Climate Change Adaptation Plans in Latin American Cities

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ABSTRACT: Climate change will be a reality that cities must face in the coming decades. The magnitude of the impacts will depend on the capacity of cities to reduce their vulnerability and expand their capacity to cope with these changes. In this way, Latin American cities are likely to be seriously affected by climate change because they have a high rate of urban poverty, lack of appropriate infrastructure, as well as a significant number of people living in slums located on environmentally fragile sites. This research aims to analyze qualitatively the current state of the art of adaptation of cities in the Latin American scenario by identifying the cities that have already designed an Adaptation Plan, and the level which this document addresses adaptation issues, such as reduction of vulnerabilities in urban areas and improvement of adaptation capacity. Therefore, this paper will firstly conduct a literature review related to climate change adaptation, regarding concepts like vulnerability, risk and adaptive capacity considering the Intergovernmental Panel on Climate Change concepts (IPCC, 2014); and secondly, it will examine the Adaptation Plans, together with scientific articles related to them. Finally, it will discuss the level of Climate Adaptation aspects through those selected plans. This work is part of the research being developed as a Master's thesis.

Keywords *Climate Change, Adaptation Plans, Planning for Climate Change, Latin America adaptation plans.*

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1. INTRODUCTION

The warming of global temperatures is already considered an irreversible phenomenon that humanity must face in the coming decades. Among the expected effects will be an increase in average temperatures, a rise in average sea levels, changes in precipitation, and increasing intensity and frequency of extreme weather events such as hurricanes, heat waves, droughts, forest fires, among others. (IPCC, 2014). These will be hazards for sustainable urban development of cities, resulting in loss of human lives and ecosystems, damage to urban infrastructure and buildings, problems for the provision of urban services, etc. In addition, there is a need for cities to mitigate the factors that induce and negatively affect climate change, in conjunction with its adaptations to new climate realities. In this sense the idea of "adaptation" seeks to prevent or reduce future damage from various sources, as well as explore new opportunities and benefits to reduce poverty, improve of housing and provide of public services, technological advances and information, together with the improvement of urban governance. It is what is conceptually called adaptive capacity, which is the ability of people, institutions and ecosystems to adapt to these new climate scenarios (IPCC, 2014). Adaptation also contributes to improving urban resilience – the ability of social, economic and environmental systems to bounce back from dangerous disturbances, in way to return of an initial or improved function (IPCC, 2014, UN-HABITAT, 2014, Carter et al., 2015)

Climate change adaptation needs to be integrated holistically in urban planning and management in collaboration with society and stakeholders. Therefore, it is important to make citizens aware of risks that climate change can damage in the quality of life and human health, in natural ecosystems, and in social and economic systems. In addition, the propensity and magnitude of climate change impacts on natural and urban environmental will rely on negative characteristics of physical, socio-economic and environmental systems and receptors (IPCC, 2014, UN-HABITAT, 2014). Those characteristics can be called of vulnerabilities, and there are strongly influenced by institutional and economic dynamics (Adger et al., 2012). The adaptation approach seeks to reduce vulnerabilities, while enhance adaptation capacity (IPCC, 2014, UN-HABITAT, 2014).

Regarding the discussion above, the Latin American cities are in a delicate situation to face climate change. The region has been highlighted in worldwide context as the most urbanized region in the world (UN-Habitat, 2012), and, despite the advances of recent decades, the Latin American cities still have a high rate of urban poverty and bad education, lack of basic urban infrastructures and services such as water and sanitation, and housing shortage (Romero Lankao, 2007). In addition, the large amount of poor population living in slums in environmentally sensitive sites - such as hillsides, riverbanks and beaches - tend to be the ones most severely affected by climate change impacts, and the ones least able to cope with (Adger et al., 2012). Furthermore, the region lacks of prepared governances and long-term planning (Wamsler, et al., 2013, Romero-Lankao, et al., 2013).

In this sense, this article analyzes qualitatively the current state of Climate Change Adaptation Plans in Latin America large cities. The methodology used to achieve this aim consisted firstly in a literature review about the theory related to Climate Change and Adaptation Plans, followed by the identification of large Latin-American cities that have already drafted Adaptation Plans. Moreover, the cities Santiago de Chile (CHI) Bogotá

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(COL) and Mexico D.F. (MEX) were selected because they presented the most recent Plans. Those plans were analyzed by the following adaptation aspects: water management, protection of ecosystems, eco-urbanism/urban planning and development, green buildings, energy, urban mobility, waste management, adaptation of infrastructures, risk reduction, social and institutional capacity. Finally, a qualitatively and comparative analysis was made in order to understand the Latin-American adaptation scenario through those selected plans.

