

ABSTRACT

Global urbanization is compounding the potential impacts of climate change, increasing greenhouse gas emissions to the atmosphere and complicating impacts to people's livelihoods. Risks include increased frequency of flooding, drought, extreme heatwaves, sea level rise and more; posing significant challenges to governments and decision makers. These challenges are especially high in dense urban areas. Despite these clear risks, many cities have not yet begun to address climate change.

However, according to UN-Habitat, when properly planned, implemented, and managed through the appropriate governance structures, cities can be places of innovation and efficiency. Together with their local authorities cities have the potential to diminish the causes of climate change (mitigation) and effectively protect themselves from its impacts (adaptation).

The goal of the research is to identify key aspects of adaptation and mitigation to climate change and identify trends among how cities are managing and approaching the issue of climate change, as well as enhance collaboration and sharing knowledge as a way to improve efficiency while building resilience to it. Additionally, this work seeks to identify holes and opportunities in these plans to help cities become more resilient and less vulnerable by managing efficiently by focusing on critical issues.

The research consists of a comparison between 50 cities worldwide, based on published "Climate Action Plans" or other key organizational government documents. Specific government actions and risks, adaptation and mitigation measures are identified. These measures are then compared across specific sectors and city characteristics including Köppen Indicator and GDP to identify trends and enhance collaboration between cities.

Actions to face climate change are organized by mitigation and adaptation measures. Mitigation measures are sorted by different sectors, and adaptation measures are divided based on identified risks. This provides governments a way to organize efficiently their measures and manage emissions issues (mitigation) and adaptation practices (adaptation).

This research shows that most urban areas face similar threats to climate change induced risks. However, many cities do not yet have action plans to minimize these risks. Identifying most common climate change-induced risks, most common adaptation and mitigation practices, and detecting where missing or incomplete information can be improved can enable cities to become more resilient both in the short and in the long term. The combination between acting based on own findings and sharing experiences and therefore learning from other cities with similar features is the best strategy to address climate change in a local scale.

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1. GLOSSARY

iCiCS: Abbreviation for Institute of Climate and Civil Systems. Seated at the University of Colorado at Boulder, this group comprises interdisciplinary researchers focusing on the effects of climate change on civil Systems.

IPCC: Abbreviation for Intergovernmental Panel on Climate Change. The IPCC assesses the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change.

GHG: Abbreviation for greenhouse gas.

CAP: Abbreviation for Climate Action Plan.

GDP: Abbreviation for gross domestic product. It is a macroeconomic magnitude that expresses the monetary value of the production of goods and services for final demand of a country (or region) for a certain period of time (usually a year).

GDPpc: Abbreviation for GDP per capita. It is calculated dividing GDP by the population.

KG: Abbreviation for Köppen Geiger. KG Climate Classification is a global climate classification that identifies each type of climate with a series of letters indicating the behavior of temperatures and rainfall that characterize this type of weather.

RI: Abbreviation for resilience indicator. Indicator created in this research that shows the level of resilience that a city has.

MI: Abbreviation for mitigation indicator. Indicator created in this research that shows the level of preparedness of reducing the GHG emissions that a city has.

2. PREFACE

2.1. Origins of the project

This research was an agreement by the Institute of Climate and Civil Systems (iClicS) and the candidate. iClicS is part of the department of Civil, Environmental and Architectural Engineering at the University of Colorado at Boulder. Once the candidate from ETSEIB arrived at Boulder, both the department and him agreed that there was a hole in finding out some trends in climate change preparedness between cities. Professor Paul Chinowsky was in that moment collaborating with a project pioneered by the Rockefeller Foundation, called 100 Resilient cities. This project was tightly related to what the department was doing and to the candidate's interests. Therefore, both from the iClicS and the candidate, it arised the willingness of studying how cities worldwide deal with climate change, by analysing public documents and plans, in order to complement the study of the 100 Resilient Cities project. After that, a paper could be published or the research could be offered to the Rockefeller Foundation as part of the 100 Resilient Cities project.

Professor Paul Chinowsky, founder of iClicS and who has developed a large number of professional studies and courses in climate change and risk management, together with PhD students Amy Schweikert and Xavier Espinet, co- founders of iClicS, have supervised the project.

2.2. Motivation

The idea of performing a research project related to climate change motivated me as I believed that engineers have an important role concerning the future of our planet. I understood a research related to climate change as a way of learning and making some key decisions in order to improve the future of human being. Moreover, I saw it as a great opportunity for me in order to be able to face professional future challenges related to what climate change involves. From my point of view, as I specialized on management and organization during the last two years, it was very interesting to relate, as far as possible, a

project concerning climate change to management so as not only to learn and deepen knowledge, but also to provide solutions through my skills.

2.3. Previous requirements

This research analyzes data extracted from online sources. This is why, in order to obtain this data, it is necessary to have a previous experience on researching in order to distinguish reliable to not reliable sources. Therefore, the candidate took a course at the Norlin Library at the University of Colorado Boulder in order to achieve this requirement previous to the start of the project. On the other hand, it is also important to have an advanced tool for MS Excel in order to deal comprehensively and manage the big amount of data analyzed.

3. INTRODUCTION

3.1. Research Problem Statement

Climate change is taking place all over the globe, affecting patterns of temperature and precipitation, and complicating human being life both in the short and in the long term (IPCC, The Fifth Assessment Report (AR5), 2014). Changes in climate patterns are causing risks such as increased frequency of flooding, dry periods, extreme heatwaves and sea level rise, which are threatening particularly urban areas and cities (Ashley, Balmforth, Saul , & Blanskby, 2005) (IPCC, The Fifth Assessment Report (AR5), 2014). Cities are not only the main contributors for greenhouse gas emissions, but they are also the most impacted areas. Despite these clear risks, many cities have not yet begun to address climate change. The reasons include: a lack of relevant city policies and action plans; slow response to climate disasters due to lack of capacity and resources; and/or lack of public awareness on climate variability and climate change-induced hazards. Therefore, urban areas have the potential to reduce the effect of many anthropogenic causes of climate change (mitigation) and efficiently increase resiliency to protect themselves against climate change induced risks (adaptation) (Tretkoff, 2010) (Satterthwaite, Huq, Pelling, Reid, & Romero Lankao, 2007).

3.2. Objectives of the project

This research introduces sharing knowledge, a learning model belonging to the Organizational Learning theory, as a way to achieve the goal of increasing resilience against climate change. Then, the authors seek to encourage city's action planners to collaborate with other cities with similar climate features, sharing information and experiences in order to build or update their local Climate Action Plans, increasing therefore resilience to changes in climate.

3.2.1. Implications

The thesis provides a robust case study for understanding the organization and governance for cities at the forefront of climate change action. It identifies key trends in identification of risk, mitigation actions, and effective adaptation options. These trends can be used to inform plans

that have missing or incomplete information and create more robust urban understanding and management of climate change.

For cities that do not yet have an action plan, the research provides information about main sectors to mitigate climate change and best adaptation measures based on similar challenges faced by other cities, resulting in a considerable reduction of efforts. Moreover, action plans are updated often, as both needs and strategies change year by year and as more information is available. This research provides useful information to efficiently update action plans.

Private companies with the aim of growing internationally will have special interest regarding both the climate change mitigation and adaptation research. By analyzing the needs of each city and identifying what adaptation measures they are missing, they will be able to recognize potential clients. Furthermore, by identifying best practices and most common mitigation measures, companies involved in the energy, transportation, building or waste management sectors can identify which are the main needs for cities, being able to adapt their products to the needs of the market.

3.3. Methodology

In order to enhance this way of learning between cities, this research presents a model based on a comparison between 50 cities. It provides information about main sectors and measures to mitigate climate change based on these city's experiences, most common adaptation measures and main climate related-risks that cities in same climate zones face. By identifying the main risks, mitigation and adaptation measures and finding out potential trends between cities with similar climate zones and GDP per capita, the authors aim to encourage city planners to use this model in order to learn from other cities that face similar challenges. This information, if used while building or updating CAPs, can result with a considerably reduction of money and city planners efforts by planning efficiently.

3.4. Research question

This study seeks to answer the following questions:

- How are cities addressing climate change?
- Could cities collaborate more efficiently while facing climate change?
- Can urban areas improve and create Climate Action Plans by leveraging existing plans and knowledge?
- Why and how sharing knowledge takes an important role in identifying risks and building Climate Action Plans?

3.5. Structure

The structure of this thesis consists of the background, methodology, results, discussion, project planning and economic viability, environmental considerations and conclusions. First, the background of this study introduces how the globe is addressing climate change, what measures have been already taken, and talks about organizations that are working on reducing vulnerability to climate change. Moreover, the background introduces organizational learning and sharing knowledge. Second, the paper presents the methodology used in this study (divided in three phases: data selection, data organization and data analysis). In the third section the results are presented for the cities analyzed. At the end, this thesis presents a discussion of the results, the planning and economic viability of the project, environmental considerations and conclusions that guide to answer the research questions.

3.6. Scope of the project

This study aims to provide unique information to local government agencies, city planners and organizations with the aim of enhancing collaboration between cities.

3.6.1. Limitations

There are several limitations to the current approach. First of all, results are based on cities' concerns, but it does not take into account the level of development of the measures. Second, a main source of uncertainty comes from the data used for analysis. Difficulty of finding government key documents and CAPs is one of the reasons, as this research only uses government documents, mainly climate action plans, as a source of information.

However, the authors seek to reduce this risk as much as possible by utilizing only available documents published after 2006. Moreover, sharing knowledge is a way of learning difficult to prove, but this study aims to show evidences to suggest that there is a trend for this way of learning between cities. Finally, this research provides complementary information for building a first step to help city planners and policy makers build and update CAPs efficiently based on other cities' experiences. Therefore, the level of detail is not deep enough to design and create a full CAP, as this study just analyzes main measures and actions in a wide perspective.

4. BACKGROUND

Climate change is a change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (United Nations Framework Convention on Climate Change). On the other hand, the rise in greenhouse gas emissions leads to overall warming of the planet. This warming then affects precipitation patterns, which together with changes in temperature patterns induce risks that are prejudicial for the globe.

According to the Intergovernmental Panel on Climate Change (IPCC), despite a growing number of climate change mitigation policies, total anthropogenic greenhouse gas emissions have continued to increase over 1970 to 2010 with larger absolute decadal increases toward the end of this period (IPCC, The Fifth Assessment Report (AR5), 2014). In conjunction with this rise, in recent decades changes in climate have affected natural and human systems on all continents and across the oceans (IPCC, The Fifth Assessment Report (AR5), 2014). In accordance with IPCC, effective mitigation will not be achieved if individual agents advance their own interests independently, as climate change is a collective action problem at the global scale.

Measures to face climate change are divided into mitigation and adaptation, depending whether a measure is implemented in order to reduce greenhouse gas emissions and therefore reduce climate change impact in the long term or whether it is implemented to increase preparedness and reduce vulnerability against immediate climate change related risks, respectively (IPCC, The Fifth Assessment Report (AR5), 2014). According to the IPCC Fifth Assessment Report, mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. By reducing these emissions around the globe we will be able to reduce climate change impact in the long-term, and urban areas have an important role in it.

On the other hand, adaptation is defined by the European Commission of Climate Action as the anticipation to the adverse effects of climate change and the appropriate taking action to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise (European Commission of Climate Action). Urban areas already identify immediate climate change-induced risks, and although there is no single approach for assessing,

planning, and implementing adaptation to climate change, some robust adaptation principles have nevertheless emerged (Füssel, 2007) (Satterthwaite, Huq, Pelling, Reid, & Romero Lankao, 2007).

The way that the globe is addressing climate change is based not only on global advice but also on city-scale assessments (Hallegatte, Henriot, & Corfee-Morlot, 2008) (Tanga, Brodyb, Quinn, Chang, & Weia, 2010). In the past decades, both global and local climate change decisions have been taken. The United Nations Framework of Climate Change (UNFCCC) was adopted in 1992 and entered into force on 1994 in order to enhance, among other things, public awareness of climate change impacts. In 1997, governments agreed to incorporate the Kyoto Protocol as an addition to the treaty. It has more robust and legally binding measures. In 2006 this protocol was introduced to the UNFCCC.

Cities are home to half of the world's population and consume 60-80% of the world's energy production (CDP-Driving Sustainable Economies), being at the same time places with a big potential of innovation and efficiency concerning climate change. Cities have the obligation, therefore, to put a step forward and plan and manage through the appropriate governance structures, taking their own decisions and facing their own climate change related impacts. Local climate change decisions include the development of city climate action plans (CAP). A local Climate Action Plan describes the policies and measures that a local government will enact to reduce greenhouse gas emissions and increase the community's resilience to unavoidable climate change (New York State Department of Environmental Conservation) (EPA, US Environmental Protection Agency). If urban areas deal locally with climate change impacts and design their own responses and Climate Action Plans, a more accurate and efficient strategy can be obtained (Hallegatte, Henriot, & Corfee-Morlot, 2008). Cities know what impacts they face and what measures best counteract these impacts. Therefore, CAPs enable cities to implement the best specific and unique measures for them.

