand flood-related information. The government finds it essential to present a uniform and a consistent set of projections for NYC to avoid the development of conflicting adaptation standards. For this purpose, measures of current climate changes as well as projections need to be refined (The City of New York, 2013). The plan is focused on strengthening the understanding of impacts and risks first, in order to develop an adequate adaptive response. An investigation was thus instigated after Hurricane Sandy, to comprehend the features that were particularly more susceptible thus majorly damaged. Also, the city investigated the features which ensured the resilience and reduced damages in some areas of the city following the devastating storm. Results have shown that some measures including the nourishment of beaches with dunes and sands and site elevations, ensured the safety of some-areas (See Figure 10).

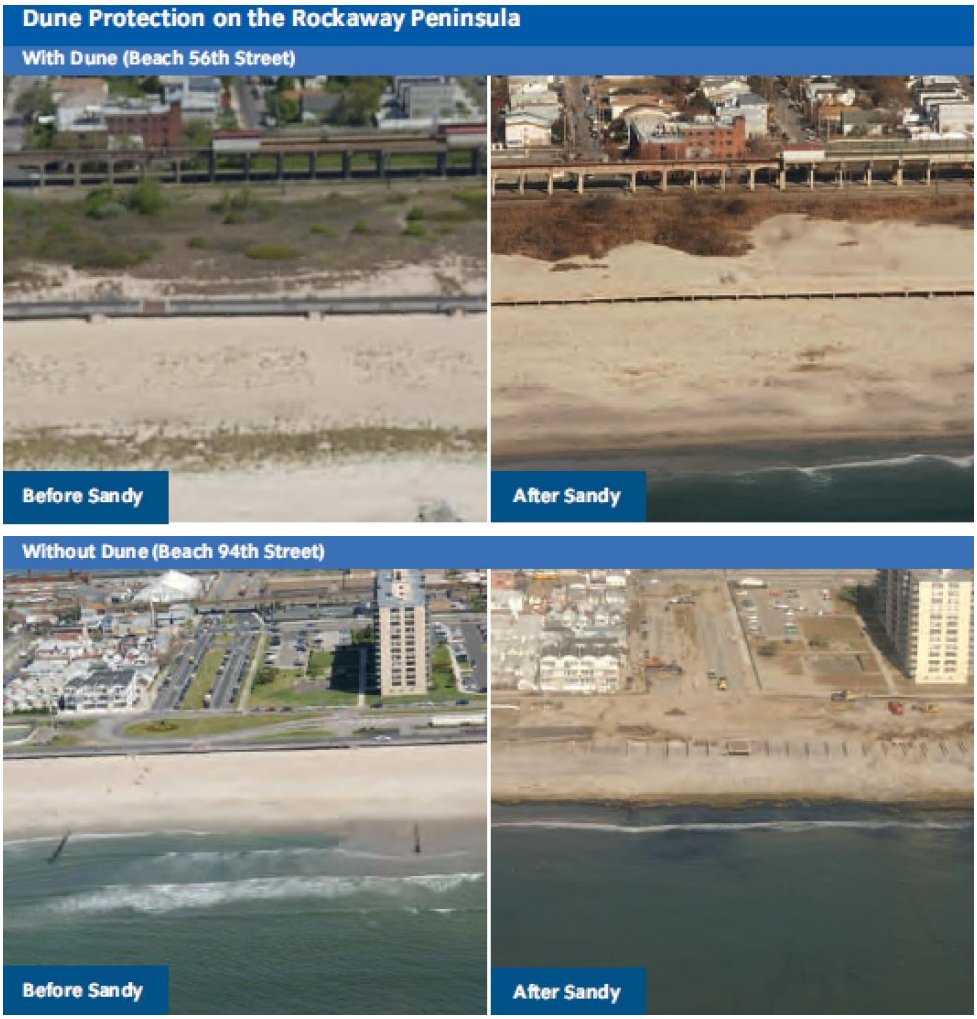

Figure 10 *Photos comparing the status of 2 shores before and after hurricane Sandy, in the presence and absence of Dune protection. Source: The City of New York, 2013*

In response to the known impacts and challenges, the city finds it important to improve the safety of the coastline and to implement typical flood defense systems as well as other creative protective measures. Therefore, coastal flood strategies were developed to protect NYC from the impacts of climate change, including the intensification of coastal edge elevations with beach nourishments, the attenuation of waves and an improved coastal design approaches and governance systems. The city also plans on maintaining and renewing the drainage systems (The City of New York, 2013).

The SIRR approaches the built environment through strengthening resiliency standards of new structures and retrofitting as many constructed buildings as possible. To this end, the governor aims on repairing constructions that were damaged by the Hurricane Sandy. He also looks forward to improving the zoning regulations and building codes in place to incite the retrofitting of old buildings and the erection of new resilient constructions in the floodplains.
Moreover, the SIRR highlights the importance of developing energy efficient construction as well as ensuring a resilient power supply, including power generation, transmission and the implementation of a smart grid system.

In brief, the strategy's main focus is on integrating the concept of resiliency into both planning and project development. NYC is developing an understanding of climate resilience through understanding and investigating unfortunate events that occurred in the past and is trying to address these challenges to better be prepared for projected changes in weather conditions. The strategy develops on various areas, including coastal protection, buildings and constructions, insurances and healthcare, transportation, energy, water management and social awareness.

4.4.3 Implementing Developed Strategies to Build Resilience in New York City

Despite the United States' decision to withdraw from the Paris Agreement, NYC's governor re-instated his commitment to combat climate change (Dearden, 2017). Prof. Yohe asserted that contrary to common believes, the national decision has positively affected planning for climate change as individuals and corporations all over the country are engaging more to address the topic, for instance, many companies have taken the issue very seriously and have changed their business models (Yohe, 2018). Similarly, in the city of New York, various projects are planned, designed, being constructed and completed to build climate change resilience and to turn the developed strategy into reality. "Unfortunately investments in adaptation measures are concentrated in the areas with high value of real-estate, while more attention needs to be given to poorer areas" (Interviewee 3, 2018). This section further investigates the implementation of developed projects.

As NYC's government is keen on addressing the impacts of UHI and heat-waves in the city, various adaptation actions have been developed. The city government promoted the emergence of green infrastructure as well as other initiatives to moderate the UHI effect and limit the magnitude and occurrence of projected heat-waves. For instance, "NYC Cool Roofs Program" was launched in 2009. The program focuses on training local individuals to collaborate with a team to cover the city's rooftop with a white coating, releasing and reflecting the heat. Since its launch, the program reduced cooling costs for building owners by 30%, it also proved to be effective in tackling the UHI effect. Over 620 buildings' roofs have been coated in this initiative, the program aims at further developing by coating 92,900 m² annually (C40 Cities, January, 2015). Additionally, a 'Cool Neighborhoods NYC' project was launched in 2017, in which the city ensured financing and developing projects in order to alleviate the impacts of UHI effect, particularly in vulnerable neighborhoods. Moreover, NYC developed the Million Trees city wide project. This public-private initiative aims at increasing the share of green areas in the city through planting and caring for one million trees throughout the city (EPA, n.d.).

New York's Recovery and Resilience office's program started by modifying the zoning and land use law in order to improve the city's public realm. A "Climate Resiliency Design Guidelines" was thus released in 2018 in order to regulate and direct the design of the urban infrastructure. To this purpose, commitments of 700 million USD have been made to develop the urban infrastructure. Moreover, this program supported the creation of 'green jobs' and ensured trainings for building operators and property managers to install green infrastructure. The

preparation program is expected to last in order to train additional staff in the coming years. The development of the city's green infrastructure is not only used as a tool for limiting the UHI effect, but also it is seen as an opportunity for storm water management. The city's 'Green Infrastructure' initiative, committed till 2030, allocates 1.5 billion USD to the development of rain-gardens, porous and permeable pavements constituting storm water green streets. "To date, over 4,000 green infrastructure assets are either completed or in construction with several thousand more in planning or design" (NYC Mayor's Office of Recovery and Resiliency, 2018).

To further address the problem of flooding, the DEP has invested in over 20 million USD to complete 6 sewer projects and over 100 million USD to construct more draining projects.