2. ADAPTATION PLANNING FOR CLIMATE CHANGE

In relation to all complexity and cross-cutting fields involved in climate change, the Adaptation Planning should focus on an integrated, participatory, values-based and strategic approach to be effective. This means that an Adaptation Plan should seek synergies to others policies, programmes and projects related to climate change that are in course, for example natural resource management plans, disaster preparedness programmes, sustainable urban planning and development, economic development plans, among others. As well, it is important to make smart choices regarding the use of available natural and economic resources when designing adaptation measures, it is necessary to always seek co-benefits measures and efficient spending. Furthermore, the planning should embrace important community values, such as urban sustainable development and poverty reduction. In this sense the engagement of stakeholders, city practitioners and leaders in planning and monitoring of actions are also a crucial issue to achieve in an Adaptation Plan (UN-HABITAT, 2014, Fussel, 2007, Ribeiro, et al., 2009).

There are many definitions and characteristics of adaptation. In this paper, we use the concept of G.R. Biesbroek et al. (2010, 441p., apud Niang-Diop and Bosch, 2005) which define an Adaptation Plan as '.. .a general plan of action for addressing the impacts of climate change, including climate variability and extremes. It will include a mix of policies and measures with the overarching objective of reducing the country's vulnerability. Depending on the circumstances, the strategy can be comprehensive at a national level, addressing adaptation across sectors, regions and vulnerable populations, or it can be more limited, focusing on just one or two sectors or regions'.

The major scope of an Adaptation Plan contains four main areas: (1) assessment and management of impacts, risks and vulnerabilities; (2) integration climate change adaptation (and mitigation) into existing city plans, policies, programmes and planning process; (3) improvement of the social and institutional adaptation capacity (awareness, knowledge, skills and resources); (4) enhance cross-cutting relations among governmental institutions, third sector, academia and stakeholders (UN-HABITAT, 2014, Ribeiro, et al., 2009). In addition, adaptation frameworks should respect local characteristics, prioritize the main issues and treats for the city sustainable goals, be conscious of the life-cycle of planning, building and infrastructure (Carter et al., 2015).

The scope of a Climate Change Adaptation Plan should assess what will be the climatic differences between future and past scenarios. On the basis of this information, it will be possible to suggest what types of measures should be addressed in the plan (Fussel, 2007). Moreover, the approach of the Adaptation Plan can vary in robust hazards and

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impacts assessments, risk assessments, qualitative vulnerability assessments based on city practitioners and stakeholders experience and socioeconomic data, or a mix among all (GIZ, 2014, Ribeiro, et al., 2009).

The direction of the planning depends on the institutional capacity, political will, access of information and data, awareness and enrollment of stakeholders, as well with the level and complexity of vulnerability present in the city. The selection of strategies and adaptation measures should be aligned to the planning objectives, reduction of the urban risks and vulnerabilities, and the municipal economic funds. In this sense developing countries usually lack in resources, data and properly governances. Thus, it has been shown a satisfactory strategy the focus on reducing vulnerabilities measures, especially pro-poor, and solutions that bring multiple benefits to the city (GIZ, 2014, Adger et al., 2012).

Moreover, the arrangement of grey, green and blue measures has been presented a good opportunity to improve quality of life, social cohesion and health to urban environmental into the cities. Grey measures can be understood as actions in man-made infrastructures, like improvement or maintenance of dikes, sewerage and drainage systems. In contrast, Green and Blue infrastructures are measures based on natural process and re-naturalization of ecosystems, and can be opportunities to mitigate and adapt the externalities of urbanization in urban environment. The examples can be related to the flexible uses of water lands that protect from flooding as well as an open space for recreation and fresh air the cities; the use of green wall and roof to absorb the heat and improve quality of the city environmental, etc (Wamsler et al., 2013, Carter et al., 2015).