Despite all the climate change potential risks, many cities don't have policies and action plans to address climate change yet (United Nations Habitat). A global survey conducted in 2012 between 468 cities worldwide inform that sixty-eight percent of cities worldwide are pursuing adaptation planning, with Latin American and Canadian cities having the highest rates of engagement (95% and 92% respectively) and the U.S. having the lowest (59%) (Carmin, JoAnn, Nadkarni, & Rhie, 2012). Many organizations, including: The World Bank; the Rockefeller Foundation; ICLEI - Local Governments for Sustainability; Delta Cities; the

Climate and Development Knowledge Network (CDKN); the Connecting Delta Cities (CDC) Network; and the Carbon Disclosure Project (CDP-Driving Sustainable Economies); identified the need to guide cities in reducing local vulnerability to climate change, and are promoting events in order to enhance working together as a way of building worldwide climate change resiliency. These organizations have already developed projects that enable cities to have more facilities to network with other cities and share best practices in order to increase urban resiliency. Some of them are: “100 Resilient Cities” by The Rockefeller Foundation; “Resilient Cities” (The Annual Global Forum on Urban Resilience and Adaptation) by ICLEI; “Learning from CDKN’s city experience: Resilient Cities” webinars or “Acting together for bold outcomes” by CDKN; and “Connecting Delta Cities” by Delta Cities. Although there are many frameworks designed to globally guide cities in thinking about resilience, there is still the need of not global but more specific local CAPs review in order to give advice for building and updating them. This research provides a worldwide methodology for identifying cities with similar risks, with the aim of enhancing sharing knowledge between cities and therefore complementing the projects that the mentioned organizations are developing, particularly the “100 Resilient Cities” project pioneered by the Rockefeller Foundation.

100 Resilient Cities

The Rockefeller Foundation’s 100 Resilient Cities Project seeks to help cities around the world become more resilient to the physical, social, and economic challenges that are a growing part of the 21st century. It identifies and works with cities that are “ready to build resilience to the social, economic and physical challenges of an increasingly urbanized world”.

As explained before, one of the most threatening challenges that urban areas face during the 21st century is Climate Change. Therefore, the research “How cities deal with climate change: From individual to collective performance” aims to complement the 100 Resilient Cities project from a more specific climate change point of view, providing information of how cities build resilience to face a change in climate and creating a 50 cities database in order to enhance sharing knowledge between them.

Organizational Learning, Knowledge Sharing and Climate Change

Organizational learning is defined as a process in which entities transform information and data to knowledge in order to increase innovation and competitiveness, based on four basic

principles: Long term vision and proactive management of the change, flexible organizational structure based on communication and permanent dialogue, putting collective efficiency forward individual performance and ability to adaptation to changes. Organizational learning includes learning from direct experience, learning from the experience of others, and developing conceptual frameworks or paradigms for interpreting that experience (Levitt & March, 1988). This way of learning enhances, therefore, the idea of knowledge sharing as a way of learning and improvement. In a city government scale, inter-organizational learning consists of the same process but extrapolated between cities. It consists of transferring cumulative store of knowledge, skills, resources, and public awareness regarding risks that provides an invaluable basis for informed action between cities facing similar challenges (Comfort, 1994).

As the mentioned organizations hold: by comparing, learning and extracting ideas from other cities, urban areas can achieve a higher level of efficiency and effectiveness while designing responses and plans to address climate change. In spite of being this statement strong and convincing, there are still some factors that affect the collaboration between cities. One of the most important failure factors concerning knowledge sharing happens when stakeholders are unwilling to contribute, as it depends on organizational culture and its ability to foster reciprocity, openness, and trust (Frost, 2014).

5. METHODOLOGY

This methodology provides a model for gauging and improving local action plans effectiveness while facing the impacts of a changing climate. This model is based on a comparison between 50 cities worldwide. Using published CAPs and other key organizational government documents, this methodology identifies and categorizes key sectors of climate change mitigation, most common risks and most implemented mitigation and adaptation practices. Moreover, this model gives quantitative information about how prepared and resilient are these cities, as well as proves that sharing knowledge between cities with similar needs and concerns is a useful way of first learning and then creating or updating future action plans. This model aims to be, therefore, a useful piece to extend all the work already done concerning helping city policy makers and planners innovate, incorporate and adapt the most efficient climate change measures into their local CAPs.

This research uses a content analysis methodology, defined as "the study of human communications materialized such as books, websites, paintings and laws" (Babbie , 2003). This methodology enables the research to do a comparison of measures and risks reflected on government documents between different cities. The methodology of this study has four phases. The first phase consists on collecting the data used in the analysis. During the second phase the data is sorted and organized. Then, in the third phase the data is analyzed and results are presented. Finally, in the fourth and last phase conclusions are drawn.

5.1. Phase 1: Data Selection. Cities and CAPs

The first phase is focused on obtaining data from each of the 50 cities studied. 25 of the cities have been selected because they are part of the 100 Resilient Cities project pioneered by the Rockefeller Foundation, which has the aim of helping cities around the world become more resilient to the physical, social and economic challenges that are a growing part of the 21st century. The other 25 cities have been selected based on climate zone, GDP per capita and geographical distribution in order to have a decent amount of cities inside each indicator's category. This enables to compare preparedness between cities, and encourages inter-organizational learning between vulnerable cities and resilient cities. Cities will be able to

identify the best adaptation and mitigation practices based on their needs and this will help to gain efficiency and effectiveness while designing and updating action plans.

On the other hand, the input data comes from CAPs, published government documents that reflect a holistic city approach about how cities are working not only on mitigating but also on adapting to climate change. Additionally, most CAPs identify local climate change-induced risks. CAPs are a good reflection of how a city approaches the issue of climate change. CAPs are the first choice because they show the main measures that a city implements in order to face the impacts of a change in climate. However, some cities analyzed do not have yet published CAPs. Therefore, the data can also come from other key government documents for those cities that still do not have published plans but are already implementing measures to face climate change. CAPs between cities can be compared, as they all show implemented measures no matter what is the level of development. For each city this study identified its climate change-induced risks, as well as both its mitigation and adaptation measures. CAPs are analyzed and compared in order not only to determine best actions against climate change both for mitigation and adaptation, but also to identify trends and enhance sharing knowledge by recognizing similar risks and needs.

Cities

<u>Africa</u>	<u>Asia</u>	<u>Europe</u>	<u>North America</u>	<u>Oceania & South America</u>
Abuja	Da Nang	Venice	Miami	Melbourne
Accra	Mumbai	Glasgow	Boulder	Christchurch
Dakar	Phnom Penh	Amsterdam	Monterrey	Rio de Janeiro
Alexandria	Bangkok	Hamburg	El Paso	Santa Cruz
Enugu	Abu Dhabi	Bristol	Boston	Caracas
Kigali	Shanghai	Budapest	Berkeley	Medellin
Nairobi	Hong Kong	Barcelona	Los Angeles	Montevideo

Durban	Tokyo	London	Mexico City	Buenos Aires
Casablanca	Seoul	Moscow	Toronto	Quito
Addis Ababa	Kuala Lumpur	Stockholm	Chicago	Santiago

Table 5-1 50 cities analyzed [own]



Figure 5-1 Map of the 50 cities worldwide analyzed [own]

5.2. Phase 2: Data organization

After collection, this study sorted the cities according to Köppen-Geiger Climate Zones (KG Zones) and GDP per capita. Cities with different geographical attributes, climate zones or economical features have different risks and therefore focus on implementing different measures. On the other hand, for each city this study has sorted the mitigation measures by sectors and the adaptation measures by risks. This enables a better comparison between cities and measures. In order to organize all the data and afterwards extract the results, a 50 cities excel database has been created (The whole database is presented in Annexe B).

5.2.1. Cities

5.2.1.1. Sorted by Köppen-Geiger (KG) Climate Classification

The KG Climate Classification is a global climate classification system that identifies each type of climate with a series of letters indicating the behavior of temperature and rainfall that characterize this type of climate (Petersen, Sack, & Gable, 2011). The KG Indicator organizes cities according to climate characteristics, sorting into five different categories: A (Tropical/megathermal climates), B (Dry (arid and semiarid) climates), C (Temperate/mesothermal climates), D (Continental/microthermal climates) and E (Polar and alpine climates). This distribution enables us to compare cities with similar features, climates, and needs.

Group A	Kigali, Phnom Penh, Enugu, Accra, Da Nang, Santa Cruz, Abuja, Mumbai, Caracas, Rio de Janeiro, Bangkok, Kuala Lumpur, Miami
Group B	Dakar, Alexandria, Medellín, El Paso, Monterrey, Boulder, Abu Dhabi
Group C	Addis Ababa, Nairobi, Durban, Quito, Casablanca, Mexico City, Montevideo, Shanghai, Santiago, Buenos Aires, Budapest, Venice, Barcelona, Glasgow, Christchurch, Berkeley, Melbourne, Tokyo, Amsterdam, Hong Kong, Hamburg, Bristol, London, Los Angeles, Boston
Group D	Seoul, Toronto, Moscow, Stockholm, Chicago

Table 5-2 Cities sorted by Köppen Geiger group [own]

CITIES	INDICATORS	
	Köppen Climate Classification	Köppen Climate Definition
ADIS ABABA	Cwb	Maritime temperate climates or Oceanic climates
ALEXANDRIA	BWh	Desert Climate
AMSTERDAM	Cfb	Maritime temperate climates or Oceanic climates
BANGKOK	Aw	Tropical wet and dry or savanna climate
BARCELONA	Csa	Dry-summer subtropical or Mediterranean climates

Table 5-3 Example of cities sorted by KG climate classification in the database [own]

5.2.1.2. Sorted by GDP per capita

On the other hand, the 50 studied cities have been organized by four different groups, which have been created basing on having a similar number of cities in each. To begin with, the first group (Group 1) includes cities with a GDP per capita from 0 to 6.000 US\$. There are 13 cities included in this group: Kigali, Phnom Penh, Addis Ababa, Enugu, Dakar, Accra, Da Nang, Santa Cruz, Abuja, Nairobi, Durban, Alexandria and Mumbai. On the other hand, group 2 include cities from 6.000 to 30.000 US\$ of GDP per capita, and there are 13 cities included in this group: Quito, Medellin, Casablanca, Caracas, Rio de Janeiro, El Paso, Mexico City, Montevideo, Shanghai, Santiago, Bangkok, Kuala Lumpur and Buenos Aires. Moreover, group 3 includes cities with a GDP per capita from 30.000 to 45.000 US\$, and there are 13 cities included in this group: Monterrey, Seoul, Budapest, Venice, Barcelona, Glasgow, Christchurch, Berkeley, Melbourne, Tokyo, Miami, Toronto and Moscow. Finally, group 4 includes cities of more than 45000 US\$ of GDP per capita, and there are 11 cities included in this group: Amsterdam, Hong Kong, Hamburg, Bristol, London, Boulder, Stockholm, Chicago, Los Angeles, Abu Dhabi and Boston.

5.2.2. Measures

In order to better summarize information and have a good basis to make an appropriate comparison between cities, measures have been organized between mitigation and adaptation.

5.2.2.1. Mitigation measures sorted by sectors

Mitigation measures have been sorted into six different sectors: (1.) energy supply, (2.) buildings and industry, (3.) transportation, (4.) waste management, (5.) education, and (6.) green landscape. This way of organizing mitigation data has been chosen because of being the most common way of sorting all the mitigation measures by the majority of the CAPs reviewed. Inside each sector the authors identified the main specific measures that each city implements so as to diminish the causes of climate change. Sorting mitigation measures into sectors enables the study to better organize all the cities measures, detecting most common measures taken between cities of similar features and identifying each sectors' most common practices to reduce emissions.

CITIES	MITIGATION					
	ENERGY SUPPLY	BUILDINGS/INDUSTRY	TRANSPORTATION	WASTE MANAGEMENT	EDUCATION	GREEN LANDSCAPE
ADIS ABABA	•		•		•	
ALEXANDRIA	•	•	•			
AMSTERDAM	•	•	•	•	•	
BANGKOK		•	•	•		•
BARCELONA	•	•	•	•	•	

Table 5-4 Example of mitigation sectors in the database [own]

Energy Supply

The energy supply sector includes every process related to extract energy resources, convert them to ready-to-use forms of energy and deliver this energy to places where there is demand. The world energy consumption has increased by a rate of approximately 2% per year for the last two centuries, and is one of the most relevant sectors concerning climate change. Because of this, governments are more aware year by year, and according to IPCC's Fourth Assessment Report, based on past trends the GHG emissions related to the energy supply sector will probable increase more slowly than energy consumption will

increase, due to a gradual trend of decarbonization of energy supply, which denotes the declining average carbon intensity of primary energy over time.

