Sustainable Transitions of Urban Projects towards Mitigation and Adaptation Projects for Climate Change: The case of Medellin

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Abstract. The research investigates the relationship between cities and climate change by examining how urban projects shifted to mitigation and adaptation for climate change at an urban scale. The article is based upon two complementary approaches, a multilevel analysis from sustainable transitions theory and a framework of interrelations of urban mitigation and adaptation projects. The methodological design is a case study; we analyzed the case of Medellin that, at the beginning of the 2000’s, implemented public transport projects, urban parks, educational and cultural facilities, and risk mitigation projects in the surrounding hills. The main findings are that specific projects at an urban scale are operating as niches or experiments, taking advantage of windows of opportunities, and triggering changes in the urban design routines, framing a new sociotechnical system. It is found that governance, leadership, teams of experts and urban planners are drivers for the transition of urban projects, which were initially designed for social and transport needs, to urban mitigation projects for climate change. At the same time, urban mitigation projects such as the Metropolitan Green Belt are transiting to adaptation projects for climate change. The conclusion for this case study is that while most urban projects retain their traditional role, a new generation of projects with mitigation and adaptation features is emerging in the context of climate change. This article contributes to expanding the empirical analysis of the literature on the theory of sustainable transitions specifically related to cities and urban projects. The theoretical framework of urban projects and their linkages with climate change are enriched. The conceptual framework of the analysis is replicable and useful for practitioners in the field of urban design and researchers interested in comparisons to identify patterns or typologies. In addition, the article contributes to sensitize actors involved in public urban design policies in their roles as managers of transitions.

1. Introduction
Climate change is nowadays the world’s main challenge [1] and cities are both blamed for the current state and called to have a paramount role in tackling climate change [2]. A growing urban population puts pressure on the flow and stock of greenhouse gas (GHG) emissions, reinforcing the global issue of climate change. By 2030, the world’s urban population is expected to reach 60% [3] and this trend represents the main driver of macro change in the man-environment system. Cities are called upon to address this shift through the development of their own transformative urban capacities and innovation [4–6]. In this sense, scholars endorse the concept of sustainable urban transitions as a non-linear
sustainable change that produces transformations in cities and the systems in which they are immersed. [7, 8].

Actions oriented to tackle climate change are mainly two: mitigation and adaptation, whose objectives are different but acknowledge the same phenomenon [9]. While adaptation strategies are oriented to minimizing the negative impact of climate change on rising sea-levels, floods and rivers’ changes through green and blue infrastructures, mitigation strategies are twofold: one oriented to minimizing CO2 gas emissions and the other to reducing the risks of deterioration of natural systems due to human intervention or natural causes. Studies of actions for climate change in terms of mitigation tend to be directed towards technological solutions and empirical evidence focused mainly on European cities, neglecting developing countries or the South [10] with some exceptions [11–13]. Adaptation emerged as a necessity to avoid damage from extreme natural climate events. Although natural risks have always existed, they have been exacerbated as an effect of global warming [1].

While research that jointly addresses climate change mitigation and adaptation actions are scarce [9, 11, 12, 14–16] separate analysis is dominant in the literature, although the idea that both are “sides of the same coin” has spread more recently, especially after the Paris Agreement [17]. Prior research that combines mitigation and adaptation actions has privileged empirical studies, highlighting governance aspects in developed countries [18]. This analysis is enriched with contributions from sustainable transitions in the urban environment in which cities play a role in their own urban transformative capacities [6]. European cases or megacities are predominately explored with some exceptions and the focus is mainly on more traditional topics such as energy, mobility, water, food and health [7].

In prior research on the combination of mitigation-adaptation and sustainable transitions at the urban level, the scale of the urban project as a tool for urban action [19] is scarcely acknowledged to understand the operationalization of actions of mitigation and adaptation. We assume that urban projects are units of micro analysis that have a positive effect on climate change efforts. We recognize the need to advance towards a level of pragmatic operational analysis in cities, the urban project, as the product of innovations within a conception of sustainable transitions, that is, connected changes that feed off with ramifications that go beyond the strictly urban [20]. In this way, urban mitigation and adaptation projects are generated in protected spaces such as urban planning units of municipalities that are associated with niches, the micro-level. These niches are protected spaces where innovative initiatives or experiments emerged as windows of opportunity. The routines of project practices are challenged through pressures from the highest level such as the landscape which exerts pressure on the intermediate level called regime [20].