3. ADAPTATION PLANNING IN LARGE LATIN AMERICAN CITIES

Making a comparison between large cities in Latin America is challenging. Firstly, the cities are complex in their level of development, size of population, housing and urban services provisions, inequality, and political and institutional capacity (Krellenberg & Heinrichs, 2010). Regarding urbanization patterns, Latin-American cities present some similarities, such as the formation of large metropolitan areas, characterized by an extremely high population density growing at fast rate, and socio-economic and territorial inequalities (Hardoy & Romero Lankao, 2011). The region also presents a large urban sprawl associated with a highly speculative real estate market, which results in the expulsion of poor people from the inner city areas to occupy urban fringes and/or high-risk environmental sites without access to goods, urban services and infrastructure. As a consequence, the territorial distribution of the risks and impacts are unequal in the region, where the poor are the most sensitive to the impacts of climate hazards, and the least able to cope with them (Hardoy & Romero Lankao, 2011; UN-HABITAT, 2012, Adger et al., 2012).

Secondly, the cities are located in different climate zones and tend to face distinct climate changes impacts. By the same token, IPCC's prediction models foresee that the major trends for the region will be an increase in average temperatures of up to 6.7 ° C by the end of the century, in addition to a variation of average precipitation levels (IPCC, WGII, Cap 27, 2014). The urban impacts will be most related to changes in precipitations levels,

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resulting in flooding, landslides, water supply problems, impacts on ecosystems, human health, among others. Moreover, the Latin American urban areas will have to face problems related to air pollution on health (Romero Lankao, 2007).

Regarding large Latin American cities, only eight big cities have already developed their Adaptation Plans, such as São Paulo (in 2009), Montevideo (in 2010), Buenos Aires (in 2010), Lima (in 2012), Quito (in 2012), Santiago (in 2012), Bogota (in 2012) and Mexico City (in 2014). Overall, those plans deal with adaptation and mitigation concerns, presents greenhouse gases inventory of emissions, as well as with impact or top-down assessments supported by scientists, and vulnerability assessments (Hardoy & Romero Lankao, 2011).

This research study will analyze and compare qualitatively the three most up to date adaptation plans elaborated in the cities of Santiago, Bogotá and México D.F.

a. Santiago de Chile

Santiago is the capital of Chile and its metropolitan region represents an agglomeration of more than six million inhabitants. It is located in a subtropical central zone in between two Andean mountain ranges. The climate is dry in general, with an annual average temperature of 14 ° C and precipitation of 312.5 mm (Krellenberg et al, 2014). The major trends expected as a result of climate change will be an increase in the average temperature of 2.5°C by to 2065, and 3-4 º C from 2071 to 2100, and a decrease of more than 40% in rainfall by the same period. Moreover, the number of days with temperatures above 30°C is expected to increase to up 30% in urban areas. Additionally, the number of days below zero degrees Celsius is also expected to decrease. The impacts of Climate Change will prolong dry periods and generate a water demand for human, agricultural, industrial and energy supply, addition to extreme situations of water shortages, related to melting snow in the Andes glaciers. (PACCRMS, 2012, Krellenberg et al, 2014).

The city developed its Adaptation Plan for the metropolitan region (PACCRMS) in 2012. It is a product of a broad research project known as Climate Adaptation Santiago (CAS), which primarily focuses on adaptation. Moreover, first, it had a top-down approach based on the interdisciplinary work of fifteen social, natural and engineering scientists from two Helmholtz Center, in Germany, and from the University of Santiago de Chile. Second, it engaged stakeholders from both public and private sectors, civil society and academia to select and design robust adaptation measures for the city (Krellenberg, Katrin, 2014).

b. Bogotá

The Colombian Capital, Bogotá, is a large city with a population of more than 7 million inhabitants (DANE, 2015). It is geographically located on the equatorial belt, and it has a climate characterized by an average annual temperature of 13.5°C, and precipitation levels varying between 600mm and 1,200mm. The city climate is also affected by the intertropical convergence zone and trade winds, as well as by extreme weather events such as the El Niño and La Niña phenomena (Krellenberg et al, 2014). Regarding vulnerability, Bogotá deals with big issues like its spatial and income inequality, and its expected population growth, especially the Cudinamarca area which is expected to experience a population growth of 260% by 2050 (PDAMVCC, 2014). The hazards expected as a result of Climate Change will cause an upward trend in average temperature