New York is conducting a research under the title "Cloudburst Resiliency in New York City" to investigate the best practices implemented in different parts of the world in order to adopt projects to its contexts. The city is learning from a 'blue-green infrastructure' project implemented in Copenhagen[6], "where rainwater is retained and used on the surface for water areas in parks and other places instead of being allowed to overload the sewage system." (Rotheborg, 2016). The New York's DEP's study is working on a vulnerable area in the south-east of queens in order to develop a project specific to the city yet inspired by the successful adaptation project implemented in Copenhagen. NYC is going through the methodology developed in the Denmark in order to integrate environmental solutions with recreational spaces.

Furthermore, the city is working on implementing creative defense systems to protect itself from the rise of sea level. The most remarkable project is the "Big U" development designed by the architecture firm "Bjarke Ingels Group" (BIG). "In collaboration with New York City, The BIG U proposal was developed to protect Lower Manhattan from floodwater, storms, and other impacts of a changing climate" (Rebuild by Design and 100 Resilient Cities, n.d.). The project offers both a place for recreational activities as well as a protection from rising sea level and storm surges. More than 800 million USD were dedicated for implementing these initiatives (Rebuild by Design and 100 Resilient Cities, n.d.). It offers a 'tailored resiliency' based on the understanding of the impacts the city is experiencing, along with the integration of future risks. The project evoked the collaboration among various stakeholders, including public corps, community members, businesses and corporations. Workshops took place involving the participation of New Yorkers in the design process in order to develop the programs and functions along the presented public spaces and to include a protection scheme (Rebuild by Design and 100 Resilient Cities, n.d.). These workshops allowed for the active participation of the city inhabitants in the decision making and for the creation of an urban project which is tailored to the public's needs. The Big U project depicts vulnerable areas and offers protection to

[6] Copenhagen worked with the water service on an inclusive restructuring of the city's drainage system to separate rainwater from grey-water and to re-invent the streetscape. The project was supplemented with the implementation of "the Sustainable Urban Drainage System" preventing rain water from running into the sewers. The city succeeded in direct water to retention basins and ensured a better adaptation of the city in the face of cloudbursts (C40 Cities, 2016)

susceptible residents through its design approach. The architecture firm has developed an understanding of exposed areas through overlapping maps flood risks, maps of previous impacts, maps of social distribution according to yearly income division and maps of transportation systems in place. Long term ambitions are also developed in the project, as it first addresses urgent issues however offers the opportunity for expansion at later stages. The Big U is a great example illustrating how defense systems can be integrated with urban planning and architectural projects. A well-designed system which not only improves the resilience of the physical infrastructure and the built environment but also improves the social infrastructure and the well-being of communities through their engagement in the implemented adaptation strategy. Such projects could raise the awareness of people and lead adaptation approaches by example. Nonetheless, this project only stretches over 13 km, when NYC's coastline extends over 830 km, thus leaves a great part of the city's shoreline vulnerable to the rise of sea level.

The anticipated impacts and risks of climate change are shaping the way the buildings are designed and built in NYC (Yohe, 2018). For example, penthouses are being substituted by rooms for emergency generators providing sufficient power for occupants, in cases of flood or other emergencies, for as long as an entire week. Also, flood-resistant materials as well as special drainage systems are being introduced for ground floor levels. "New York began requiring that mechanical systems be installed above the "design flood elevation" — one or two feet higher than the highest expected flooding" (Dunlap, 2017). "American Copper Buildings", a new iconic skyscrapers' project in NYC, is one example of new buildings' design integrating adaptive responses to climate change. The project reserved the last floor for the placement of five generators, to be used in cases of emergency, able to power up the elevators in the building, the hallways and the staircases, water pumps and the refrigerators as well as one electricity outlet in of each of the apartments. Moreover, these generators function with the use of natural gas and are not dependent on the delivery of fuel which could be disrupted in the light of extreme natural events. Besides, the building's mechanical systems are installed allowing for the collection of storm water and its disposal through connected pipes (Warerkar, 2017).
New developments are responsive to predictions and incorporate adaptation responses, however there are a lot of old buildings in the city, which remain a challenge in terms of adaptation (Yohe, 2018). Therefore, old buildings and infrastructure are being fortified to be able to withstand the impacts of climate change. The city's mayor launched the "NYC Retrofit Accelerator" initiative in 2015, which projects to be "accelerating retrofits in up to 1,000 properties per year by 2025" (Office of the Mayor de Blasio, 2015). The program is providing free technical assistance and is expected to ensure an improved housing quality and increased resilience. The program is important to strengthen and fortify the existing infrastructure and buildings in the face of impacts of climate change.

The city is expanding the transit systems through integrating new routes and connections. The initiative is projected to reduce the pressure on the environment on one hand and to increase the resilience of the city, through ensuring a better accessibility and an alternative to transportation

systems in place. As storm Sandy has caused much damage to the transportation railway system, investments have been made to repair the infrastructure and to increase its resilience. These investments include the elevation of critical equipment, sealing vents and closing the doors of stations during a storm. Moreover, redesigning initiatives were adopted incorporating anticipated sea level rise through including and implementing flood protection barriers as for instance many entrances to the subway have been elevated to reduce the risk of flooding (Yohe, 2018). The adopted initiatives increase the resilience of the transportation system at various levels including design, operations and maintenance (Rios, 2017).

4.4.4 Addressing Barriers to Implementation in NYC

No recent updates have been made to the valuation of the impacts of global warming on New York City in the past few years. The last impact assessment was developed following Super storm sandy which shook the city. The assessment was followed by the development of the SIRR strategy, under the title "A Stronger, More Resilient New York" in 2013. Nonetheless, the NPCC is currently developing a 3rd report which is expected to be released by the end of 2018 and include updated impact assessments. The report will also include a manageable number of indicators for monitoring and assessing not only the physical aspect but also the socio-economic ramifications of impacts of climate change (Yohe, 2018).

The barriers impeding the implementation of adaptation initiatives have been identified in NYC. Building resilience has been challenging in this megacity because the responsibilities of assessing impacts and risks, limiting vulnerability and hazard exposure and developing a quick adaptive response is distributed among various local offices and departments and not well communicated (Climate Smart Communities, 2014). Regulatory structures in place co-tangles with funding challenges as well as lack of climate-focused information and data restrain further growth (The City of New York, 2013; Leichenko et al., 2014).

The City's Mayor's office includes a division for "Long-Term Planning and Sustainability" (OLTPS) with a responsibility to ensure the implementation of sustainability initiatives underlined in the PlaNYC document and an improved sustainable development of the urban infrastructure. Nonetheless, no clear long-term plan or projects have been developed to ensure the resilience of the city over the coming 100 years (Interviewee 3, 2018).

New York is also working with the city's emergency management division to improve and develop emergency preparedness. Thus, it has updated its evacuation plan to better aid susceptible populations in cases of emergency. The analysis of transportation needs have been undertaken to evaluate the transport services during severe storms. Moreover, trainings have been developed to ensure a 'community-based' organization in recovery plans. The city developed an enhanced approach for mapping risks of future floods including the rise of sea level. An online platform tool "The Flood Hazard Mapper" was founded to allow new Yorkers to better understand the risks of flood they are at in order to be better prepared (NYC Mayor's Office of Recovery and Resiliency, 2018).

4.4.5 Measuring Urban Resilience in NYC

The methodology used to measure resilience and provide a weighted average over 10 is elaborated in Section 3.8.

The urban resilience index portray that NYC is trying to formulate comprehensive adaptation strategies based on a thorough and an in-depth understanding of the impacts of climate change particular to the context. Nonetheless, the city lacks national political support to adaptation. This lack of national support could lead to the perturbation of the implementation of adaptive measures. For instance, experts are concerned that with the decision of withdrawal from the Paris agreement could lead to delays in the implementation of the defensive Big-U flood-protection project (Templin, 2017). Moreover, funding challenges along with the lack of climate-focused information and data disrupts the city's preparedness to adapt to climate change (The City of New York, 2013; Leichenko et al., 2014). NYC could still be vulnerable to severe impacts and need to constantly update their strategies and address the barriers to the implementation of adaptation approaches. Hence a new report on climate change is expected to be released by the end of 2018 and include updated impact assessments (Yohe, 2018). The release of this report could boost the adaptation initiatives in NYC since adaptation is a continuous and a perpetual process to ensure a desirable state in the face of the dynamic urban development and constant internal and external pressures and therefore requires a long term commitment (Suárez et al., 2016).