Consequently, the research explores how urban projects can be transformed into mitigation and adaptation projects to climate change on an urban scale based on the theoretical approaches of sustainable transitions and the interrelationships between mitigation and adaptation. The analysis of urban projects and their interrelationships is carried out in Medellin where a transition process was introduced at the beginning of 2000 with projects born from sectorial problems such as public transport, especially metro-train and cable cars which are in turn drivers of synergies with other initiatives such as urban parks, educational and cultural facilities and risk mitigation projects in the hills surrounding the city.

The paper contributes to the theoretical and empirical integration of sustainable transitions, climate change actions and generations of urban projects in a less explored geography. Second, the paper contributes to sensitize professionals of public policies in areas of urban design in their management of transitions role.
The article’s structure is as follows. In a second section, a literature review on sustainable transitions and the interrelationships between mitigation and adaptation of urban projects is presented. The third section summarizes the methodological and contextual design of the case study to continue in a fourth section with the main findings and discussion, and finally in the fifth section the conclusions are exposed.

2. Literature review

2.1. Sustainable transitions
In many scientific disciplines, the term transition is often used to refer to a non-linear change from a complex equilibrium to another complex equilibrium state, while the concept of sustainable transitions encompasses large-scale societal changes that aim to address the challenges called “Grand challenges” or global challenges [21]. The concept of transition is defined as:

“a gradual, continuous process of change where the structural character of a society (or a complex sub-system of society) transforms… A transition is the result of developments in different domains. In other words, a transition can be described as a set of connected changes, which reinforce each other but take place in several different areas, such as technology, the economy, institutions, behaviour, culture, ecology and belief systems” [22]

According to this broad definition, transitions’ impact on society can be identified in the inherent social functions or the so-called basic functions of society that permeate areas such as energy, transport, housing, water systems, food, health, and communications. In order to fulfil social functions, sociotechnical systems are required in turn. These systems are understood as a series of networks of actors such as people, companies, organizations, institutions (including social and technical norms, regulations, or standards), knowledge and also elements that are materials [23].

Thus, a sociotechnical transition is a set of processes that promote changes in sociotechnical systems [23–25] that occur beyond the sphere of influence of the actors themselves, in a wide time horizon which includes technological transitions as one of their components and also contemplate changes in institutional practices and structures with their regulatory and cultural components. Sustainable transitions represent a threat to the conservative forces that promote a status-quo. Incremental innovation initiatives are promoted over radical ones [21, 23] that embody windows of opportunity.

In the last two decades, the literature on transitions has been described from different perspectives such as the Multi-Level Perspective (MLP), technological innovation system, strategic niche management and transition management. As an analytical-conceptual framework, the MLP has received greater attention among researchers [26–28] who acknowledge that transitions are the product of dynamic processes that operate at three levels, niches (micro level), regimes (meso level) and landscape (macro level), and also work in the spaces between these levels. The first level is made up of niches which are protected spaces where actors introduce changes with respect to the existing regimes through experimentation, repositories or test benches. These actors generate radical innovations that nurture the development of alternatives and have the potential to expand or challenge what exists to the extent that the landscape puts pressure on the regime that experiences breaks, tensions and windows of opportunity [20]. A second level includes the sociotechnical regimes where the structural rules that coordinate and guide the perceptions and decisions of the actors are located. In this dominant order or configuration in a social subsystem [21], routines, culture, institutions and technologies tend to be maintained and reproduced over time [26, 29]. The third level called landscape is the broadest level. It is the indisputable backdrop of society [24] whose purpose is to influence regimes and niches through political ideologies, social values, and infrastructures. In summary, the MLP perspective offers the understanding of the sociotechnical transitions that emerge from the pressures exerted by the landscape, the difficulties of the
regime and the innovations of the niches to benefit from windows of opportunity and challenge the prevailing sociotechnical order.