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between 2 and 4 ° C by 2070, in addition to a reduction of rainfall levels in specific areas of the city by more than 30%, such as the Bogotá river basin where the city is located (Krellenberg et al, 2014). In contrast, the rainfall on the other side of Bogotá in the river basin – where the grater water flows are located – will increase. As a consequence, the major impacts expected are an increase in vector-diseases such as malaria and dengue; desertification, altering agriculture, erosion and flooding, habitat changes and potential loss of biodiversity, affecting ecosystems - especially for the Andean and sub-Andean forests, wetlands and high Andean xeric shrublands – and finally changes in the production of hydro energy and water supply (PDAMVCC, 2014).

This research focuses on the document "Plan Distrital de Adaptación y Mitigación a la Variabilidad y el Cambio Climatico"(PDAMVCC, 2014), developed by the Environment Municipal Office (Secretaría Distrital de Ambiente) in 2014. The Plan´s approach is both Adaptation and Mitigation, and aspects of reducing vulnerabilities and enhancing adaptation capacities. The city´s main vision is to transform Bogota into a green territory, designed around the water sources, and collaborative with its neighboring cities. Moreover, Bogota will also be adapted and mitigated for the impacts of climate change, and the citizen quality of life and the ecosystems environmental health will be improved by 2038.

c. Mexico D.F.

The capital of Mexico is a Federal District divided into 16 delegations, which occupying a land area of 1,495 km^2. The city is one of the biggest in the world, with a population of 8,851,080 inhabitants (in 2010) and its metropolitan area approximates around 19 million inhabitants. Its geographic location is inside the Valley of Mexico, situated at an altitude of 2,240 meters above sea level, and built above three river basins: Panuco, Balsas and Lerma Santiago. In addition, the territory of Mexico D.F. is composed of 41% by urban areas and 59% by conservation land. The city has a predominantly humid temperate climate (87%), however it has a few regions of semidry climate. The average annual temperature ranges between 10 ° C to 18 ° C. The annual rainfall can reach up to 1,400 mm in the humid temperature region, and 600 mm in the semidry region (UNAM, 2013 apud ELACCM, 2014). The climate change scenario predicted will encompass an increase in average temperatures, which can reach up to 4°C by 2080, as well as an increase in precipitation level of 20%. Extreme climate events, such as droughts and heat waves, will also be expected (KRELLENBERG et al, 2014). The major impacts related will be related to changes in the rainfall seasonality, which results in floodings, landslides, agricultural problems, development of disease vectors or pests, changes in biomes and biological biodiversity, shortage of water resources and hydro power for electricity, among others. The major risk will be related to water supply and contamination of water resources as an effect of the increase in population (ELACCM, 2014).

Its Adaptation Plan (ELACCM) was developed in 2014 and encompasses both Mexico City and its metropolitan region. The document has a broad approach to Adaptation, Mitigation and Resilience, in addition to the improvement of adaptation capacities. The main objective is to promote quality of life and sustainable development on the basis of low carbon economic development, as well to engage society and the government in order to mitigate climate change and prevent risks (ELACCM, 2014). Furthermore, the document

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was designed by the Mario Molina energy and environmental research center and the Environment Municipal Office.

4. COMPARATIVE ANALYSIS

In this research, the adaptation plans of Santiago de Chile, Bogota and Mexico D.F. were analyzed for their most important aspects: Water management, Ecosystems Protection, Eco-urbanism and Urban Planning, Green Buildings, Energy, Urban Mobility, Waste Management, Adaptation of Infrastructures, Risks reduction, and Social and Institutional Capacity. These aspects address mitigation and/or adaptation concerns and are related to measures and strategies in the cities' being in study. Furthermore, the information obtained was systematized in Table 1. It should be noted that it is common to find synergies and co-benefits in these adaptation measures and strategies presented in the plans, but in order to avoid redundancies, the aspects were selected for their main topics. However, one aspect was not mentioned directly in the scope of the studied plans, which is health. Although there is a consensus that all adaptation measures and strategies should positively affect human and environmental health, the plans failed to address a specific measure to deal directly with climate change impacts in health, such as the increased incidence of diseases vectors like Dengue, or respiratory diseases related to climate and air quality, like asthma and bronchitis.