Promising approaches to reduce future emissions, not ordered according to priority, include more efficient conversion of fossil fuels; switching to low-carbon fossil fuels; decarbonization of fuels; CO₂ storage; switching to nuclear energy; and switching to renewable sources of energy.

Buildings and industry

According to the U.S. Energy Information Administration (EIA), the Building Sector consumes nearly half (47.6%) of all energy produced in the United States. Seventy-five percent (74.9%) of all the electricity produced in the U.S. is used just to operate buildings. Globally, these percentages are even greater. Therefore, buildings are the largest contributor to climate change. With so much attention given to transportation emissions, many people are surprised to learn this fact. In truth, the Building Sector was responsible for nearly half (44.6%) of U.S. CO₂ emissions in 2010. By comparison, transportation accounted for 34.3% of CO₂ emissions and industry just 21.1%. Energy efficiency in the buildings sector offers more potential for cost-effective greenhouse gas emissions reductions than any other major abatement category. In addition, investments in energy efficient buildings and appliances can create jobs and help to delay investments in costly new electricity generation technologies. In this research, both buildings and industry sectors are analyzed together, identifying best practices to improve energy efficiency and new alternative energy sources.

Promising approaches to reduce future emissions, not ordered according to priority, include the construction of green buildings, with cooler materials, big windows and green roofs. Moreover, measures to reduce GHG emissions include a more efficient way to manage energy consumption in buildings and industries and the use of new alternative energy sources.

Transportation

Transportation is a crucial factor to boost economic growth, reduce poverty and achieve the Millennium Development Goals (MDGs). The World Bank investments in this sector have facilitated more efficient trade and a better human development through greater mobility, all with due attention to climate change. In addition, the World Bank involvement in the rail, air,

maritime and urban transport is growing steadily in response to global development needs. Since 2002, projects financed by the World Bank have helped build or rehabilitate more than 260,000 kilometers of roads.

Promising approaches to reduce future emissions, not ordered according to priority, include the promotion of bike and walking activities, the improvement of the public transport, not only the construction of more parking areas to reduce road congestions but also reducing parking areas to avoid more cars in urban areas, and the improvement and promotion of low-carbon vehicles.

CITIES	MITIGATION						
	TRANSPORTATION						
	Bike and walking	Bus	Public transport	Rail system	Parking	low-carbon vehicles	Other measures
ADIS ABABA							•
ALEXANDRIA						•	
AMSTERDAM	•	•	•			•	•
BANGKOK		•	•	•			•
BARCELONA	•	•	•	•		•	

Table 5-5 Example of transportation measures in the database [own]

Waste management

Waste management is the collection, transport, processing or treatment, recycling or disposal of waste material, generally produced by human activity, in an effort to reduce harmful effects on human health and aesthetics of the environment, although currently working not only to reduce the harmful effects caused to the environment but to recover its resources. Waste management may include solid, liquid or gaseous substances with different methods for each.

Promising approaches to reduce future emissions, not ordered according to priority, include the 3R's: Reduce, Reuse, Recycle.

Education

Education sector and awareness raising is a way to develop issues, mobilize greater public support for action against climate change, give citizens tools to engage critically with global development issues, to foster new ideas and change attitudes concerning climate change issues with the objective of reducing GHG emissions.

Green landscape

Green landscape sector refers to landscape measures so as to reduce GHG emissions. Expanding park areas and planting trees are some of the measures to reduce emissions included in this sector.

5.2.2.2. Adaptation measures sorted by risks

Adaptation measures have been organized based on the following identified risks: health (water, air and food quality), flooding, coastal erosion, drought, wildfires, earthquakes, high wind and typhoons, storms and heavy rains, sea level rise, heat waves and landslides. These risks have been the main climate change-related risks identified for all the cities CAPs and key documents. For each city this research detected the main adaptation measures per risk identified. These risks are, currently, the greatest climate change threat to urban areas. By categorizing the adaptation data by risks this study finds out how cities are working on adapting to their own threats, detecting the most common adaptation practices, and enhancing collaboration between cities that face similar risks.

CITIES	RISKS						
	HEALTH				FLOODING	COASTAL EROSION	DROUGHT
	WATER QUALITY		AIR QUALITY	FOOD QUALITY			
	SALINE INTRUSION	OTHER (DISEASES,RIVERS...)					
ADIS ABABA		•	•	•	•		•
ALEXANDRIA	•		•	•	•	•	
AMSTERDAM	•				•		•
BANGKOK	•	•			•	•	
BARCELONA			•		•		•

CITIES	RISKS						
	WILDFIRES	EARTHQUAKES	TYPHOON/HIGH WIND	STORMS AND HEAVY RAIN	SEA LEVEL RISE	HEAT WAVES	LANDSLIDES
ADIS ABABA				•		•	
ALEXANDRIA			•	•	•	•	
AMSTERDAM					•	•	
BANGKOK					•	•	
BARCELONA	•			•	•	•	

Table 5-6 Example of risks identified by city in the database [own]

Health

The risks of health include water quality, air quality and food quality. Due to temperature and rainfall changes these three areas are threatened in some places of the globe. Water quality is threatened by saline intrusion and water-borne diseases related to climate change, and can be faced by desalinization plants or diversification of rivers. On the other hand, air quality is threatened by gas emissions in the air, and can be faced by planting trees or expanding green areas. Finally, food quality is the last health area threatened by climate change, and measures to face this risk include improving irrigation systems in crops and crops growth efficiency.

Flooding

On the other hand, flooding is a risk that many cities identify related to climate change. Flooding is one of the most common natural hazards in the world, as most places are subject

to some kind of flooding from extreme rainfall, melting snow or ice, cyclones, hurricanes, etc. Unlike other natural hazards, floods can be considered as a resource because they provide water and sediments that make the most fertile land and necessary for the proper functioning of river ecosystems.

Some of the measures so as to face flooding include the construction of dikes, pumps, dams, the improvement of the drainage system and planting trees.

CITIES	ADAPTATION					
	FLOODING					
	Dikes	Pumps	Drainage system	Dams	Planting trees	Other measures
ADIS ABABA			•			•
ALEXANDRIA			•			•
AMSTERDAM	•				•	•
BANGKOK	•	•	•			•
BARCELONA			•			•

Table 5-7 Example of flooding measures adapted by city in the database [own]

CITIES	ADAPTATION					
	RISKS					
	FLOODING					
	Dikes	Pumps	Drainage system	Dams	Planting trees	Other measures
ADIS ABABA			•			•
ALEXANDRIA			•			•
AMSTERDAM	•				•	•
BANGKOK	•	•	•			•
BARCELONA			•			•

Table 5-8 Example of risk identified by city (in red: flooding) and adaptation measure implemented to face this risk by city (point) [own]

Coastal erosion

Coastal erosion is the wearing away of land and the removal of beach or dune sediments by wave action, tidal currents, wave currents, drainage or high winds (see also beach evolution). Waves, generated by storms, wind, or fast moving motor craft, cause coastal erosion, which may take the form of long-term losses of sediment and rocks.

Measures to face this risk include relocation of houses, the construction of dikes and the improvement of the drainage system.

Drought

Drought can be defined as a transient abnormality in which water availability is below the statistical requirements of a given geographical area. Water is not enough to meet the needs of plants, animals and humans.

The risk of drought can be countered by reducing water consumption and increasing water efficiency, grey water use and rainwater harvesting.

Wildfires

A wildfire is the fire that spreads uncontrolled forest land affecting vegetable fuels. A wildfire differs from other types of fire for its wide extension, the speed with which it can spread from their place of origin, their potential to change direction unexpectedly, and their ability to overcome obstacles such as roads, rivers and firewalls.

Measures to face wildfires include an early warning system and fire protection measures.

Earthquakes

A changing climate isn't just about floods, droughts and heatwaves. It brings erupting volcanoes and catastrophic earthquakes too. As professor Roland Burgmann (of the Department of Earth and Planetary Science at the University of California in Berkeley) says, "seismic faults are very sensitive to the small pressure changes brought by change in the climate. Warming ice sheets and flooding are changing the weight load of the planet and putting stress on seismic faults like the one in the Himalayas".

Typhoon, cyclons and high winds

Tropical cyclones and typhoons can produce winds, large waves, tornadoes, torrential rains (which can cause flooding and landslides) and can also cause storm surges in coastal areas.

Measures so as to face this hazard include planting trees to reduce wind velocity and break high winds.

Storms and heavy rain

The risk of storms and heavy rain refers to the risk of power and electricity outages due to this phenomena. Measures to face this risk include infrastructure measures as protecting cable tunnels in the form of embankments, tunnel reinforcements and relocation of technical infrastructures.

Sea level rise

The current sea level rise has occurred at an average rate of 1.8 mm / year since the last century, and more recently estimated rates near 2.8 ± 0.43 to 3.1 ± 0.74 mm per year (1993-2003). The current sea level rise is mainly caused by anthropogenic global warming.

There are not many measures to avoid efficiently sea level rise, but cities are working on relocating areas threatened by this risk and building dikes and walls for protecting against sea level rise.

Heat waves

A heat wave is a more or less prolonged period, too warm. The term depends on the temperature considered "normal" in the area, so that the same temperature in a warm climate is considered normal can be considered a heatwave in an area with a temperate climate.

Measures so as to face heat waves include the promotion of green buildings by the construction of green and cool roofs, the use of cool pavements and planting trees to give shade.

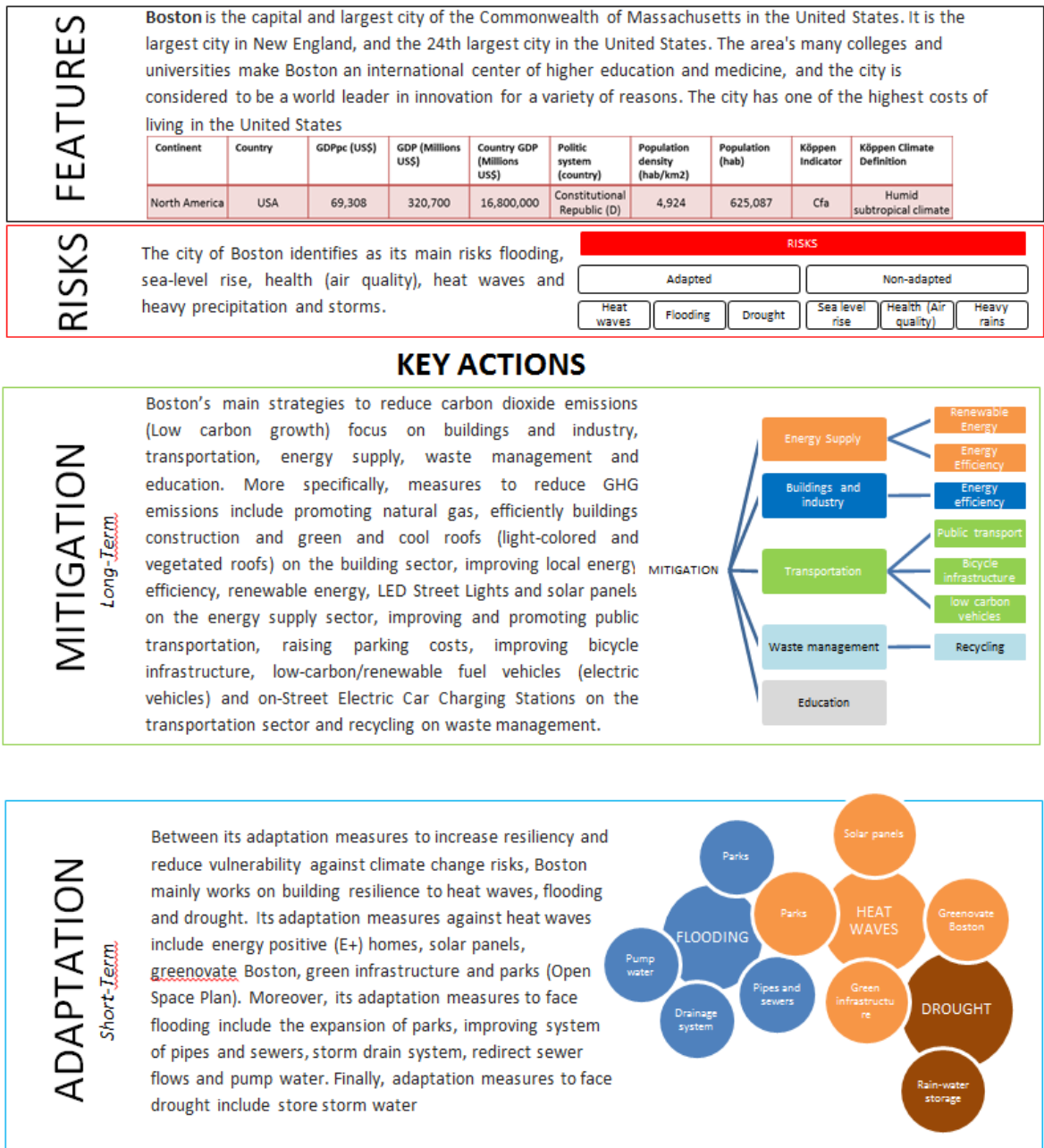
Landslides

A landslide is a type of shift or movement of land mass, caused by the instability of a slope. Drastic changes in temperature and rainfall cause degradation and, therefore, landslides.