Scholars of sustainable transitions in the realm of empirical application recognize the key role of cities [6–8, 30, 31], highlighting the spaces for experimentation associated with open and non-standardized processes resulting from unique contexts, governance, articulation of networks of actors, policies for sustainable transitions and acceleration of impacts and sectoral interrelations.

2.2. Interrelations between mitigation and adaptation of urban projects

Mitigation and adaptation strategies have received uneven attention over time [11] so 90% of climate change financing has been allocated to mitigation actions [32, 33], as this is especially critical in developing countries [12]. More recently, the United Nations Framework Convention on Climate Change has recognized that the parties must develop mitigation measures to climate change and measures that facilitate adaptation to it. Although both are deliberate responses to face climate change, they offer several differences: objectives, time to capture their benefits, implementation scales, sectors involved, degree of dependency on the national economic reality, built environments, and policy development [34].

At the planning level, it is observed that the mitigation and adaptation integration process shifted from a national level analysis [14, 35, 36] to a more local one at the beginning of the 2000s [37]. Scholars distinguish differences between mitigation and adaptation policies through several criteria such as sector focus, geographic scale of impact, temporal scale, level of governance, effectiveness, secondary benefits (or mutual benefits), benefits of the stakeholders, sanctions for the polluter and monitoring [9, 11]. However, the real experiences of mitigation actions could come to light before the formality of the climate action plans, which are then a general framework [38].

On the other hand, urban projects are the way to operationalize climate change adaptation and mitigation strategies, even if they do not initially arise in the context of climate change. Although the concept of urban projects raises controversies [39], Manuel de Solà-Morales’s definition is widely accepted by urban planners [40]:

“An urban project means taking the geography of a given city, with its claims and suggestions, as a starting point, and allowing architecture to introduce language elements to give form to the site. An urban project means trusting the complexity of the work to be accomplished more than the rational simplification of urban structure. It further means working in an inductive fashion, generalising what is particular, strategic, local, generative” [19].

According to Portas [41], three generations of urban projects are identified. The first generation of the 1960’s is featured by the modern city approach with large scale unitary architecture. The second generation in the 1970’s is focused on typology, language and collective spaces and the third generation of the 1980’s is more sensitive to markets opportunities with large scale projects within strategic planning. More recently, the concept of urban projects within sustainable transitions is just being explored so that the adjective "sustainable" is added to the urban project. To this extent, Devolder and Block [42] advocate that urban projects have the capacity to exert pressure on the regime and consequently can be considered as niches.

In summary, we built up an integrating theoretical framework of how urban projects inserted in a process of sustainable transitions can express their potential for mitigating and adapting to climate change. They represent a scale of local intervention and belong to the micro level of analysis (niches) where innovations are generated that, thanks to the pressures of the landscape, manage to mobilize the regimes to face climate change (Figure 1). It is observed that urban mitigation projects produce effects
on the flow and stock of GHGs and on the mitigation of natural disaster risks that in turn can feed adaptation projects. This link occurs when a project aimed at tackling the vulnerability of a geographic area exposed to risks such as landslides or floods can successively become a space with adaptation features (e.g. Barigui and Tanguá floodplains in Curitiba, Parque Flood Intercommunal Victor Jara in Santiago de Chile or Parque Fluvial del Besò in Barcelona).

![Image](image)

**Figure 1.** Integrated framework, Source: own elaboration.

3. **Methodology**

The research explores a single Latin American case study, Medellin in Colombia, using mainly qualitative data. Primary data are built upon descriptive observations made by the researchers in the field in 2014 and 2019. Secondary data were obtained from different instruments released by the Mayor's Office, the Urban Projects Company (EDU), international organizations, interviews in specialized journals of urban planners and mayors. The case of Medellin was chosen because it is a medium-sized city in a less studied continent with the highest rate of urban population in the world, exposed to natural risks and exacerbated by the effects of climate change. Medellin represents an empirical laboratory for experimentation and dissemination of urban projects in a region where heterogeneous and eclectic urban instruments are challenging the neoliberal urban project imported from European countries at the end of the 20th century [43]. As other Latin-American cities, Medellin has local problems in peripheral neighborhoods, known as social urbanism.