Regarding the aspects presented before, it was noted that, firstly, Santiago and Bogota have more addressed water management than Mexico D.F. In both the importance of the management and restoration of the most important rivers basins of the cities and wetlands was mentioned. Moreover, is important to highlight the vision presented in Bogota´s plan: "Bogota around the Water," which denotes the importance of water sensing planning and design in the scope of the Plan. It should also be noted that one of the major challenges expected to affect Mexico D.F will be water stress, with concerns ranging from water supply for the increasing population to contamination of water resources, so the Mexico D.F. Adaptation Plan failed to mention the adaptation strategies related to water supply.In addition, ecosystem protection was better incorporated in Bogota´s Adaptation Plan**.** One of the strategies proposed was a conservation program for the "Páramos" corridors, which are important Andean ecosystems and waterlands. Eco-urbanism and Urban Planning were highlighted by all plans. The City of Santiago presented as an adaptation measure, the establishment and management of green areas through popular participation. In Bogotá, the Plan´s strategy was the use of urban policies in favor of Eco-urbanism design and planning, as well as the reduction of population vulnerability through territorial planning. In the case of Mexico City, the creation of a territorial planning program has been proposed, which integrates urban environmental policies and the sustainable rehabilitation of intra-urban areas.

Furthermore, Green Buildings was also shown in all of the cities' plans**.** The cities of Santiago and Bogota have focused their attention on aspects of mitigation, like regulatory policies to promote new sustainable buildings and green investments, for example the use of green roofs and green walls, and measures for the reduction of energy and water consumption, among others. In contrast, Mexico D.F. strategy of retrofit buildings in urban areas is worthy of recognition. Energy is an important aspect of planning for climate

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change, especially for the cities being studied, where the danger lowering levels of rainfall could affect energy security because of their reliance on hydro-energy. The Santiago, Bogotá and México D.F. strategies and measures are in line with diversification of energy sources on major focus on sustainable sources, as well as energy saving measures. In addition, the urban mobility approach was only addressed by Bogota and Mexico D.F. plans. Bogotá has added its Master Mobility Plan, which focuses on promoting the use of bicycles and conversions for hybrids and electric cars. In the case of Mexico D.F., the use of energy efficiency measures in public transport systems was proposed.

Table 1. Comparative Analysis among Santiago, Bogota and Mexico D.F. Adaptation Plans

Cities	Water management	Protection of ecosystems	Ecourbanism/ Urban planning and development	Green Buildings	Energy
Santiago	Utilization of the existing irrigation channels along the Andean waterways to minimize the risk of flooding; The implementation of a water management structure for the River basin of Maipo / Mapocho;	-	Management and creation of urban green areas through public participation;	Green Factor in new (public and commercial) buildings; Implementation of Green Roofs; Introducing sanitary facilities of low water consumption in homes and existing hotels; Reducing energy consumption in buildings;	Passive cooling for low-income households; Diversification of energy sources for energy supply;
Bogotá	Recovery of Bogotá River Basin and wetlands.	Conservation of Páramos´s corridors program	Public policies of Ecourbanism; Reduce the vulnerability of the population by territorial planning.	Public policies of sustainable construction	Energy security
Mexico City	Conservation of soil and water in Preservation Areas;	Public Police for Protection, Preservation and Sustainable Use of Biodiversity in the Federal District;	Creating a territorial planning program for Mexico City that integrates environmental and urban policies; Increased green rehabilitation of intra-urban area;	Program for the identification of underutilized premises or buildings and definition of the strategies to increase use and rehabilitation	Electric power savings program in the operation of wells and pumping plants

Cities	Urban Mobility	Waste management	Adaptation of Infraestructures	Risk Reduction	Social Capacity	Institutional Capacity
Santiago	-	-	-	-	Education on climate change and energy; Public awareness about treatment and re-use of gray water and the implementation of the system in new residential areas;	Monitoring system for climate change - WebGIS
Bogotá	Master Mobility Plan: promotion of bicycle use and conversion of car´s motors to hybrid and electric systems.	Integrated Waste Management	Adaptive infrastructure		Formal and Informal Education	Regional Integrated Climate Change Plan: Special regional administrative planning.
Mexico City	Modernization actions and energy efficiency in the Public Transport System; Implementation of new Metrobus corridors; Implementation of schemes for intermodal mobility in strategic areas of the city;	Use of technologies to take advantage of the city's solid waste output	Program of suppression of leakage and rehabilitation of pipes	Update the Atlas of dangers and risks of the DF; Hydro-meteorological risks prevention program	Public access of climate change concepts in information centers at museums; Development of an environmental education catalog;	Design of a climate change environmental fund for Mexico City; Regulate freight transport; Improvement of adaptation indicators; Creation of mitigation indicators;