Measures so as to face the risk of landslides include the relocation of settlements from areas exposed to landslides and reforestation to make the land more stable.

5.2.3. City report

Figure 5-2 shows a model of a city report, particularly the case of Boston. A report has been done for each of the 50 cities analyzed. Annexe A (From A.1 to A.50) shows the report of each of the 50 cities analyzed.



Boston has a Climate Action Plan that provides strategies and actions to help adapt and mitigate the effect of climate change on the city.

Figure 5-2 Model of a city report (Boston) [own]

5.3. Phase 3: Data analysis

Once the authors organized all the cities from this research, actions were categorized and the database was created, results were analyzed in order to extract some conclusions that guide to answer the research questions. The authors first sought to prove hypothesis such as whether cities are addressing their risks; whether cities in the same KG climate zone identify the same risks and face them similarly; or whether there is some evidence that knowledge sharing between cities explains data. After that, the study concluded answering the research questions.

In order to better summarize and compare the information extracted from the comparison between cities, both a resilience and a mitigation indicator have been created. Using these two indicators enabled the authors to enhance the comparison of the preparedness and involvement of cities on climate change issues, and therefore identify some trends between them.

5.3.1. Resilience indicator and mitigation indicator

The resilience indicator provides a metric by which the study can compare cities' adaptation actions on an equal scale. This indicator consists of calculating the percentage of risks that a city not only identifies but also acts in order to face them. This research considers that a city "acts" to face a risk if their CAP or other key documents mention adaptation measures that are or will be implemented in order to face the risk. It is calculated dividing the number of risks that a city adapts by the total number of risks identified. The resilience indicator gives, therefore, an idea of how resilient to climate change-related impacts a city is, as the higher the resilience indicator is, the more resilient the city is likely to be.

$$RI = \frac{\textit{Number of risks adapted}}{\textit{Number of risks identified}} \quad (\text{Eq. 5.1})$$

Figure 5-3 Resilience Indicator equation [own]

The mitigation indicator is the percentage of mitigation measures that a city implements over all the 12 most common mitigation measures. The 12 most common measures are the mitigation practices that have appeared the most in the 50 local city CAPs review. These measures are: (1.) energy efficiency and (2.) renewable energy for the energy supply sector; (3.) energy efficiency and (4.) renewable energy for buildings and industry; (5.) bike and walking, (6.) public transport, (7.) parking, (8.) low-carbon vehicles and (9.) other transportation-related measures for the transportation sector; (10.) waste reduction, solid waste management and recycling for the waste management sector; (11.) awareness for the education sector and (12.) CO₂ sequestration for green landscape. It is calculated dividing the number of mitigation measures belonging to this group of 12 practices that a city has implemented by 12. This indicator gives an idea of how much a city is involved in reducing carbon dioxide emissions and mitigating climate change in the long term.

$$MI = \frac{\text{Number of main mitigation measures implemented}}{12} \quad (\text{Eq. 5.2})$$

Figure 5-4 Mitigation Indicator equation [own]

5.3.2. Data analysis

To begin with, this study did a comparison between all the cities analyzed. The authors extracted some quantified results such as most common mitigation sectors, most common mitigation measures, most identified risks, most common adapted risks and most common adaptation measures by risk.

Second, this study compared cities belonging to the same KG climate group (A, B, C and D) in order to determine not only what are the most common risks (the most identified ones) in each group but also which are the most threatened zones. Moreover, this research studied the relation between the Resilience and Mitigation Indicators and the KG Indicator in order to extract a possible trend between the climate zone and how prepared and conscious a city is.

Third, cities belonging to the same GDP per capita group (1, 2, 3 and 4) are compared in order not only to identify trends between cities with similar economical features, but also to find out if data explains a relation between wealthness and preparedness to climate change.

Finally, this study compared CAPs designed and published before 2010 to CAPs published after 2010. KG group C is the climate zone with more cities analyzed (25). Therefore, this comparison has been done between cities belonging to this group in order to have a sample with more than 20 cities and achieve more accuracy. The aim of this comparison was to find out whether there is a trend in identifying risks related to climate change, as well as to prove the existence of knowledge sharing based on results.

5.4. Phase 4: Conclusion

By identifying trends and similarities between CAPs of major cities this research aims to be a complementary work and help toward enhanced knowledge sharing between cities. This study shows similarities between risks identified by cities, most common practices for adaptation and mitigation, and the relationship between other variables that proves knowledge sharing.

6. RESULTS

6.1. Introduction: Comparison between 50 cities

6.1.1. Most common mitigation sectors

Using the methodology described above and according to the database created, the most common sectors in order to reduce GHG emissions are the following: energy supply (88% of the cities implement measures related to this sector in order to mitigate climate change), transportation (84% of the cities), buildings and industry (78%), waste management (56%), education (50%) and green landscape (48%). These results suggest that cities are mainly focused on working in the energy supply, transportation and buildings and industry sectors while mitigating climate change by reducing GHG emissions. Green landscape is the less common sector between urban areas concerning the goal of reducing emissions.

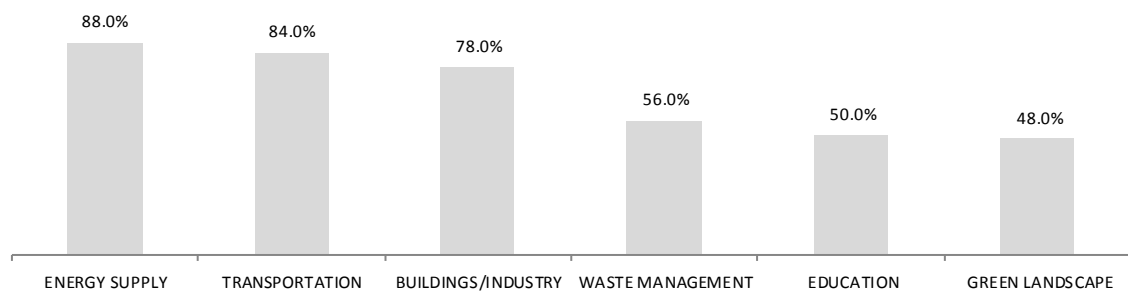


Figure 6-1 Most common mitigation sectors [own]

6.1.2. Most common mitigation measures

This analysis finds out the most used measures or most common practices by all the cities as aimed at reducing emissions. This study suggests that the most common practices in order to address this issue are renewable energy in the “energy supply” sector (86% of the cities are working on it), improving public transport and promoting low-carbon vehicles in the “transportation” sector (68%), increasing energy efficiency (68%) and promoting renewable energy (66%) in the “buildings and industry” sector and waste reduction and recycling (56%) in the “waste management sector”. Measures such as creating more parking lots in order to avoid congestions or planting trees to sequester CO₂ are, on the other hand, implemented

by less than the 50% of the cities analyzed, which suggests that they are not the most popular ones between urban areas.

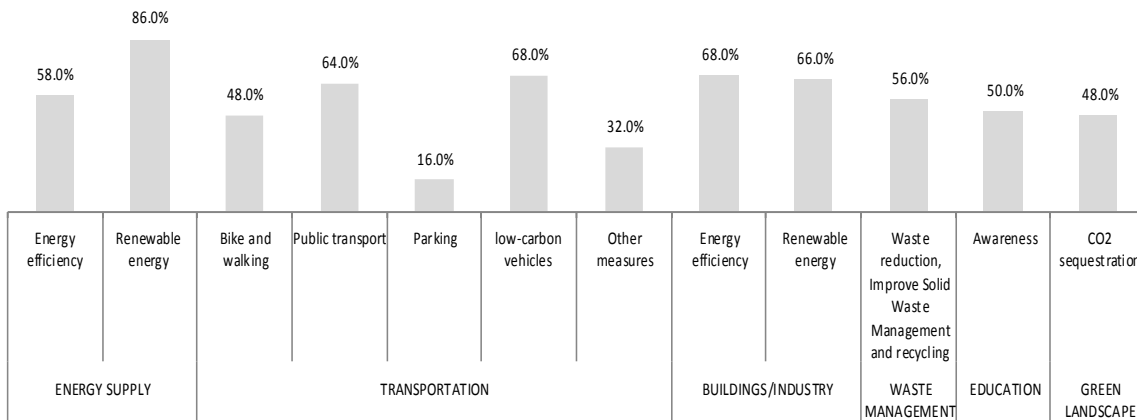


Figure 6-2 Most common mitigation measures [own]

6.1.3. Most identified risks

The most commonly identified climate change induced risks are flooding (92% of the cities identify this risk as a threaten), health (72%), heat waves (68%) and drought (62%); followed by sea level rise (46%), storms and heavy rains (38%), typhoon and high winds (24%), landslides (24%), coastal erosion (20%), wildfires (12%) and earthquakes (10%).

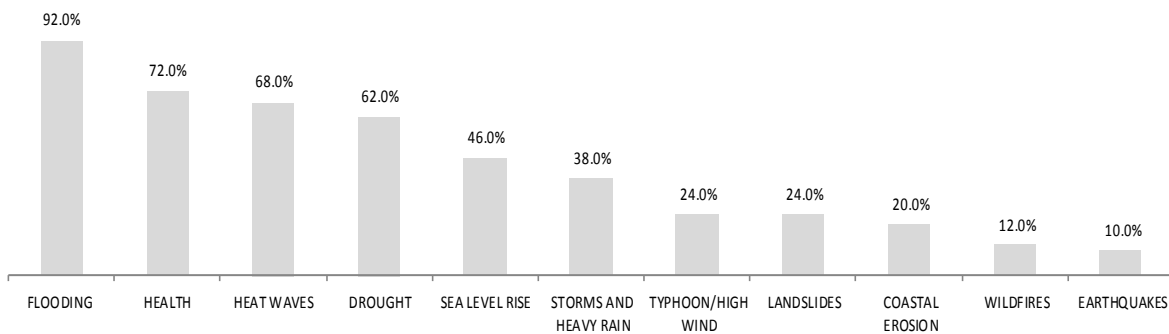


Figure 6-3 Most identified risks [own]

6.1.4. Most common adapted risks

In relation to the risk assessment identification, a timeline is important: some risks are more imminently threatening (such as flooding) while others may have severe consequences but are projected to be felt in the longer term (such as sea level rise). Cities work on building resiliency and adapting to some risks more than other risks that also threaten the same city. In this case, the identified risks that are most commonly adapted by the cities are the following ones: Drought (81%), flooding (80%), water quality (62%) and food quality (60%).

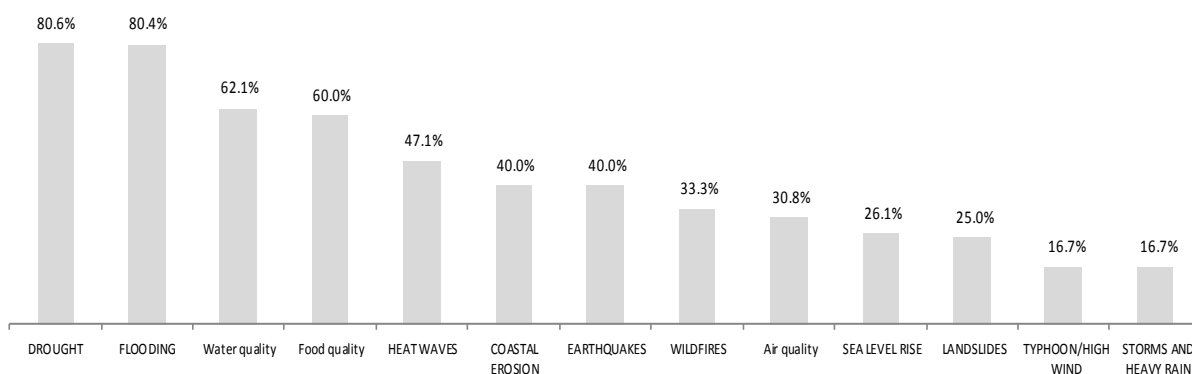


Figure 6-4 Most common adapted risks [own]

6.1.5. Most common adaptation measures by risk

Table 6-1 shows the most common adaptation practices by risk, according to the 50 cities analyzed.