The score below is based on evidence from document reviews as highlighted in Appendix B.

	Questions	**Yes/No**	**Score**
Understanding Impacts and Vulnerabilities	Is there a national vulnerability assessment of Impacts of climate change?	Yes	1
	Is there a local vulnerability assessment of Impacts of climate change (addressing impacts on New York City)?	Yes	1
	Is there an understanding of indirect socio-economic implications of climate change on NYC?	Yes	1
	Is there a mapping of climate impacts based on data collection and monitoring?	Yes	1
	Are changes in climate patterns projected and anticipated?	Yes	1
	Is the national/local government inciting research and studies in the field of climate change adaptation?	Yes	1
	Is there a national political support to adaptation to climate change?	No	0
	Is the local government (NYC governorate) committed to climate change adaptation?	Yes	1
	Is there a clear determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate change?	Yes	1

Formulating Comprehensive Strategies	Is the strategy "tailored" to the assessed local impacts on the urban infrastructure?	Yes	1
	Is the strategy coordinated with scientific experts?	Yes	1
	Is the strategy coordinated with the local community (including NGO's, cultural forums, civil societies and non-political councils)?	Yes	1
	Is the adaptation strategy addressing and prioritizing urgent matters?	Yes	1
	Is there a land use and zoning addressing adaptive measures?	Yes	1
Implementing Developed Strategies	Are short terms adaptation initiative being implemented?	Yes	1
	Is funding made available for the adaptation of the urban infrastructure?	Yes	1
	Is the local community playing a role in enhancing the implementation of adaptation project?	Yes	1
	Is the local government transparent in the implementation of adaptation projects? (preventing corruption)	Yes	1
	Are houses built to ensure the safety of their inhabitants and withstand extreme weather events?	+/-	0.5
	Are initiatives for greening NYC being implemented to reduce the effects of UHI?	Yes	1
	Is there a defensive flood protection system in place to protect NYC?	+/-	0.5
	Is there an efficient drainage system preventing from flooding in cases of cloudburst?	+/-	0.5
	Do citizens have access to fresh water?	Yes	1
	Is the transportation system resilient to extreme weather events?	+/-	0.5
	Is there a secure energy supply?	Yes	1
Addressing Problems	Are impacts recently updated integrating new findings (after 2015)?	+/-	0.5
	Is the strategy recently updated integrating recent impacts assessment (after 2015)?	No	0
	Are the barriers impeding the implementation of adaptation initiatives identified?	Yes	1
	Are long term adaptation (Year 2050-2100) initiatives and projects being developed?	No	0
	Are there any emergency plans to act in cases of occurrence of extreme devastating environmental events?	Yes	1

Total (Over 10) $i = \frac{\sum_1^{30} p}{3}$			8.17

Table 6 *Urban Resilience Index Measuring the Resilience of the Physical Infrastructure in New York City to Overcome Impacts of Climate Change.*

4.5 Comparative Analysis

4.5.1 Understanding the Impacts and Vulnerabilities

The results from the three cases highlight the fact that megacities of both developing and developed countries are susceptible to impacts of climate change and need to address the topic as an urgent matter as the effects are already being felt and are putting the urban infrastructure at risk. The nature of the impacts of climate change, their frequency and intensity could vary from one geographical location to another. Other factors could further affect the manifestation of the impacts such as the existence of outdated infrastructures, poverty, rapid and unplanned urbanization as well as the adaptation efforts in place. Therefore, developing megacities such as Cairo seem to be more vulnerable to the impacts of climate change due to the high number of informal settlements, the presence of fragile urban infrastructure and the lack of serious adaptation efforts based on a thorough understanding of impacts.

Vulnerability assessments are more elaborate and developed in London and New York. These assessments are based on data collection and monitoring as well as projections and anticipation of future climate patterns. Moreover, the valuations are more elaborate and site specific as they are conducted on both a national and a city scale and not only at a national level as it is the case in Egypt. These cities' administrations seem to consider climate challenges as a priority, while developing megacities, such as Cairo, consider to have more urgent political and socio-economic problems to address first (Al Genzoura, 2012). The problem hindering the development of impact vulnerability assessment in Cairo is underlined by the lack of technical and financial resources for mapping the impacts based on data collection and monitoring. Moreover, Cairo hasn't developed an understanding of both direct consequences and indirect socio-economic ramifications in a particular context rather than just on a national level. In spite of publishing impact assessments and efforts to raise awareness, in Cairo residents are still not cognizant of the impacts of climate change (Interviewee 1, 2018).

New Yorkers have proved to be more aware of the impacts of climate change on their city as hurricane Sandy has shook NYC and caused severe damages. Meanwhile the citizens of London don't have the same responsiveness and climate change is not a primary concern for many residents in London as they haven't faced major consequences yet except for heat-waves which for many isn't considered a major issue (interviewee 2, 2018). However, all three cities selected as cases, are trying to build a better understanding of the impacts of climate change as the government is inciting research and studies in the field of climate change adaptation. This is an important starting point to address the topic.

4.5.2 Formulating Strategies to Build Resilience

The assessment of vulnerabilities at a local level in London and New York have allowed local governments to formulate adequate strategies addressing both direct and indirect impacts. The developed strategies in these both cities have been coordinated with the local community including NGO's, cultural forums, civil societies and non-political councils. The recently developed strategy plans to transform London into a National City park and emphasizes the importance of the emergence of smart cities and focuses on the role of technology in sustainable urban developments. In New York, the strategy emphasizes retrofitting the infrastructure and addressing the issues of heat waves and the rise of sea level.

However, the strategy in Egypt is rather general, addressing the rise of sea level and its impact on coastal cities, the lack of water resources and the impacts on the agricultural sector. The adaptation plan is not tailored to address the vulnerability of the physical and social urban infrastructure in Cairo to impacts of climate change.

Both national and local assessments are important, each is appropriate for different purposes. National assessments are important for impacts which need to be operated over a large geographical scale and which cannot be manageable at the level of a city scale such as a river flooding or the level of sea rise (Dodman, 2018). However, local assessments are critical for the development of clear action plans at a city level (Dodman, 2018). The lack of comprehension of particular vulnerabilities would impede the development of a "tailor-made" strategy addressing the issue.

4.5.3 Implementing the Developed Strategies

The implementation of adaptation measures is remarkable in New York. This megacity has been incentivized to take action particularly following the destructive Hurricane Sandy, which traumatized the city and its inhabitants and caused serious damages to urban infrastructure. Meanwhile in London, some of the developed strategies haven't been implemented yet, such as the retrofitting of houses to be able to withstand extreme weather events, and the upgrade of drainage system to prevent from flooding in cases of cloudburst. Moreover, the enactment of the national strategy is somehow weak in Cairo. This frail implementation is underlined by the presence of fragile urban infrastructure with 65% of the urban population living in informal settlements with limited access to fresh water. It is also emphasized by the lack of a flood defense system and efficient drainage system preventing the city from flooding. The situation is attributed to the lack of funding made available for the adaptation of the urban infrastructure (INDC, 2015), as well as "the lack of well-coordinated and transparent decision-making" (GEF, et al., 2016).