Waste management is a mitigation approach and it was presented in the Bogota and Mexico D.F. plans. In addition, the adaptation of infrastructures was presented in both cities´ plans, and it was observed that the Mexico D.F. plan gave attention to ending leaks and rehabilitation pipelines program. Risk Reduction was only mentioned directly by the Mexico City Plan, which presented, as strategies, the mapping of risk areas and a prevention of rainfall risks program. The social and institutional capacity aspects are important soft measures that affect directly how far the Adaptation Plan can reach. They are related to the organization of the society, and institutional bodies, and how they are prepared to cope with extreme weather events. Regarding the Adaptation Plan in study, it

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could be noticed that all plans focused on development of urban legislations, buildings codes, generation of data, open access to information for members of society, etc. In this sense, the creation of Santiago´s WebGis monitoring system and Mexico D.F.´s climate change fund stand out among the measures. Furthermore, all plans addressed metropolitan planning integration in their scopes, which demonstrates that it is already a consensus that climate change do not rely on administrative boundaries, so it is fundamental a comprehensive territorial planning to achieve the desired adaptation and mitigation goals. In addition, it is very positive that all cities in study have been developing indicators to monitor their Plans. Santiago has already drawn up its indicators, and Bogota and Mexico D.F.´s indicators are in study. Plans´ long-term indicators are important to evaluate the effectiveness and efficiency of policies and actions implemented, hence allowing evaluating plan´s success levels achieved.

Finally, as an additional information, this research have searched on the official websites of Cities government departments what actions are being taken or carried out relating to the Adaptation Plans field. In this regard, Santiago city has been projecting the first park in its metropolitan area (*La Reserva Nacional Río Clarillo*); as well as Santiago has started actions for the reforestation of Cerro Chena Metropolitan Park; has enrolled in natural disasters resilience issues; has elaborated city school campaigns for use efficient water. Additionally, Bogota has elaborated regulatory actions in favor of energy saving; has decided to plant 2,900 trees in the area of the *Cerros Orientales*; has been designing the Thomas Van Der Hammen forest reserve forest reserve; has been developing a plan focused in urban rivers quality improvement; has been organization a Bogota Climate Commission and Climate Pact . In contrast, it was not possible to find information related to the Adaptation Plan in Mexico D.F. However, it was found that Santiago and Mexico DF have approved a Climate Change fund focusing on investment in the use of bicycles due to climate change mitigation.

5. CONCLUSIONS

Adaptation Plan´s approach is a key element for Cities to face climate change. It is important that an Adaptation Plan enhances institutional and social adaptation capacities, impacts/risks and vulnerabilities assessments, promotion of cross-cutting relations among institutions and stakeholders, integration of the adaptation plan into others plans in course on city planning, and development of adaptation measures and strategies that focus on reduction of vulnerabilities and the improvement of adaptation in urban and natural environmental. In addition, Latin America climate predictions have shown that an urgent urban sustainable development agenda will be necessary to reinforce the cities´ abilities to cope with the climate hazards and impacts. In this sense, pro-poor strategies and no-regret measures will be more suitable to the region urban context. Although few cities have already elaborated the adaptation plans, the climate change concern is increasing in the region. Santiago, Bogota and Mexico D.F.´s adaptation plans have satisfactorily addressed adaptation and mitigation concerns on their sustainable development objectives. On the other hand, adaptation planning needs a long-term agenda, and this will be challenging for the most of Latin-American municipalities, especially because they usually lack integrated government arrangements and properly distribution of data and technical frameworks. Due to that, it is even more important to

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develop mechanisms to monitor the measures and strategies, in order to analyze the effectiveness and efficiency of those in dealing to climate change disturbances. Finally, it is also important to emphasize those others institutional agendas must integrate adaptation urban planning, as well as stakeholders and city community must engage climate change issue. That is the only way to make adaptation planning reality.

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