WATER QUALITY		AIR QUALITY	FOOD QUALITY		FLOODING			
Diversify water supply	Desalination plants	Planting trees	Improve irrigation systems	Dikes	Pumps	Drainage system	Dams	Planting trees
COASTAL EROSION		DROUGHT			WILDFIRES	EARTHQUAKES	TYPHOON/HIGH WIND	
Coastal retreat	Dikes	Reduce water consumption	greywater use	Rainwater harvesting	Fire-resistant building codes	Resistant structures	Planting trees	
STORMS AND HEAVY RAIN	SEA LEVEL RISE		HEAT WAVES			LANDSLIDES		
Infrastructure measures	Dikes & bulkheads		Green and cool roofs	Cool pavements	Planting trees		Reforestation and relocation	

Table 6-1 Most common practices by risk [own]

6.2. Comparison between KG climate zones

6.2.1. Group A

Between KG climate classification A (Tropical/megathermal climates), the most identified risk is flooding (100% of the cities identify it as a risk), followed by water quality (85%), drought (69%) and heat waves (62%). The fact that all the cities identify flooding as a risk means that it is a very significant threat to this group of cities. A change in precipitation patterns in the future has potentially a huge impact to these cities, and they need to be aware of it.

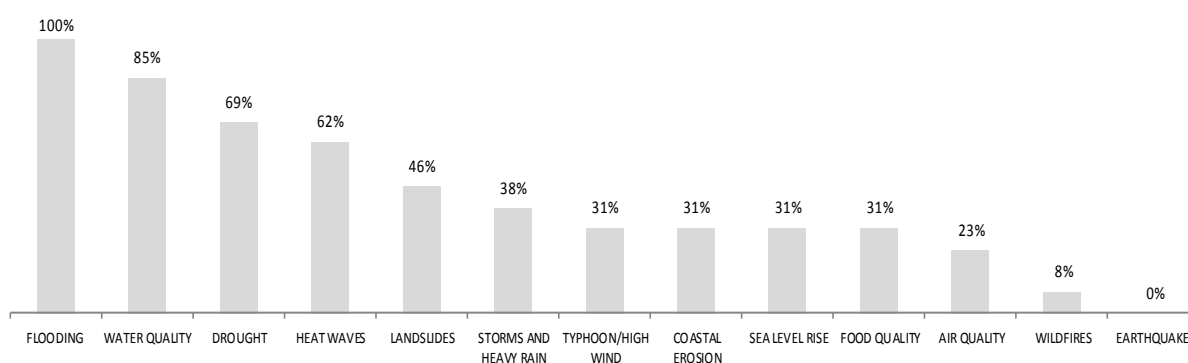


Figure 6-5 Risks identified by KG group A [own]

In general terms, the set of 13 cities belonging to group A have identified a total of 72 risks, which equals to a ratio of 5,54 risks identified per city.

6.2.2. Group B

On the other hand, for KG climate classification B (Dry (arid and semiarid) climates), the most identified risk is flooding (86% of the cities identify it as a risk), followed by water quality (71%), heat waves (71%) and drought (57%). The four main identified risks for the KG group B match with the four main identified risks by cities belonging to KG group A, but the percentages are different, usually lower. It suggests that cities belonging to group B may be less threatened by climate change, and therefore less adaptation is needed than the ones belonging to group A.

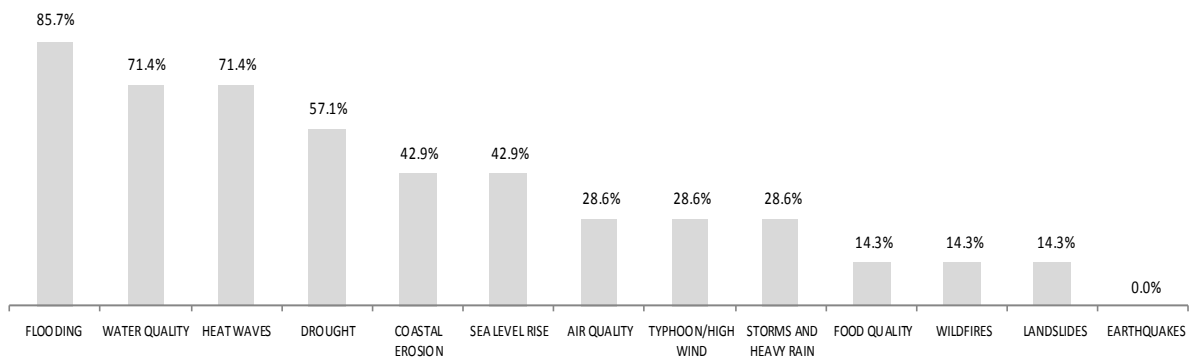


Figure 6-6 Risks identified by KG group B [own]

In general terms, the set of 7 cities belonging to group B have identify a total of 35 risks, what equals to a ratio of 5,0 risks identified per city, lower than category A.

6.2.3. Group C

In KG group C (Temperate climates), the most identified risk is flooding (88% of the cities identify it as a risk), followed by drought (64%), heat waves (64%) and sea level rise (60%).

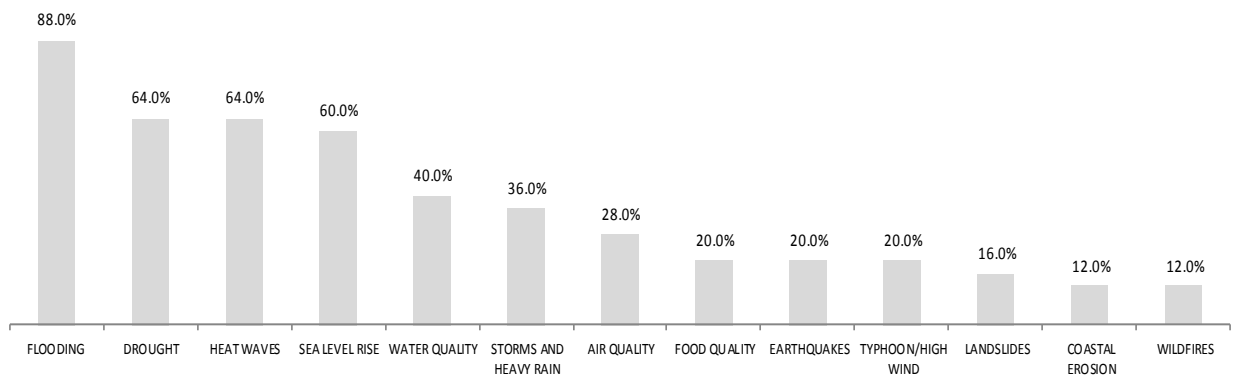


Figure 6-7 Risks identified by KG group C [own]

In general terms, the set of 25 cities belonging to group C have identify a total of 120 risks, which equals to a ratio of 4,8 risks identified per city. Therefore, this ratio suggests that cities belonging to group C are less exposed to risks than cities belonging to group A and B. Therefore, less potential climate change impacts this group of cities will have to face, and more focused on the ones they face they will be able to be.

6.2.4. Group D

In KG climate classification D (Continental/microthermal climates), the most identified risks are flooding and heat waves (100% of the cities identify them as a risk), followed by storms and heavy rain (60%) and water quality (60%).

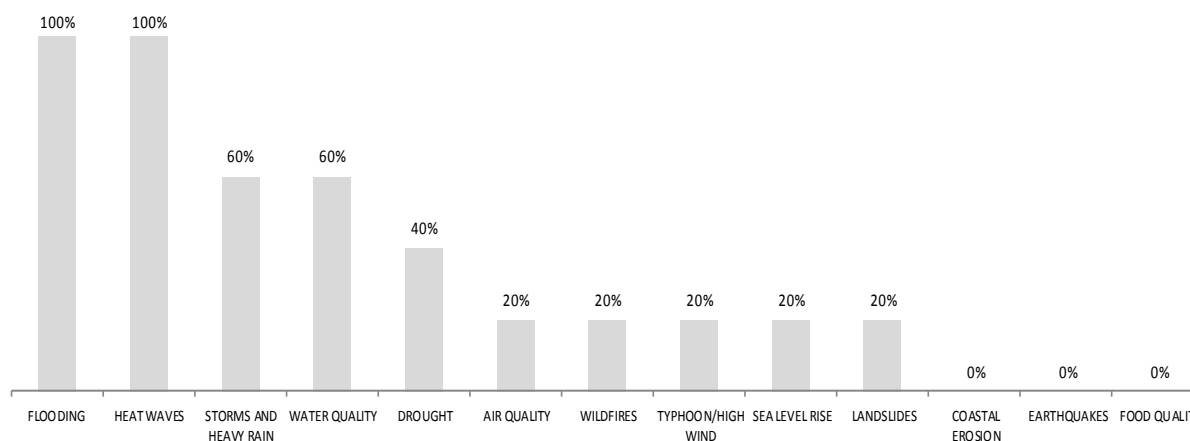


Figure 6-8 Risks identified by KG group D [own]

In general terms, the set of 5 cities belonging to group D have identified a total of 23 risks, what equals to a ratio of 4,6 risks identified per city. Therefore, this ratio suggests that cities belonging to group D are the less exposed to risks, as its risks per city ratio is lower than for cities belonging to group A, B and C.

6.2.5. Resilience indicator and mitigation indicator by KG climate groups

As a way of looking for trends, this study also presents the resilience and mitigation indicator for each KG zone. Table 6-2 shows the RI mean for each KG group, as well as the most and less adapted risks for each climate zone. On the other hand, Table 6-3 shows the MI mean for each KG group, as well as the main mitigation sectors and last mitigation sectors for each climate zone. Moreover, Table 6-2 shows the percentages of cities belonging to the specific KG group that adapt to the risk evaluated, whereas Table 6-3 shows the percentage of cities that work on the sector evaluated in order to mitigate. Most and less adapted risks are relative to the number of cities that identify this particular risk. Main and last mitigation sectors are absolute to the total number of cities.

GROUP	Adaptation				
	RI (Mean)	Most adapted risks	%	Less adapted risk	%
A	45.0%	Drought	77.8	Air quality	0
		Food quality	75	Sea level rise	0
B	37.9%	Water quality	80	Air quality	0
		Drought	75	Heat waves	20
C	58.8%	Flooding	95.5	Typhoons/High wind	0
		Drought	87.5	Storms and heavy rain	0
D	60.6%	Air quality	100	Sea level rise	0
		Flooding	80	Wildfires	0

Table 6-2 RI and most and less adapted risks by KG zone [own]

GROUP	Mitigation				
	MI (Mean)	Main mitigation sectors	%	Last mitigation sectors	%
A	36.5%	Energy supply	77	Education	31
		Transportation	69	Waste management	38
B	32.7%	Energy supply	71	Waste management	43
		Buildings and industry	71	Green landscape	43
C	66.7%	Energy supply	96	Green landscape	52
		Transportation	92	Education	60
D	66.2%	Buildings and industry	100	Education	20
		Transportation	100	Green landscape	60

Table 6-3 MI and main and last mitigation sectors by KG zone [own]

6.3. Comparison between GDP per capita groups

One of the hypotheses of the research consists of whether there is a correlation between GDP per capita and more mitigation and adaptation measures. Then, by sorting the 50 cities by GDP per capita and with the use of the resilience and mitigation indicator, some trends are identified.

6.3.1. Resilience Indicator

This study has calculated the resilience indicator for each city analyzed. Then, once organized by GDP per capita groups, it has been extracted the RI mean and standard deviation for each group. Table 6-4 shows the results of the RI mean for each group of cities sorted by GDP per capita, as well as its standard deviation:

GROUP	RI mean	Standard deviation
1	57%	20%
2	43%	24%
3	59%	29%
4	55%	21%

Table 6-4 RI mean and standard deviation by GDPpc group [own]

On the other hand, the comparison of the 50 cities sorted by GDP per capita does not explain a trend between the resilience indicator and GDP per capita, as figure 6-9 shows ($R^2 < 0.5$). Based on the 50 cities analyzed, there is not a significant relation between more GDP per capita and more resilience indicator, what means more risks identified and at the same time adapted by a city. Moreover, Figure 6-10 presents the RI for each of the cities analyzed. It shows the level of adaptation of each city. There are three cities (Moscow, Medellin and Monterrey) with a RI of 0%. This is due to the lack of local adaptation plans (Medellin and Monterrey) or the lack of harmony between risks adapted and risks identified (Moscow).