The contrasted case studies portray that various adaptation approaches could be implemented. The increase of green urban spaces, including green roofs, green walls and city parks have proved to sooth the effects of the UHI and improve the overall quality of the built environment. The development of green infrastructure has been given a great attention in the cases of London and New York. Green urban spaces are also being introduced in Cairo but are rather small scale initiatives. Other solutions have also been developed to limit the heat reflection in cities such as

the “NYC Cool Roofs Program” which introduced white coating to release the heat. Hard infrastructure and engineered systems, for example flood-control barriers, are built as solutions to protect from the inundation of rivers. This approach has been adopted in London where the Thames Barriers have been built to prevent the city from being flooded by storm surges and high tides. However, more recent concepts are favoring BwN initiatives such as sands and dune nourishments which have been implemented in New York City to protect the coast from the rise of sea levels. Improved drainage system initiatives have been developed such as the SUDS which is a solution for both flooding due to heavy rainfalls and to droughts and water scarcity. As excess water is filtered through permeable drainages and surfaces to underground systems offering storage. This measure has been implemented in London as the country has strengthened the planning policy in order to ensure the inclusion of the SUDS in all new major developments unless proven not suitable. Creative architectural design approaches are also being adopted as an adaptation measure such as the case of NYC, where innovations were introduced in design to ensure the resilience of newly erected buildings (i.e. American Copper Buildings). The retrofitting of houses and the upgrade of old infrastructure were also adopted by NYC to increase the city’s resilience following the occurrence of hurricane sandy. Furthermore, both New York and Cairo have resorted to the development of a big scale infrastructure project to address the issue of climate change in megacities, respectively the Big U and the New Capital project.

4.5.4 Addressing Barriers to Implementation

Given that building resilience requires continuous efforts, ensuring a long-term commitment to climate change adaptation as well as addressing barriers to implementation is crucial to a resilient development of megacities (Suárez et al., 2016).

Cairo and London have both recently updated their impact assessments integrating new findings and are currently developing new strategies succeeding the most recent valuations. However, in NYC, no recent strategy has been developed yet as an impact assessment is currently being worked on. Among the selected cases, London is the only city with a clear long term adaptation strategy ensuring the commitment of the government to plan for climate change. In all three cities barriers to implementation have been identified allowing them to overcome and bridge gaps and to put adaptation initiatives into practice. Moreover, all three cities have developed emergency plans to act in cases of extreme environmental event.

Despite the overall low resilience of the urban infrastructure in Cairo in comparison to the selected cases, the city is actively working on addressing the barriers to implementation to bridge the gap, build resilience and improve its preparedness overcome the consequences of climate change.

Chapter 5: Recommendations and Conclusion

5.1 Conclusion

In this research, questions are raised to develop an understanding of the impacts of climate change in megacities and to investigate the current strategies in place allowing to build a resilient infrastructure in these urban context. Moreover, questions are addressed to assess how resilient megacities are for impacts of climate change and how could these cities build adaptation to become more resilient to predicted and unpredicted changes of climate.

In conclusion, the impacts of climate change on megacities vary from one context to another. However, these impacts could affect the social and physical urban infrastructure and could disrupt the day to day activity if no proper environmental management is adopted. Vulnerability and impact assessments have been developed by national or local governments presenting the issue. However, in the cases where assessments are conducted at a city scale and not a country level, the understanding of the impacts is more thorough and particular to the urban context, taking into consideration local socio-economic factors.

Understanding the impacts of climate change specific to an urban context is the stepping stone to developing comprehensive adaptation strategies. Various strategies are set and developed to build resilience in megacities. In some cases, the strategy is being developed by the city government addressing impacts particular to an urban level. In other cases, the strategy is rather general, addressing the topic on a national scale. In this case, and with the absence of local strategy addressing impacts specific to a megacity, the social and the physical urban infrastructure are likely to remain vulnerable to environmental events as the issue will not be tackled profoundly, such as the case of Cairo. Moreover, the lack of national support is likely to lead to delays in the implementation of adaptation strategies and the setting back of local governments (Templin, 2017).

The occurrence of extreme environmental events could stimulate cities to take action and address impacts of climate change as an urgent priority such as the case of NYC following the devastating events of Hurricane Sandy. However, “It has been shown that well planned, early adaptation action saves money and lives later” (European Comission, n.d.). Therefore, building resilience and implementing adaptation measures should be seen as an opportunity to boost the country’s economy through the creation of new green jobs, and to improve public health and the quality of life of urban dwellers (Rosenzweig, et al., 2015). The development of innovative and creative adaptation solutions as well as the implementation of environmental urban planning approach is crucial to increase the resilience of the urban infrastructure. However, in some cases the lack of awareness or the lack of technical and financial resources stood in the way of the implementation of adaptation initiatives. The adaptation of the urban infrastructure not only requires technological and engineering solutions but also social and political changes: adaptation

implies systemic changes including technological progress, changes in individual behavior patterns and new collective political, legal and social organizations (Sokoloff, 2016).

Assessing how resilient the urban infrastructure in megacities is for impacts of climate change is a complicated task. Nonetheless, this research developed and applied an urban resilience index to give a single, weighted value allowing to measure the resilience of the urban infrastructure. Among the selected cases, both London and New York proved to have a high resilience. These cities are leading climate change adaptation based on a thorough understanding of the impacts, the development of a well-rounded strategy particular to the city and the availability of technical and financial resources allowing for the implementation of the strategy. However, these cities could still be vulnerable to impacts and need to persevere their adaptation efforts. While Cairo proved to have a moderate resilience as it is starting to realize the importance of addressing this global issue at an urban level, adaptation efforts are still rather limited and not tailored.

Given that building resilience requires perseverance, megacities selected as cases are addressing the topic through updating their impact assessments, and their strategies based on new findings and developing emergency responses. Also, resilient cities proved to have the ability to learn from its experience and understand barriers to implementation and address the issues.

In summary, megacities present an interesting topic of research as each case present different findings, challenges and opportunities. Megacities are critical and vulnerable contexts as they have to deal with both, population growth and impacts of climate change. More research is needed on the topic investigating the urban resilience of other megacities, as well as the development of the urban infrastructure in cities which are expected to become megacities by 2030, such as Johannesburg and Bogota.

5.2 Recommendations

The recommendations below are deduced from the comparative analysis of the selected cases and answer the main research question through identifying the ways forward in building a resilient infrastructure in megacities

5.2.1 Understanding the Impacts and Vulnerabilities

Given that a better understanding and assessment of impacts should be a starting point for increasing the resilience of the urban infrastructure, it is important to increase and improve monitoring stations and use smart systems for data collection. Also, it is crucial to prepare and train human resources to have the proficiency and the knowledge to work in data collection. The impact assessment and mapping of vulnerabilities should be carried out by scientists and experts and should be overlaid with social and demographic facts. This allows for the comprehension of socio-economic ramifications of this global issue on a particular context and for the mapping the areas vulnerability.

Data collection and monitoring should be done at the city level rather than only at the national level, especially in the cases of megacities and large urban agglomerations, to allow for a precise assessment of impacts and vulnerabilities. Therefore, it is recommended that each local government or municipality would carry out its own assessment of impacts and vulnerabilities. Therefore, the national government should enact laws requiring city governors to assess impacts regularly integrating new findings, and use it as a foundation for the development of adaptation strategies.

In addition, it is important to make the data collected available to the public in megacities. Interactive online platforms or mobile applications can be developed to inform citizens about areas of vulnerabilities, i.e. maps of flood plains and remote sensing figures of UHI. This increases public awareness and allows for the development of creative adaptation initiatives. It is not sufficient to publish the data, but it is crucial to allow for urban residents to understand the consequences of this global issue on their land. To increase public awareness, various tools can be used such as the integration of the topic in the schools' curriculum, awareness campaigns and trainings for people to have a better understanding of the topic and to know how to act in cases of extreme environmental events.

5.2.2 Formulating Strategies to Build Resilience

The national government plays an important role in supporting local actions and initiatives. The government is recommended to define, in a national adaptation initiative, how it will ensure the access of local authorities to guidance and technical expertise (Holmes, 2018).Moreover, it should define the responsibility of local governments in developing updated adaptation strategies and proposals based on recent impact assessment integrating new findings. Furthermore, stronger sub-national approaches to climate change adaptation should be developed promoting business and infrastructure resilience, healthy communities, and investment in natural capital (Holmes, 2018). Local governments are key stakeholders in ensuring climate change adaption in urban contexts as they act as the link between urban societies and the national government (Dodman, 2018).