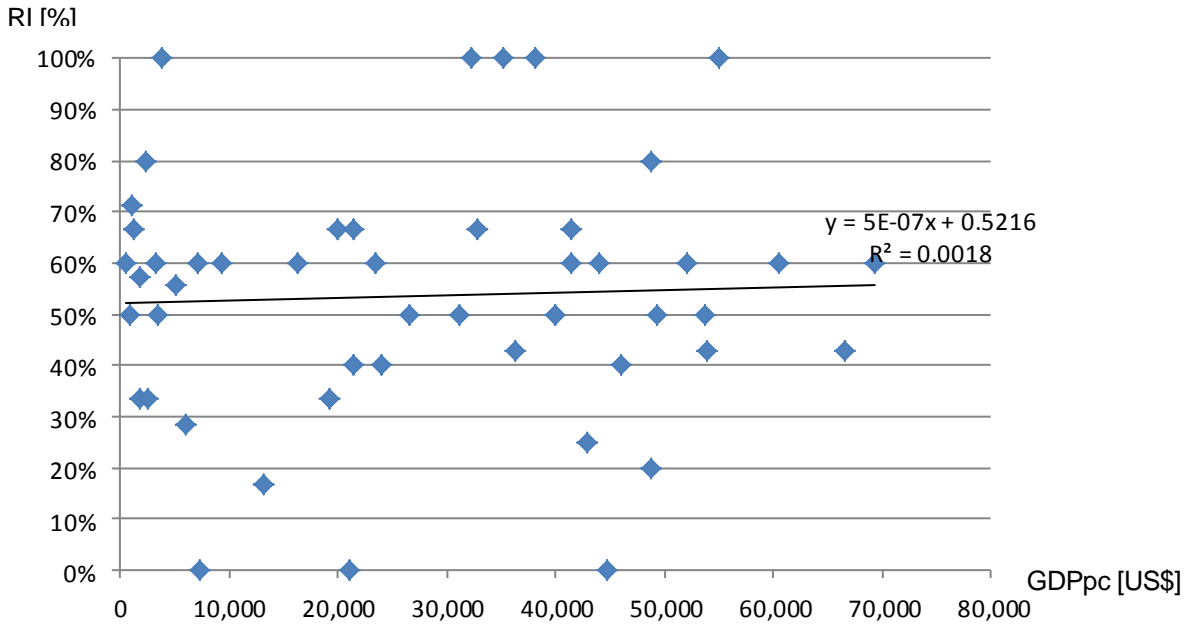


Figure 6-9 Relation between RI and GDPpc (50 cities) [own]

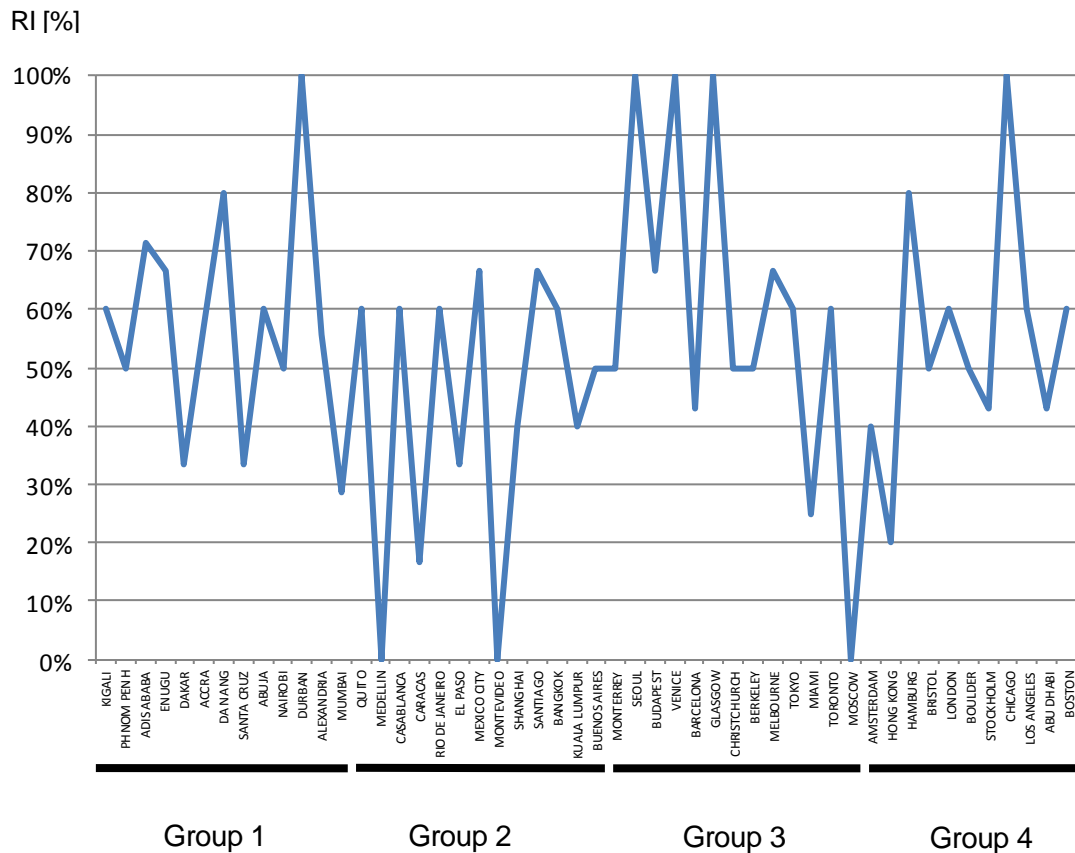


Figure 6-10 RI by city for each GDPpc group [own]

6.3.2. Mitigation Indicator

Furthermore, this study has obtained the mitigation indicator for each of the 50 cities analyzed. Then, it has been calculated the MI mean and standard deviation for each of the four different groups. Table 6-5 shows the results of the MI mean for each group of cities sorted by GDP per capita, as well as its standard deviation:

GROUP	MI mean	Standard deviation
1	34%	26%
2	49%	25%
3	68%	15%
4	68%	14%

Table 6-5 MI mean and standard deviation by GDPpc group [own]

On the other hand, the comparison of the 50 cities sorted by GDP per capita suggests a trend between the mitigation indicator and GDP per capita. Figure 6-11 shows the relation between this two indicators based on the 50 cities studied, and it draws a trend that as more GDP per capita a city has, more mitigation measures they tend to implement. However, these results suggest instead of give a statement. $R^2=0.3186$ (lower that 0.5), and therefore this value is not high enough to guarantee the statement and strongly affirm the relation. Moreover, Figure 6-12 presents the MI for each of the cities analyzed. It shows the level of preparedness in the long term (reducing emissions) of each city. There are three cities (Da Nang, Santa Cruz and Casablanca) with a MI of 0%. This is due to the lack of local mitigation plans or strategies.

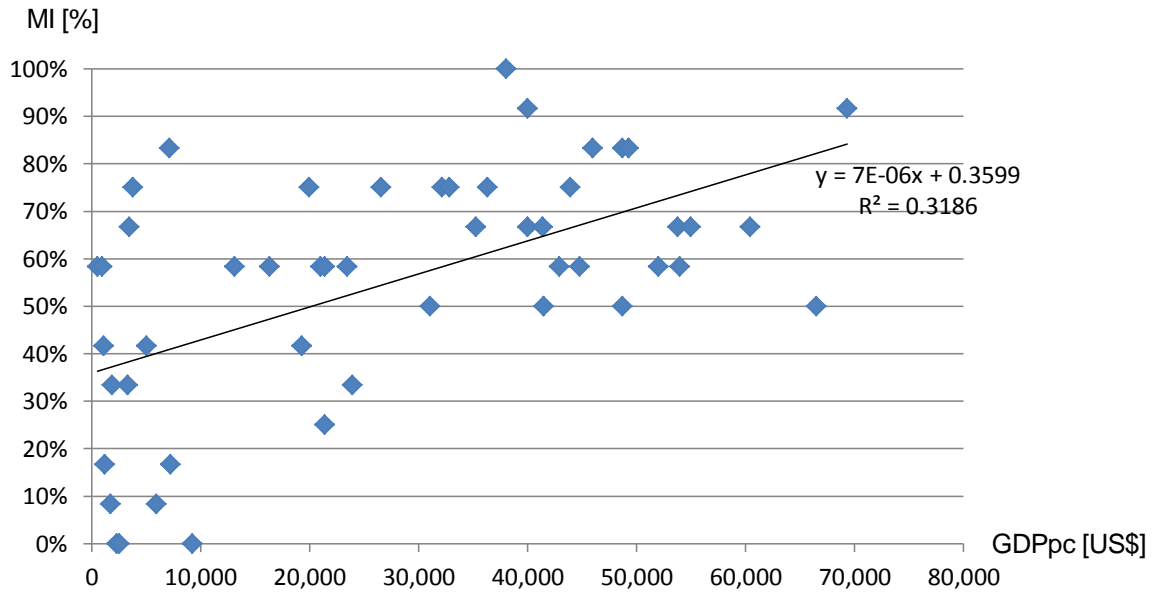


Figure 6-11 Relation between MI and GDPpc (50 cities) [own]

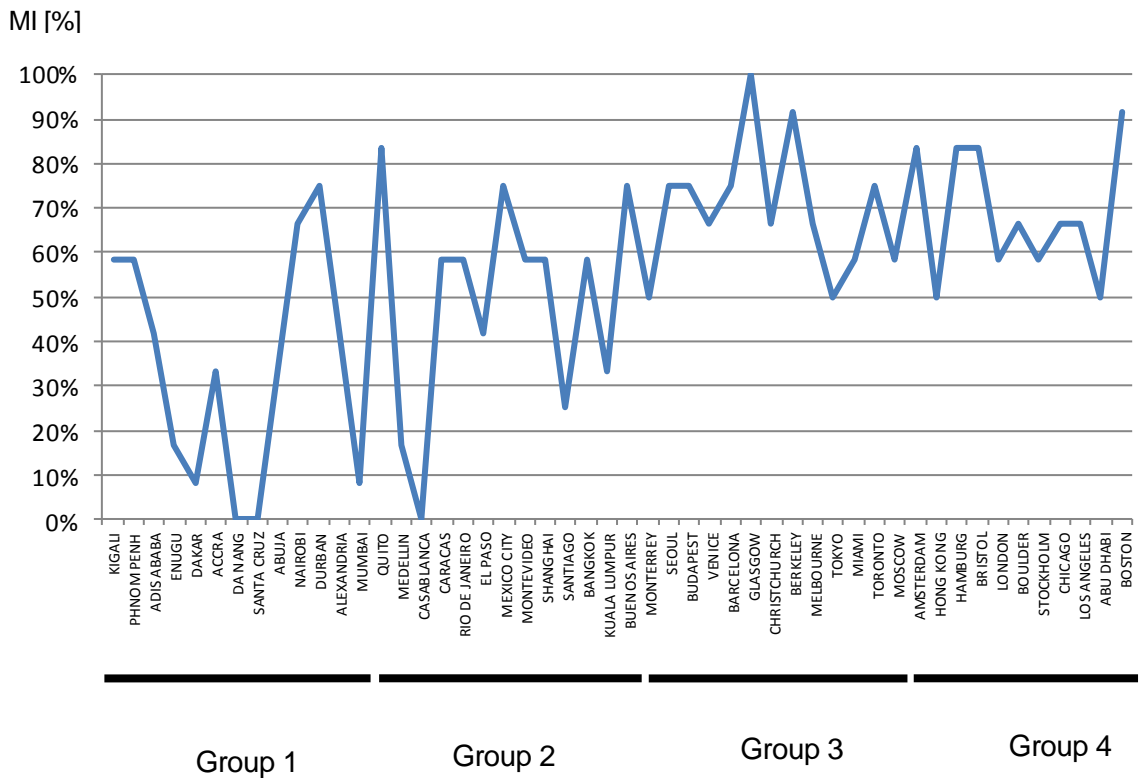


Figure 6-12 MI by city for each GDPpc group [own]

6.4. Other results

6.4.1. Before 2010 vs After 2010

This study made a comparison between CAPs created and published before 2010 and after 2010 for those cities belonging to KG climate classification group C. The 78% of the cities with a CAP published before 2010 are coastal, whereas the 75% of cities with a CAP published after 2010 are also coastal. That enables the comparison to be done. This study has extracted the risks identified and noticed the difference of concern between CAPs issued before and after 2010. Figure 6-13 presents this difference between risks identified before and after 2010 in order to prove the existence of knowledge sharing. Based on the 25 cities belonging to KG group C, CAPs published before 2010 tended to identify sea level rise (66.7% of CAPs) more often than after 2010 (56.3% of CAPs). Contrary, CAPs published after 2010 tend to identify air quality as a risk (37.5% of CAPs) more often than before 2010 (11.1% of CAPs). Finally, flooding (most common risk before and after 2010), heat waves and drought have always been risks identified by more of the 50% of the cities belonging to KG group C. The existence of knowledge sharing is further discussed in Chapter 7 (Discussion).