Given that megacities are quite dynamic and complex, the strategy should allow for a gradual implementation of adaptation initiatives. Therefore, the action plan should be set in phases and divided into short-term, medium-term and long-term plans. This allows for introducing adaptation initiatives addressing areas of priorities first and ensures the commitment of the local city government on the long run.

The climate adaptation strategy should be developed in coordination with experts in various fields including climate experts, environmentalists and urban planners. Urban planning is crucial and helps shape the exposure of the city to the impacts of climate change. Therefore, the master plan of a city should be revisited to incorporate environmental concerns. Moreover, the strategy should also be communicated and collaborated with the local community. Urban residents are more familiar with the local context and therefore could have an insightful input for developing

adaptation strategies. The engagement of stakeholders from an early stage can increase the acceptance, quality as well as the effectiveness of proposed strategies and implemented projects. The collaboration among citizens ensures a better preparedness to overcome impacts of climate change (Huq, 2018). Therefore, the local governments should organize public assembly meetings and develop online platforms allowing for citizens to share their opinions and knowledge for the development of strategies and plans (i.e. Talk London). Also, a draft of the strategy could be shared for public consultation as it is the case in London.

5.2.3 Implementing the Developed Strategies

The implementation of the developed strategy should be considered as the responsibility of all levels of administration including local, regional, national, transnational and international (European Commission, n.d.). Businesses should be seen as drivers to change given that businesses and environment do not have conflicting interests. London have found a way to ensure the involvement of businesses in the process of adaptation through developing policies that incite private firms and communities to increase the share of green spaces. Similarly, policies should be set to incentivize the foundation of environmental NGOs as well as the development of "green businesses" which plan on developing adaptation projects increasing the resilience of a city.

Several implemented initiatives and projects have proved to increase urban resilience and improve the adaptation of cities in the face of climate change. For cities to know which measure to implement, they should experiment and learn from their trials (Huq, 2018). Cities are quite dynamic, with many variables and many factors that could affect the resilience of their urban infrastructure, therefore cities should be perceived as 'built laboratories' (Mijatovic, 2017). The development of small scale initiatives is important, the ones which prove to be successful therefore should be scaled up.

The mindset of designing cities should shift from building against nature, to embracing the natural features in cities. This could be supported through the development of well-rounded urban planning policies and through adjusting the zoning and building regulations to incite the strengthening and retro-fitting of existing infrastructure as well as the development of green buildings, parks and other adaptation projects. Therefore, the building regulations in place should be re-visited and new policies should be developed enhancing environmental considerations. Creativity and innovation are really important as the topic cannot be approached and cities cannot be built the same way which made them vulnerable to impacts at the first place, a new mind set is needed (Rodin, 2015). The government should support research in a variety of fields to support the development of innovative and suitable adaptation measures. Scholarships and financial incentives could be awarded to incite research in the field as well to stimulate the implementation of creative adaptation measures.

5.2.4 Addressing Barriers to Implementation

As financing projects seems to be one of the main barriers to implementation. Local governments can finance projects through the collection of taxes from residents and businesses. For instance, the local government could develop ‘carbon taxes’ as a mitigation measure, and use the collected taxes for the development of adaptation projects. This will allow for a sustainable development of cities and a well-versed approach to planning for climate change. Local governments could also borrow money from development banks and receive money through trading bonds and equities. Building adaptation could seem more appealing to businesses when perceived as an opportunity for investment.

The government should also be clear and transparent in the implementation of adaptation projects and their respective costs and benefits in megacities. The public should have access to detailed expenditures highlighting each project and its costs. This is essential to limit corruption and to increase the citizens’ trust in the system. Policies should be developed requiring local governments to regularly present balance sheets disclosing the municipality’s assets, liabilities and equities. This will allow people to know where the money is coming from and what it is being spent on.

The development of emergency programs is crucial to allow megacities to recover and regain a balanced state following the occurrence of environmental events. These emergency systems can include the development of immediate warning alerts, improving the connectivity and the accessibility of emergency divisions, as well as the training societies to improve and develop emergency preparedness to be able to act fast following the occurrence of unfortunate weather events.

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Appendices

Appendix A: Interview Design

Interview Contact Form

Dear Sir/Madam,

I am a masters' student in Environmental and Energy Management program at the University of Twente, The Netherlands. Currently, I am developing my thesis addressing the question "How should the urban infrastructure develop in Mega-cities in order to build resilience and adapt to climate change?". In my thesis I am adopting a comparative approach through selecting 3 case studies: Cairo, London and New York. The thesis is co-supervised by Dr. Gül Özerol and Dr. Kris Lulofs from the Department of Governance and Technology for Sustainability at the University of Twente.

As the impacts of climate change are coming up to the surface, adaptation is crucial to ensure a resilient development of cities. Results of desk research have highlighted that the topic has been addressed on a national/local level. However, examining the real-life situation and the status of current implementations of initiative is crucial to deduce recommendations for climate change adaptation in megacities and to address the barriers impeding the implementation. For this purpose, I would highly appreciate your answers to a set of questions, which can be discussed via a skype or phone call. I re-assure you that the collected data will uniquely serve the purpose of the research and if desired your participation can remain anonymous.
Looking forward to hear back from you in order to schedule a meeting at your convenience.
Thank you in advance for considering to contribute to this academic research project,

Rim Khamis
Master of Environmental and Energy Management
University of Twente
Email: r.khamis@student.utwente.nl / reemckhamis@gmail.com
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Interview Consent Form

Responsible Researcher and Interviewer	Rim Khamis, MSc Student in Environmental and Energy Management at the University of Twente
Interviewee	Key Stakeholder (Government, Activists, Environmentalists, Local Communities and Businesses)
Duration of the Interview	60 minutes
Topic	Urban Infrastructure and Climate Change Adaptation in Megacities: A Comparative Assessment of New York, London and Cairo
Research Question	How should the urban infrastructure develop in mega-cities in order to build resilience and adapt to climate change?

Table A *Interview Topic*

Dear Sir/Madam,

Thank you very much for your participation in this research project and taking the time to answer the questions.

Since my research paper is responsibly written and respects ethical principles, I would like to ask you whether I can use your name to reference the information you provided, or whether you wish that your identity remains anonymous.

If you agree, your participation will be referenced as follows (APA style):

Surname, Initial(s). (Year, Month Day). Topic discussed in the interview [Written/Skype/Phone Interview].

If you prefer to remain anonymous, the information will be referenced, the surname and initial(s) will be omitted and simply replaced by Interviewee.

Looking forward to hear back from you concerning this matter.

Again, Thank you very much for participating in this academic research project,

Kind Regards,

Interview Guide

The table below was used as a basis for the questions addressed to interviewees. In each selected megacity, multiple interviewees represent the perspectives of different stakeholders, including the government, the local community and environmental experts and advisors. The interview questions are tailored to each interview according to the interviewee's field of expertise to develop an understanding of the actual situation in a particular context.

Elements of the Conceptual Model	**Research Questions**	**Questions addressed to interviewees**	**Interviewees**
Understanding the Impacts and Vulnerabilities	What are the impacts of Climate Change in (mega) cities?	Are impacts of climate change visible and sensed in the city? If yes, What are these impacts and how are they affecting the city?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector
		Is there an in-depth understanding of impacts of climate change on the city? If Yes, how has this understanding been developed (are experts being involved? is research being conducted? Etc.)	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector
		Is the national/local vulnerability assessment of impacts offering a full overview of the direct and indirect effects? If yes, when has it been developed? Do you think it's up-to-date?	- Local community - National/local government - Environmental Expert
		Is the national/local vulnerability assessment of impacts offering a full overview of future projections of climate change based on data collection and monitoring?	- Local community - National/local government - Environmental Expert
		Are urban communities becoming more familiar with the consequences of climate change on their environment? If No, why? If Yes, are they acting upon it?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector
Formulating Strategies to Build resilience	What are the current urban planning	Is there a clearly determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate	- Local community - National/local government

	strategies in place to build resilience in each of these mega cities?	change? If No, what is the issue?	- Environmental Expert - Urban Planner
		Is the strategy coordinated with key actors (experts, urban planners, local community)?	- Local community - National/local government - Environmental Expert - Urban Planner
		Are policies supporting the development of an environmental urban development of the city? If Yes How?	- Local community - National/local government - Environmental Expert - Urban Planner
		Are building laws, zoning and regulations supporting the development of an environmental urban development of the city? If Yes, How? If No, How could they be improved?	- National/local government - Urban Planner
Implementing the developed strategies	How prepared are megacities for impacts of climate change?	Is the local government ensuring the implementation of developed strategies? If Yes, How? If No, What are the barriers to implementation?	- Local community - National/local government - Environmental Expert
		Are megacities addressing climate change issues in ongoing projects?	- Local community - Environmental Expert - Urban Planner - Private Sector
		Are key actors involved in the implementation process?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector
		Are technical and financial resources available for the implementation of adaptation projects?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector

		Do you consider that the implemented initiatives and measures are adapting the city to impacts of climate change and increasing its resilience? How?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector
Addressing Barriers to Implementation	How could megacities be better prepared for climate change impacts that may occur in the future?	Are there plans to increase the climate resilience of the city? If yes, which measures do those plans include?	- Local community - National/local government
		Do you believe the city is prepared for extreme weather events (floods/ droughts/ heat waves/ cloudbursts.)? If no, what are the barriers against being prepared?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector
		In your opinion how could the urban infrastructure in this city be more resilient to impacts of climate change?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector
		Who are the main stakeholders ensuring a more resilient city?	- Local community - National/local government - Environmental Expert - Urban Planner - Private Sector

Table B *Interview Questions*

Appendix B: Urban Resilience Index

Urban Resilience Index - Cairo

	Questions	Yes/No	Evidence from document reviews and interviews
Understanding Impacts and Vulnerabilities	Is there a national vulnerability assessment of Impacts of climate change?	Yes	Various 'National Communication on Climate Change' were developed in 1999, 2010 and 2016 introducing vulnerabilities of Egypt to changes of climate.
	Is there a local vulnerability assessment of Impacts of climate change (addressing impacts on Cairo)?	No	There is no officially published vulnerability assessment of particular impacts on the area of Cairo.
	Is there an understanding of indirect socio-economic implications of climate change on Cairo?	No	Given that the national vulnerability assessment report focuses on coastal region and that there are no assessments particular to the area of Cairo, indirect socio-economic implications have not been addressed.
	Is there a mapping of climate impacts based on data collection and monitoring?	No	"There is a lack of basic information, such as meteorological data, land use, and crop and livestock distribution, particularly the quality and distribution of crops grown in different areas" (UNDP and Egyptian Cabinet Information and Decision Support Center, 2011).
	Are changes in climate patterns projected and anticipated?	Yes	For instance, the OECD published a report "Development and Climate Change In Egypt" in 2004 projecting changes in temperature and precipitations in 2030, 2050 and 2100. These projections were used as a basis for the developed national strategy.
	Is the national government inciting research and studies in the field of climate change adaptation?	Yes	The Egyptian government is supporting research in the field of planning for climate change. The policy intends to encourage the exchange of information and the cooperation between universities and research institutes in areas related to understanding impacts and developing adaptation responses.

Formulating Comprehensive Strategies	Is there a national political support to adaptation to climate change?	+/-	The Egyptian government has adopted international initiatives on climate change and developed national initiatives to address the issue (elaborated in section 4.3.2). However, the issue of climate change adaptation is not given sufficient attention in the national priority list of decision-makers as the country is prioritizing other political and socio-economic problems (Al Genzoura, 2012).
	Is the local government (Cairo governorate) committed to climate change adaptation?	+/-	The governor of the city of Cairo have committed to collaborate with 'C40 Cities' to address the subject of climate change and to make the city resilient. However, the city's governorate hasn't to date developed its own strategy to ensure its commitment to adapt to climate change.
	Is there a clear determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate change?	No	Cairo's governorate has no official or clear determined strategy to adapt the urban infrastructure to climate change.
	Is the strategy "tailored" to the assessed local impacts on the urban infrastructure?	No	Given that there's only a national vulnerability assessment of impacts of climate change and not an assessment of local vulnerabilities (Cairo level), the strategy is rather general and not tailored to address the impacts on an urban level.
	Is the strategy coordinated with scientific experts?	Yes	The national strategy is supported by a panel of experts including staff members of the crisis and disaster management, as well as many others scientific researchers in various disciplines (UNDP, and Egyptian Cabinet Information and Decision Support Center, 2011).
	Is the strategy coordinated with the local community (including NGO's, cultural forums,	No	The national strategy highlights the importance of the participation of local communities in decision making and recognizes the fact the role of civil societies is still weak (UNDP, and Egyptian Cabinet

Formulating Comprehensive Strategies	civil societies and non-political councils)?		Information and Decision Support Center, 2011).
	Is the adaptation strategy addressing and prioritizing urgent matters?	+/-	Areas of priorities and their associated costs have been identified in the NEEDS for climate change. Nonetheless, interviewee 1 highlighted the lack of long-term plans as short-sighted planning have caused adaptation efforts to lag behind.
	Is there a land use and zoning addressing adaptive measures?	+/-	"We certainly have building codes and laws. However the problem is in the enforcement and the implementation of these regulations." (Osman, 2018). There's no adequate land use and zoning, highlighted by the unplanned growth of the city and emergence of informal settlements and slums.
Implementing Developed Strategies	Are short terms adaptation initiative being implemented?	Yes	For example the new capital project and the PDP.
	Is funding made available for the adaptation of the urban infrastructure?	+/-	One of the main barriers to climate change adaptation is the lack of financial funding (INDC, 2015). However international funding is being awarded to support adaptation in Egypt (ex. Green Climate Fund).
	Is the local community playing a role in enhancing the implementation of adaptation project?	Yes	For instance, the PDP is working implement small-scale adaptation measures in urban slums in cooperation with the urban population and civil society in order to enhance resilience (PDP, 2018).
	Is the local government transparent in the implementation of adaptation projects? (preventing corruption)	No	"One of the key obstacles that continue to face Egypt's development process is the lack of well-coordinated and transparent decision-making" (GEF, et al. 2016).
	Are houses built to ensure the safety of their inhabitants and withstand extreme weather events?	No	Given that 65 % of the Egyptian capital population live in informal settlements.

Implementing Developed Strategies	Are initiatives for greening Cairo being implemented to reduce the effects of UHI?	+/-	For example "Greener Cairo: Sustainability through Urban Agriculture" developed in 2010. However, the extensive unplanned urbanization, limiting green spaces, have reinforced the UHI effect in the city. (Saab and Tolba, 2009; Osman, 2018).
	Is there a defensive flood protection system in place to protect Cairo?	No	Flooding due to both irregular rainfalls and the rise of groundwater surfaces is threatening Cairo.
	Is there an efficient drainage system preventing from flooding in cases of cloudburst?	No	Cairo was flooded in April 2018 as "the accumulated water exceeded the capacity of some public sewers in the city, causing heavy damage in the drainage system" (Ismail, 2018).
	Do citizens have access to fresh water?	No	Water scarcity is among the major problems this city is facing.
	Is the transportation system resilient to extreme weather events?	+/-	Following heavy rains, roads flood submerging cars, due to an unreliable drainage systems causing unbearable traffic. (For example, events of April 2018). However, the transportation system is currently being improved as 2 new metro lines are being constructed amd a cycling initiative is being introduce (bicyletta) (Osman, 2018).
	Is there a secure energy supply?	Yes	Egypt has recovered from its electricity deficit as the government has invested in 3 major power plants, and is looking to further increase its investments.
	Are impacts recently updated integrating new findings (after 2015)?	Yes	In 2016, the country has released the "Third National Communication on Climate Change" integrating new vulnerabilities which haven't been addressed in the first and second publication.
	Is the strategy recently updated integrating recent impacts assessment (after 2015)?	+/-	The current strategy in place is the one developed in 2011. However, a new strategy is currently being developed as expected to be released in a couple of years (Osman, 2018).
	Are the barriers impeding the implementation of adaptation	Yes	The 3rd national communication on climate change identified barriers impeding the implementation of adaptive measures which include lack of database and monitoring, lack

	initiatives identified?		of financial resources and uncoordinated institutional activities.
Addressing Barriers	Are long term adaptation (Year 2050-2100) initiatives and projects being developed?	No	No clear long-term adaptation approaches, initiatives or projects have been announced to ensure the resilience of Cairo.
	Are there any emergency plans to act in cases of occurrence of extreme devastating environmental events?	Yes	The GFDRR have worked with the government from 2014 till 2017 and offered financial and technical support to allow for the development of warning systems and management capacity allowing the country to develop a better preparedness following the occurrence of environmental hazards.