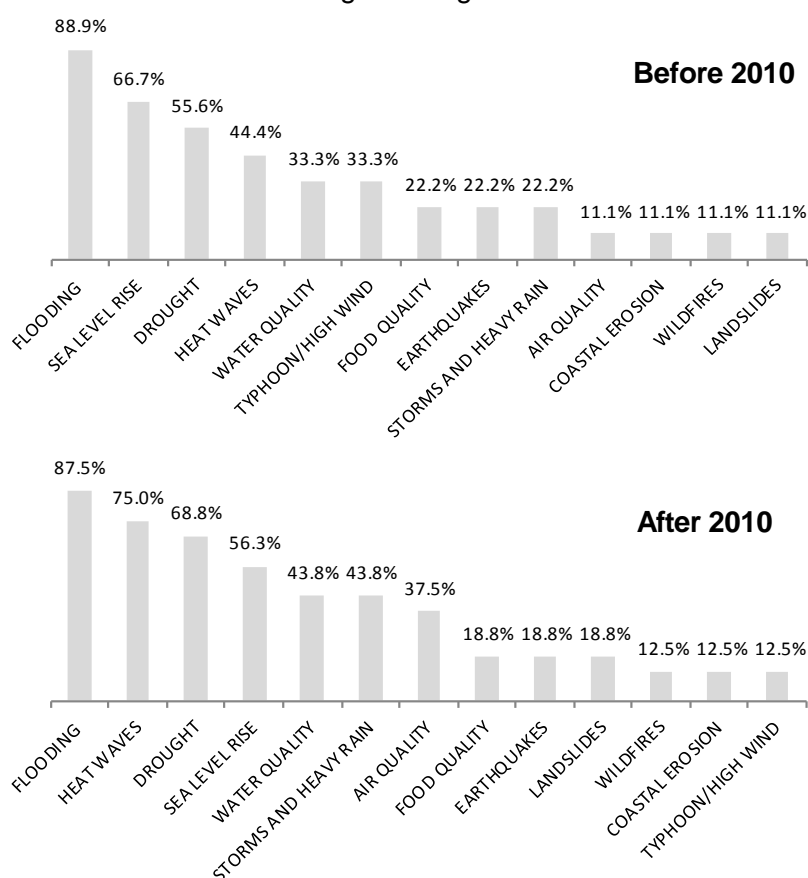


Figure 6-13 Risks identified before and after 2010

[own]

7. DISCUSSION

The results suggest a wide range of conclusions. First of all, by comparing 50 cities, this research identified that cities seem to give less consideration to green landscape and education sectors while mitigating climate change. Most of the cities focus on energy supply, buildings and industry and transportation sectors in order to reduce GHG emissions. If cities realize the importance of the green landscape and education sectors, CAPs can be improved and new measures can be implemented. On the other hand, the most common measures can be easily shared and improved by learning from the experience of cities that already implemented them. The fact that these measures are implemented by most of the cities suggests that this research found quite efficient practices. However, every city has to analyze these practices and see whether or not they are the most suitable ones for them.

Through the comparison between the risks identified by all the cities, the results come up with a thought. Correlated risks caused by similar hazard are differently identified as a potential risk. Flooding and storms and heavy rain are risks caused by the increase of rainfall intensity however, while flooding is identified by the 92% of the cities, storms and heavy rain is only identified by 38% of the cities, which suggests that cities are focusing on the main risks already identified by other cities (which are flooding, health, heat waves and drought) sometimes in spite of looking at their own needs. Cities should understand learning from others as a way of improving, complementing, completing and updating their own information. Therefore, this example means that cities still have to develop their own strategies to address climate change through the most efficient and coherent way.

By organizing by KG climate zone some suggestions can be extracted. In all four groups of cities, the four main risks are identified by more than the 50% of the cities. This suggests that cities with similar climate conditions face similar risks, and enhances the comparison between their plans so as to build new measures together and improve the ones that already exist. As an interesting reflection based on the results, group A has a ratio of 5,54 risks identified per city, group B of 5,0 risks identified per city (lower than category A), group C of 4,8 risks identified per city and finally group D of 4,6 risks identified per city. Therefore, these results suggest that cities belonging to group A are the most exposed to climate change (it could be from other causes, but the findings of this research are exclusively based on the results of the

cities analyzed), followed by group B and group C. On the other hand, cities belonging to group D show that they are the less exposed to risks.

The study has calculated both the resilience and mitigation indicator per each KG climate groups. KG group B seems to be the most vulnerable one, with the lowest ratio for RI and MI. All the KG zones show their concern about drought, flooding, air quality and sea level rise. However, the results suggest that drought and flooding are the most adapted risks by most of the KG zones, whereas air quality and sea level rise are the ones with less adaptation measures. On the other hand, the study suggests that energy supply and transportation are the two most popular mitigation sectors for most of the KG climate zones, whereas education and green landscape need more support in order to become significant while facing climate change.

On the other hand, by sorting cities by GDP per capita and analyzing the RI and MI for each of the groups, some trend are identified. As the results show, there is a limitation concerning the standard deviation for the measures. This indicator is high for each group and for both the resilience and mitigation indicator. Therefore, conclusions could not be extracted taking into account the high value of the standard deviation. However, in order to do a first approximation and in order to identify some trend, the authors concluded with a linear regression of first MI and GDPpc and second RI and GDPpc. This regression confirms that there is no direct relation between GDP per capita and the RI, therefore it is not true that more GDP per capita involves more resilience and adaptation measures for a city. This is a suggestion, as there have been analyzed only 50 cities worldwide. One of the reasons why there is not a relation between these two indicators may be the high level of concern to adaptation by underdeveloped cities, finding climate change risks as a big and main threat to them. Finally, group 2 is the one with a lowest RI mean (43%). Particular cities with a low RI can learn and share knowledge with other resilient cities, and start increasing resilience. On the other hand, the results for the MI suggest that there is a direct relation between this indicator and GDPpc, as the value of the R^2 is equal to 0,31. This value is not high enough to make a strong statement, but it is high enough to suggest that this relation may exist. As a note, this relation may be at the same time influenced by other external features like political situation, as it is known that mitigation is also a political-related issue. To conclude, the results of this part are a way of enhancing collaboration between cities. Cities with similar GDP per capita (and cities belonging to the same group) could learn from each other by sharing their mitigation

measures, as it is shown the relation between MI and GDP per capita. Also, cities with low MI values can realize the need of working on reducing greenhouse gas emissions and therefore reducing climate change impact in the long term.

Finally, by organizing KG group C cities between CAP publication dates, there has been noticed some identifying risks trends, as cities with CAPs issued before 2010 tend to be more concerned about sea level rise (66,7%) instead of air quality (11,1%), drought (55,6%) and heat waves (44,4%), whereas cities with CAPs issued after 2010 are less concerned about sea level rise (56,3%) and more concerned about air quality (37,5%), heat waves (75%) and drought (68,8%). Conclusions such as the difference of concern about sea level rise would not be significant if the percentage of coastal cities with CAPs before 2010 and after 2010 differed. The study guarantees that the 78% of the cities with CAPs before 2010 analyzed are coastal. On the other hand, the 75% of the cities with CAPs after 2010 analyzed are coastal. Therefore, conclusions related to the risk of sea level rise are significant. Sea level rise was identified as the second main risk by the cities with CAPs published before 2010. However, it is identified as the fourth main risk after 2010. Air quality was, on the other hand, identified as a risk before 2010 by the 11,1% of the cities. This same risk was identified by the 37,5% of the cities after 2010. That suggests the influence of sharing knowledge and information as a way of identifying similar risks between cities and following a common trend between them. The study suggests, therefore, historical evidences of sharing knowledge between cities.

8. PROJECT PLANNING AND ECONOMIC VIABILITY

8.1. Gantt diagram

Before explaining the economic viability, the cost of the project and the hours spent in order to elaborate this thesis, it is necessary to see how the time has been organized.

Following, the Figure 8-1 consists on a Gantt diagram, which shows in weeks each of the project stages, as well as the duration of each phase.

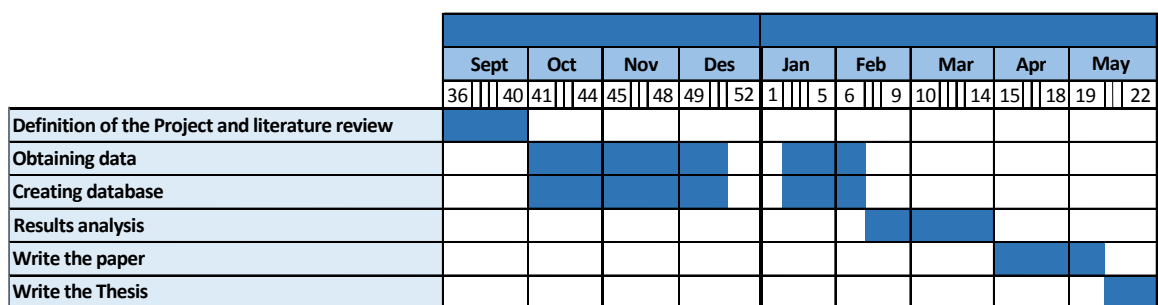


Figure 8-1 Gantt diagram of the elaboration of the project [own]

Therefore, as it has been shown, the total duration of the elaboration of the project has been nine months (which is equivalent to 34 working weeks).

8.2. Economic viability

The following financial budget estimation details the total cost of the elaboration of this thesis. The budget is divided into work (hours) dedicated to research and prepare the thesis, the material costs and the amortization costs of the tools used during the elaboration of it.

8.2.1. Work hours

The main cost of this project is the amount of hours needed in order to first understand the tools used and climate change concepts, then obtain and analyze the data and finally elaborate the results of the study. The tasks are basically engineering, except for the writing of the report. The hourly rate of the work done has been calculated considering that a recent graduated engineer has a 30\$/hour base salary in the United States.

The tasks elaborated can be divided as follows:

1. Research (Literature review and climate change issue understanding and Self-learning): 120h
2. Getting the data from online sources: 240h
3. Creating an excel database with all the data: 240
4. Obtaining and analyzing results using the excel database: 240h
5. Writing the paper: 160h
6. Writing the thesis: 80h
7. Meetings (2 hours per week): 64h

8.2.2. Material and general costs

Second, the financial budget also includes the material and general costs that the execution of the project has involved. These costs include phone and internet line, electricity, office rent, desk material and the cost of the trips (one round trip Barcelona-Colorado).

8.2.3. Amortization

Finally, the financial budget includes the amortization of the tools that have been used for the thesis elaboration. The amortization of the tools is especially intangible assets (licenses

computer) as well as tangible goods (various office supplies). Since the thesis was made in a 9 months period, the depreciable assets are calculated with the proportional cost.

The depreciable assets for the project are:

1. ArcGIS License, (Student version with 100\$ of annual cost maintenance.)
2. Microsoft Office 2013 License (Unlimited use and 100\$ cost. 4 years amortization).
3. HP Computer (Cost of 1000\$, 5 years amortization).

8.2.4. Summary tables and total cost of the project

The following tables summarize the costs taken in the development of services (Table 8-1), material and general costs (Table 8-2), amortization costs (Table 8-3) and the total cost of the project (Table 8-4).

Concept	Amount of time (hours)	Unitary cost (\$/hour)	Total (\$)
Engineering		30\$/hour	
Administrative		20\$/hour	
Define research and literature review	120h	30	3.600
Obtaining data	240h	30	7.200
Creating database	240h	30	7.200
Obtaining and analyzing results	240h	30	7.200
Writing the paper	160h	20	3.200
Writing the thesis report	80h	20	1.600
Meetings	64h	30	1.920
TOTAL			31.920(\$)

Table 8-1 Engineering and administrative costs of developing this project [own]

Concept	Amount of time (months)	Unitary cost (\$/month)	Total (\$)
Phone and internet	9	15	135
Electricity	9	30	270
Office rent	9	200	1.800
Desk material	9	8	72
Trips (1RT Barcelona-Colorado)	-	-	1.200
TOTAL			3.477(\$)

Table 8-2 Material and general costs to develop this project [own]

Concept	Initial cost	Amortization on timeframe	Annual amortization (\$/year)	Amortization cost (\$)
ArcGIS License	100\$/year	1 year	100	75
Microsoft Office 2013 License	100\$	4 years	25	19
HP Computer	1500\$	5 years	300	225
TOTAL				319(\$)

Table 8-3 Amortization costs of the elements used to develop this project [own]

Concept	Cost (\$)
Engineering Cost	31.920(\$)
Material and general cost	3.477(\$)
Amortization cost	319(\$)
TOTAL	35.716(\$)
No tax rate (International transaction)	35.716(\$)
TOTAL after tax	35.716(\$)

Table 8-4 Total cost after tax of carrying out this master thesis [own]

The total cost to develop this thesis, taking into account that there are no taxes for being an international project, would approximately be 35.716 US\$. This total cost proves the importance of having an intern research team in the department, as a project with this features would have a budget of three times the actual budget if it had been subcontracted.