Table C *Urban Resilience Index based on evidence from document reviews and interviews – the Case of Cairo*

Urban Resilience Index - London

	Questions	Yes/No	Evidence based on Document reviews and Interviews
Understanding Impacts and Vulnerabilities	Is there a national vulnerability assessment of Impacts of climate change?	Yes	"UK Climate Change Risk Assessment" released in 2012 and updated in 2017.
	Is there a local vulnerability assessment of Impacts of climate change (addressing impacts on London City)?	Yes	Identified in LCCP's technical report released in 2002 "London's Warming: A Climate Change Impacts in London Evaluation Study", in a "Climate change risk assessment for London" which was published by the LCCP in 2012 and in the Mayor's Climate Change Adaptation Strategy released in 2011.
	Is there an understanding of indirect socio-economic implications of climate change on London?	+/-	The LCCP's technical report addresses various "socio-economic scenarios" and The Mayor's Climate Change Adaptation Strategy acknowledges and highlights the impact of climate change on daily life and on the city's economy. However, the citizens are not aware of these implications (Interviewee 2, 2018).
	Is there a mapping of climate impacts based on data collection and monitoring?	Yes	Environmental data and maps are publically available on the Environment Agency's Official Website.
	Are changes in climate patterns projected and anticipated?	Yes	UKCIP02 report which predicts impacts based on 4 scenarios: Low Emissions, Medium-low Emissions, Medium-High Emissions and High Emissions.
Understanding Impacts and Vulnerabilities	Is the national/local government inciting research and studies in the field of climate change adaptation?	Yes	For instance, in the National City Park project, financial subsidies are given for research to develop new approaches to plantation and records about London's trees (Official website of Mayor of London, n.d.).
	Is there a national political support to adaptation to climate change?	Yes	The UK took an active stand against climate change as it ratified various international initiatives and developed a national approach to the issue.
	Is the local government	Yes	The mayor considers planning for climate change an important matter, and addresses

Formulating Comprehensive Strategies	(London governorate) committed to climate change adaptation?		adaptation measures to reduce flood risks, cope with droughts and reduce heat risks (Official website of Mayor of London, n.d.).
	Is there a clear determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate change?	Yes	The Mayor's climate change adaptation strategy "Managing risks and increasing resilience" released in 2011. And the "Come rain or shine: London's adaptation to the risks of severe weather" released by London Assembly Environment Committee in 2015.
	Is the strategy "tailored" to the assessed local impacts on the urban infrastructure?	Yes	The developed strategy responds to the impacts assessed and identified in LCCP's report. The Act on Climate Change specifies that the developed policies and proposals must address the risks identified in the most recent conducted risk assessment (Holmes, 2018).
	Is the strategy coordinated with scientific experts?	Yes	The Mayor is collaborating researchers on the BRIDGE75 programme to address UHI effect through urban greening. The mayor is also work in partnership AWESOME77 and LUCID to identify the risks hotspots presented by overlap of UHI effect with poorly designed urban areas.
Formulating Comprehensive Strategies	Is the strategy coordinated with the local community (including NGO's, cultural forums, civil societies and non-political councils)?	Yes	The GLA planned for workshops and invited NGOs and other stakeholders when the consultation was being drafted (Interviewee 2, 2018). Also, the community is participating in environmental matters through an online discussion platform "Talk London" allowing for Londoners to have a say in environmental issues and proposed adaptive projects.
	Is the adaptation strategy addressing and prioritizing urgent matters?	Yes	The 'UK Climate Change Risk Assessment' released in 2017, classifies "New, stronger or different government policies or implementation Activities" as the most urgent matter and conducting further research to reduce uncertainty as a priority.
	Is there a land use and zoning	Yes	"The London Plan: The Spatial Development Strategy for London" developed by the Mayor of London in 2016.

	addressing adaptive measures?		
Implementing Developed Strategies	Are short terms adaptation initiative being implemented?	Yes	For example, the collaboration of the local government with businesses to increase the share of green areas in the city.
	Is funding made available for the adaptation of the urban infrastructure?	+/-	Since the responsibility shifted from national to local authorities, the latter are being left to implement different strategies developed on a national level without receiving any additional funding (interviewee 2, 2018). However, some funding was available, such as grants amounting to 50 million pounds covered by the central government over the course of 10 years for the flood prevention plan.
	Is the local community playing a role in enhancing the implementation of adaptation project?	Yes	The "Greening London" project ensuring the cooperation of businesses, local communities and the public sector to plant rain gardens, pocket parks, green roofs and walls.
	Is the local government transparent in the implementation of adaptation projects? (preventing corruption)	Yes	The Freedom of information act 2000, ensures that governmental bodies are transparent and liable and sharing the data they possess, also "The Environmental Information Regulations 2004 provides a similar public right to access, and relates to environmental information held by public authorities." (Official website of Mayor of London, n.d.).
	Are houses built to ensure the safety of their inhabitants and withstand extreme weather events?	+/-	"The Environment Agency has identified 24,000 homes throughout Greater London at risk of flooding" (UK Government, 2014). However, the city's assembly environment committee developed a flood prevention plan to cover approximately around 40% of the houses (10,000 approx.) at risk of flooding.
	Are initiatives for greening London being implemented to reduce the effects of UHI?	+/-	Various initiatives have developed such as the 'Greening London' project and Groundwork's greening initiatives in support of the mayor's vision of making more than half of the city's area green by 2050. However, there has been a loss of green areas, gardens and open spaces due to

			new developments in London. Moreover, half of the city's residents have a meagre access to parks (Mayor Khan, 2017).
	Is there a defensive flood protection system in place to protect London?	Yes	Thames Estuary 2100 (TE2100) project which protects the city and the inhabitants of the Thames Estuary from future flooding.
Implementing Developed Strategies	Is there an efficient drainage system preventing from flooding in cases of cloudburst?	+/-	Since cloudbursts and heavy rainfalls have caused damages to the physical infrastructure in London (I.e. in 2000, 2014 and 2017) when heavy rainfalls caused the city to flood. Also, the Victorian drainage system in place wasn't aimed to cope with the stresses of the current and future population which leaves the city at risk of flooding. However, The country has strengthened the planning policy to ensure the inclusion of SUDS in all new major developments, unless proven to be not suitable (UK Government Official Website, n.d.).
	Do citizens have access to fresh water?	Yes	Londoners have access to fresh water, and the drought risks anticipated in the light of climate change are being addressed in "The Thames Water corporate strategy".
	Is the transportation system resilient to extreme weather events?	No	For instance, during heatwaves the transportation system got disrupted as the city's underground metro system became unbearably hot (Met Office Official Website, 2015). Also, when heavy rains occur and due to the centralization of services, the city suffers from traffic jams.
	Is there a secure energy supply?	Yes	The energy supply is secure; however the re-occurrence of heat-waves would increase the demand for electricity.
	Are impacts recently updated integrating new findings (after 2015)?	Yes	The impacts of global warming on the UK have been assessed in 2012 and updated in 2017 after a climate change act was developed in 2008, requiring the government to assess the impacts on a five-yearly basis and use it as a foundation for the development of adaptation programs (Holmes, 2018).
	Is the strategy recently updated integrating recent	+/-	The last launched adaptation was published in 2011 under the title of "Managing risks and increasing resilience. The Mayor's

Addressing Barriers	impacts assessment (after 2015)?		Climate Change Adaptation Strategy" (Mayor Johnson, 2011). However, a new "London Environment Strategy" is currently being developed. The finalized strategy is set to be published in 2018 highlighting both adaptation and mitigation approaches, setting out a vision and an inspiration for London in 2050.
	Are the barriers impeding the implementation of adaptation initiatives identified?	Yes	The Stern Review also known as "The Economics of Climate Change" (a long report released in 2006 for the national government of the UK) highlights the barriers to adaptation, including: ambiguity and lacking information, misaligned and missing markets and financial constraints.
	Are long term adaptation (Year 2050-2100) initiatives and projects being developed?	Yes	The TE2100 project to manage and overcome the flooding of surface water not only on short term but also on medium and long term.
	Are there any emergency plans to act in cases of occurrence of extreme devastating environmental events?	Yes	For example, the ESN project establishing a connection between citizens and emergency service departments.

Table D *Urban Resilience Index based on evidence from document reviews and interviews – the case of London*

Urban Resilience Index – New York

	Questions	Yes/No	Evidence based on Document reviews and Interviews
Understanding Impacts and Vulnerabilities	Is there a national vulnerability assessment of Impacts of climate change?	Yes	A series of four US National Climate assessments have been carried out since the beginning of the 21st century, released respectively in 2000, 2009, 2014 and 2017.
	Is there a local vulnerability assessment of Impacts of climate change (addressing impacts on New York City)?	Yes	Presented in the SIRR report developed by the City of New York in 2013 following Hurricane Sandy.
	Is there an understanding of indirect socio-economic implications of climate change on NYC?	Yes	"These impacts may make it difficult for commuters to travel to work and school and will hinder the economic and social life of the city." (The City of New York, 2013). Moreover, an assessment of the economic implications has been carried for each of the extreme weather events that have occurred since year 2000 (NCEI, 2018).
	Is there a mapping of climate impacts based on data collection and monitoring?	Yes	Presened in the NPCC report for 2015, such as the flood maps highlighting future 100-year flood zones in NYC.
	Are changes in climate patterns projected and anticipated?	Yes	Anticipations are presented in the NPCC report for 2015. These projections foresee the flooding of various areas along coastline and the occurrence heat-wave on the short, medium and long run.
	Is the national/local government inciting research and studies in the field of climate change adaptation?	Yes	According to the NYC Mayor's Office of Recovery and Resiliency's initiative report published in 2018, funding has been secured for research initiatives in the field of storm risk reduction and adaptation to urban heat.
	Is there a national political support to adaptation to climate change?	No	Following the president of the US' decision to withdraw from the Paris Agreement, climate change adaptation is no longer politically supported on a national level.
	Is the local government (NYC	Yes	Despite the United States' decision to withdraw from the Paris Agreement, NYC's

Formulating Comprehensive Strategies	governorate) committed to climate change adaptation?		governor re-instated his commitment to combat climate change (Dearden, 2017).
	Is there a clear determined strategy adopted by the local government to build resilience of the urban infrastructure and adapt to climate change?	Yes	The SIRR developed following hurricane Sandy.
	Is the strategy "tailored" to the assessed local impacts on the urban infrastructure?	Yes	Since on one hand, the government is focused on strengthening the understanding of impacts and risks first in order to develop an adequate adaptive response. On the second hand, the developed strategy addresses problem which are particular to NYC.
	Is the strategy coordinated with scientific experts?	Yes	The NPCC, including a body of scientists, developed various studies to assist and support adaptation in NYC.
	Is the strategy coordinated with the local community (including NGO's, cultural forums, civil societies and non-political councils)?	Yes	The City of New York involved the engagement and the participation of city leaders, elected officials, organizations and the general public in the PlaNYC report (The City of New York, 2013).
	Is the adaptation strategy addressing and prioritizing urgent matters?	Yes	The adaptation strategy prioritizes the problem of UHI and intense storms in the light of sea-level rise as these two issues have had the most impact on New Yorkers.
	Is there a land use and zoning addressing adaptive measures?	Yes	Building New York's Recovery and Resilience office's program started by modifying the zoning and land use law in order to improve the city's public realm.
	Are short terms adaptation initiative being implemented?	Yes	For example, the 'NYC Cool Roofs Program', training local individual to collaborate with a team to cover the city's rooftop with a white coating, releasing and reflecting the heat.
	Is funding made available for the	Yes	For instance, the New York's Recovery and Resilience office's program dedicate 700 million USD to develop the urban

Implementing Developed Strategies	adaptation of the urban infrastructure?		infrastructure. Additionally, 20 million USD were dedicated to complete 6 sewer projects and over 100 million USD to construct more draining projects.
	Is the local community playing a role in enhancing the implementation of adaptation project?	Yes	Such as, the Million Trees project is a public-private initiative aiming at increasing the share of green areas in the city through planting and caring for one million trees throughout the city.
	Is the local government transparent in the implementation of adaptation projects? (preventing corruption)	Yes	To increase the government's transparency, an open data platform (NYC open data) was made available to share information about city government, environment, health, recreation, social services, housing and development and transportation.
	Are houses built to ensure the safety of their inhabitants and withstand extreme weather events?	+/-	As an already built city, the existing infrastructure is not fit to the experienced changes of climate, however there is an "NYC Retrofit Accelerator" initiative in place ensuring the retrofitting of houses. Also newly constructed houses are being designed in a different way to increase the resilience.
	Are initiatives for greening NYC being implemented to reduce the effects of UHI?	Yes	For example, The city's 'Green Infrastructure' initiative.
	Is there a defensive flood protection system in place to protect NYC?	+/-	A Flood protection system is designed (the big U project) but not yet implemented. Experts are concerned that with the decision of withdrawal from the Paris agreement could lead to delays in the implementation of the defensive project (Templin, 2017).
	Is there an efficient drainage system preventing from flooding in cases of cloudburst?	+/-	In the 21st century, the flooding became much more frequent in NYC, to the point that it is causing disruptions to the subway system each week (Yohe, 2018). However, the "DEP is currently building green infrastructure in compliance with New York State Department of Environmental Conservation requirements to reduce combined sewer overflow discharges into

			New York City's water bodies" (New York City Government Official Website, n.d.).
	Do citizens have access to fresh water?	Yes	"New York City drinking water is world-renowned for its quality. Each day, more than 1 billion gallons of fresh, clean water is delivered from large upstate reservoirs—some more than 125 miles from the City—to the taps of nine million customers throughout New York state" (New York City Government Official Website, n.d.).
	Is the transportation system resilient to extreme weather events?	+/-	The city of New York has been experiencing frequent extreme precipitation events and heavy rains which have caused the flooding of roads, the flooding of subways, and nuisance flooding on some of the major arteries around the southern part of Manhattan (Yohe, 2018). However, investments are made to repair the infrastructure and to increase its resilience (for example entrances to subways are being elevated to limit flooding).
	Is there a secure energy supply?	Yes	Also, in cases of extreme events; as newly designed buildings include emergency generators providing sufficient power for occupants, in cases of flood or other emergencies, for as long as an entire week.
Addressing Problems	Are impacts recently updated integrating new findings (after 2015)?	+/-	No recent updates have been made to the impacts of climate change on New York City except for the impact assessment carried following Super storm sandy. Nonetheless, the NPCC is currently developing a 3rd report which is expected to be released by the end of 2018 and include updated impact assessments (Yohe, 2018).
	Is the strategy recently updated integrating recent impacts assessment (after 2015)?	No	The last developed strategy is the SIRR under the title "A Stronger, More Resilient New York, which was developed in 2013 after Hurricane Sandy shook the city.
	Are the barriers impeding the implementation of adaptation initiatives identified?	Yes	Regulatory structures in place, funding challenges as well as lack of climate-focused information and data restrain further growth (The City of New York, 2013).
	Are long term adaptation (Year	No	A focus has been made on short-term adaptation measures of which approximately

	2050-2100) initiatives and projects being developed?		73% have been completed or near-completion and no particular long-term initiatives have been developed.
	Are there any emergency plans to act in cases of occurrence of extreme devastating environmental events?	Yes	New York is working with the city's emergency management division to improve and develop emergency preparedness.

Table E *Urban Resilience Index based on evidence from document reviews and interviews – The case of NYC*