9. ENVIRONMENTAL CONSIDERATIONS

This research is directly focused on the protection of the environment. By adapting to climate change induced risks, cities will increase their resilience against unexpected hazards related to the climate. On the other hand, by mitigating climate change cities are reducing changes in climate in the long term, what will be beneficial for the Globe. By doing this research, the authors believed that the outputs of the thesis can be very useful for cities, and therefore will help to Globe's environment.

Therefore, this research is environmental friendly and aims to be a help for the future of urban areas and, consequently, for the future of our Planet.

CONCLUSIONS

Organizations can learn from their customers, employee's experiences and from the environment in which they develop, learning from diversity and discussion techniques so as to achieve a shared thinking or vision and enhance the teamwork. This way of learning can be extrapolated to a city government point of view. This paper presents an illustrative example of how cities are dealing with climate change, and how sharing knowledge can be a useful way for building CAPs. Inter-organizational learning (and particularly knowledge sharing) has the potential to take an important role in the future of CAPs, helping to create more efficient and effective plans while reducing time and money to city planners, but always being conscious of its limitations.

Both this research and other literature review suggest that there is a relation between CAPs and inter-organizational learning. Results show that cities are mostly concerned about the same risks and they implement similar measures, which guides to a possible conclusion: They are influenced by other cities' routines and actions based on global inter-organizational learning. Organizations are seen as learning by encoding inferences from history into routines that guide behavior. Within this perspective on organizational learning, learning not only from direct experience, but also from the experience of others, is a current fact happening between cities. There is not a true statement concerning organizational learning neither as a possibility of a form of intelligence nor a limitation for cities to develop themselves and become more resilient.

On the one hand, sharing knowledge and information between cities enables them to recognize and adapt the most efficient measures in order to face climate change. Therefore, cities optimize their time and money not trying to solve problems that other cities may have already solved. Mitigation measures can be shared between cities with similar economic wealth, finding out the most efficient ones for each sector. Risks can be compared between cities belonging to the same climate zone as a way of knowing which ones have similar features and enhancing to start working together. Adaptation actions can be shared between cities with similar features and risks in order to implement the most efficient and successful measures. All of this while achieving money and time savings for city planners.

On the other hand, there is always a need for own research, deepening knowledge on own necessities and risks, not only basing everything on other cities experiences. In spite of being knowledge sharing very useful to implement new ideas for adaptation and mitigation based on other CAPs, every city is different and every city has its own risks, necessities and potential efficient solutions. Therefore, in spite of being a really useful tool for developing Climate Action Plans and initiatives to face climate change, global organizational learning and specifically knowledge sharing must not be the only way of learning. Cities should not focus exclusively in other cities experiences since each city has different needs, but they should definitely compare and try to adapt other cities best actions to increase efficiency and build better climate change plans based on their own needs. Moreover, “Even within a single organization, there are severe limitations to organizational learning as an instrument of intelligence. Learning does not always lead to intelligent behavior. The same processes that yield experiential wisdom produce superstitious learning, competency traps, and erroneous inferences” (Levitt & March, 1988).

To conclude, collaboration between cities will be an efficient tool for improving CAPs. Climate change is a global problem that can be tackled more easily by learning and collaborating between urban areas, which have the potential to create and improve CAPs by leveraging and using existing plans and knowledge. However, cities must be aware of the need of own research to find out their own necessities and risks. Then, the combination between acting based on own findings and sharing experiences and therefore learning from other cities with similar features is the best strategy to address climate change in a local scale.

ACKNOWLEDGEMENTS

In this section I would start expressing my gratefulness to the iClicS (Institute of Climate and Civil Systems at the University of Colorado at Boulder) team.

First, to Professor Paul Chinowsky for giving me the opportunity to work for his team, be part of it and for his helpful recommendations during the development of this research work.

Second, to PhD student Xavier Espinet, for trusting before knowing me and helping me with all the paperwork needed before my arrival to the US.

Moreover, the project could not have been completed without the help and support of both Xavier Espinet and Amy Schweikert, PhD Candidates in the University of Colorado at Boulder, School of Civil Engineering. I would like to thank both of them for the time spent in both the preparatory work to my arrival at The University of Colorado at Boulder and the months of implementation of the project. I greatly appreciate their disposition to give his time and dedication.

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Finally, I would like to thank Professor Lázaro Vicente Cremades for her willingness to help with this project and guiding the thesis from the Universitat Politècnica de Catalunya. Also, without his support and recommendations from Barcelona this project could not have been completed.

ACHIEVEMENTS

During the elaboration of this project, the University of Colorado Boulder hosted the annual Global Development & Education Symposium, and the author exposed a poster in order to present this project. There, the author could explain and discuss with all the visitors about this project and the issue of climate change.

Moreover, the author, together with the PhD students Xavier Espinet, Amy Schweikert wrote a paper that will be published on the department's website (<http://www.resilient-analytics.com/>) as a white paper. The paper includes all the methodology created and the results extracted from the thesis. It also aims to encourage cities build resilience together by enhancing sharing knowledge.

To conclude, the research had to be presented at the 2015 Engineering Project Organizations Conference - Engineering Growth that took place on June 24-26 in Edinburgh, Scotland. Finally, due to unexpected issues the team could not assist the conference.

FUTURE RESEARCH

This section presents studies related to the continuance of the research undertaken, that could be made in the future.

On August 2015, iCliCS, who investigates the impact of climate changes on infrastructure elements through stressor-response methodologies to assist policy makers and infrastructure professionals in making investment and design decisions, decided to use the outputs of this project in order to start a market research. The department aims to grow internationally, find new clients and open new markets around the world. This paper provides information about the needs and level of development of 50 cities worldwide, as well as where the holes and opportunities are for each of the cities analyzed.

On the other hand, this project could be continued by two ways. First, analyzing new cities and creating a bigger database could be useful with the aim of completing with more cities the 100 Resilient Cities project pioneered by the Rockefeller Foundation. Second, with the data of the 50 cities analyzed, the less resilient cities could be deeply analyzed and more specific outputs could be offered to their governments.

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COMPLEMENTARY REFERENCES

This section provides a list of websites and interesting links (Climate Action Plans and key mitigation and adaptation documents) from where data have been obtained by city. As of March 20th 2015, the following cited websites were consulted and were active:

Phnom Penh (Cambodia):

- [1] <http://www.kh.undp.org/content/dam/cambodia/docs/EnvEnergy/CCCAPProjects/Cambodia%20climate%20change%20strategic%20plan%202014-2023.pdf>

London (UK)

- [2] <https://www.london.gov.uk/priorities/environment/publications/managing-risks-and-increasing-resilience-the-mayor-s-climate>

Hong Kong (China)

- [3] <http://www.epd.gov.hk/epd/english/top.html>
[4] http://www.deltacities.com/documents/CDC_volume_3_Resilient_Cities_and_Climate_Adaptation_Strategies.pdf

Kigali (Rwanda)

- [5] <http://www.eldis.org/go/home&id=61821&type=Document#.VeTSoPntmko>

Enugu (Nigeria)

- [6] http://www.area-net.org/fileadmin/user_upload/AREA/AREA_downloads/AREA_Conference_09/Presentations/Nigeria_RENEWABLE_ENERGY_MASTERPLAN.pdf

Seoul (South Korea)

- [7] http://www.mcrit.com/ADJUNTS/ciutats_sostenibles/seul.pdf
[8] <http://www.iwahq.org/ContentSuite/upload/iwa/Document/session%20a%2001.pdf>

Stockholm (Sweden)

- [9] http://www.astra-project.org/sites/download/ASTRA_Espoo_Gustafsson.pdf
[10] http://www.mc-4.org/uploads/1/2/1/4/12146463/adapting_to_climate_change_in_stockholm.pdf

Moscow (Russia)

- [11] <http://www.ci.moscow.id.us/records/City%20Reports/ghgbaselinereport.pdf>
[12] <http://greenash.net.au/thoughts/2013/03/natural-disaster-risk-levels-of-the-worlds-largest-cities/>

Chicago (USA)

- [13] http://www.chicagoclimatereaction.org/pages/renewable_energy_sources/13.php

Toronto (Canada)

- [14] <http://trca.on.ca/dotAsset/81363.pdf>
[15] <http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=78cfa84c9f6e1410VgnVCM10000071d60f89RCRD>
[16] http://www1.toronto.ca/City%20of%20Toronto/Environment%20and%20Energy/Our%20Goals/Files/pdf/toronto_cc_adapt_actions.pdf

Mexico City (Mexico)

[17] http://www.sma.df.gob.mx/sma/links/download/archivos/paccm_summary.pdf

[18] <http://cityclimateleadershipawards.com/mexico-city-proaire/>

[19] <http://www.unfpa.org/webdav/site/global/shared/images/publications/2013/The%20Demography%20of%20Adaptation%20to%20Climate%20Change.pdf>

Addis Ababa (Ethiopia)

[20] http://www.academia.edu/4856124/Climate_change_vulnerability_and_adaptability_in_an_urban_context_A_case_study_of_Addis_Ababa_Ethiopia

[21] <http://www.idrc.ca/EN/Resources/Publications/Pages/ArticleDetails.aspx?PublicationID=991>

[22] http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1232059926563/5747581-1239131985528/WBSocProtec_Final.pdf

[23] [http://ifro.ku.dk/english/staff/?pure=en%2Fpublications%2Fefficiency-of-parks-in-mitigating-urban-heat-island-effect\(dceed8f0-f9f1-4adf-8247-05a2b058aaa4\)%2Fexport.html](http://ifro.ku.dk/english/staff/?pure=en%2Fpublications%2Fefficiency-of-parks-in-mitigating-urban-heat-island-effect(dceed8f0-f9f1-4adf-8247-05a2b058aaa4)%2Fexport.html)

[24] <http://unfccc.int/resource/docs/napa/eth01.pdf>

[25] http://www.afdb.org/fileadmin/uploads/afdb/Documents/Environmental-and-Social-Assessments/Multinational_Momabasa_Nairobi_Addis%20Ababa%20Corridor%20II%20%20ESIA%20Summary.pdf

Los Angeles (USA)

[26] <http://c-change.la/pdf/AdaptLA%20Fact%20Sheet.pdf>

Berkeley (USA)

[27] <http://www.cityofberkeley.info/ContentDisplay.aspx?id=70986>

[28] http://www.cityofberkeley.info/uploadedFiles/Planning_and_Development/Level_3_-_Energy_and_Sustainable_Development/Tree%20gain%20CAP.pdf

Santiago (Chile)

[29] https://www.ufz.de/export/data/403/46050_PlanAdaptacion_121126.pdf

Barcelona (Spain)

[30] http://issuu.com/gerard.pol/docs/pecq_exec_sum/5

[31] https://w110.bcn.cat/MediAmbient/Continguts/Vectors_Ambientals/Energia_i_qualitat_ambiental/Documents/Traduccions/PECQ_english_def01.pdf

[32] <http://www.stream-project.eu/sites/default/files/David%20Sunjer%20-%20Prepared%20Dublin2012%20-%20Barcelona%20v1.pdf>

[33] http://canviclimatic.gencat.cat/web/.content/home/politiques/politiques_catalanes/ladaptacio_al_canvi_climatic/proces_escacc/docs/escacc_versio_juny_2.pdf

Casablanca (Morocco)

[34] http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Resilient_Cities_2011/Presentations/F/F4_Multiple_Presenters.pdf

Durban (South Africa)

[35] <http://www.dccs.org.za/wp-content/uploads/2013/02/DCCS-Initial-Stakeholder-Consultation-Report-.pdf>

[36] <http://www.dccs.org.za/wp-content/uploads/2013/02/DCCS-Draft-Vision-Report.pdf>

Nairobi (Kenya)

[37] <http://cdkn.org/project/from-planning-to-action-in-kenya/>

[38] http://cdkn.org/wp-content/uploads/2012/04/National-Climate-Change-Response-Strategy_April-2010.pdf

[39] <http://cdkn.org/wp-content/uploads/2013/03/Kenya-National-Climate-Change-Action-Plan.pdf>

[40] http://www.kccap.info/index.php?option=com_content&view=article&id=27

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