3.1. **Summary of contextual and urban planning antecedents of Medellin**

The Metropolitan Area of Medellin is the second largest populated area in Colombia, composed of 10 municipalities located in the Aburrá Valley with a population in 2018 of 3.9 million that is expected to grow to 4.3 million inhabitants by 2030 [3]. Its location in the Andes’ central mountains at an altitude between 1300 and 1800 mts gives Medellin a humid subtropical climate with important rainfalls [44].

The city was founded in 1674 with the name of Nuestra Señora de la Candelaria de Medellin as a mining city and commercial exchange center [45, 46] with a colonial grid designed as a network of orthogonal streets with a central plaza. In the 19th century, Medellin adopted the role of capital of the Department of Antioquia and began its economic growth driven by the extraction of gold and the development of various industries. At the end of the 19th century, the first urban proposals emerged with a manufacturing and industrial orientation [47]. Despite several urban planning efforts to control the growth of the city in the 20th century, Medellin has since been overwhelmed due to the pressures of the new migrant population from the countryside, the consequent housing deficit that is reflected in the spontaneous occupation of steep hill slopes with risks of landslides and the lack of infrastructure for its
inhabitants. These urban planning projects are mainly: 1934: Plan Gran Medellin; 1949: Pilot Plan of 1949, implemented in 1951 under the name of the Regulatory Plan; 1983-1986: Antioquia Development Plan and the first Urban Development Plan of Medellin (PDUM); 1998 the Territorial Ordinance Plan (POT) and at the end of the 1990s, the “Medellin Strategic Plan to 2015” (PEM). A more detail review of this evolution can be consulted in La Manna [46], Papantonakis Vera & Rodriguez-Villamil Cardeillac [47], Claghorn & Werthmann [48] and Castrillón Aldana & Cardona Osorio [49].

At the beginning of the 21st century, the 2001-2003 Municipal Development Plans (MDP) initiated the construction of the first Metrocable in the Commune 1 and 2 areas, to connect neighborhoods with large social problems with a Metro station; this infrastructure was inaugurated in 2004. The next MDP 2004-2007, based upon a city model centered on human beings and their wellbeing, acknowledged issues of social inequality and violence from drug trafficking and created the project “Medellin the most educated” [47]. Another important project was the “Urban green spaces master plan for the metropolitan area of Aburrá valley MAAV”, implemented in 2007 for the Aburrá valley urban environmental authority. The Municipality signed several inter-administrative agreements between the Municipality and the Urban Development Enterprise (EDU) (EDU 2018). The MDP 2008-2011 pursued urban transformation in relation to the built mass and the expansion of areas of actions [47]. The MDP 2008-2011 called “Medellin, solidarity and competitiveness” developed urban projects of the Central Eastern zone Communes 8 and 9, and the North Western Communes 5 and 6. With the MDP 2012-2015 comprehensive urban projects were contemplated with the slogan: “Equity, priority of society and government”. The MDP 2016-2019 under the expression “Medellin counts on you” (Medellin cuenta con vos) (EDU 2018) is followed by the current MDP 2020-2023 called “Medellin Future” [50].

4. Results and discussion

4.1. Mitigation projects: cable car and Cerro Moravia

One of the mitigation actions aimed at reducing GHGs was the construction of an integrated mass public transport system. The metro that runs through the city and connects Medellin with all its metropolitan areas works by means of electricity from a hydroelectric plant. In addition to the railway system, the Metro increases its clean transportation system with the incorporation of a medium capacity articulated bus system that runs on natural gas with low emissions [51, 52]. Complementing the Metro and its bus network, the cable car connects the hillside neighbourhoods with the city (Figure 2 and 3). Both the metro and the cable cars run on electricity from renewable energy sources. At present, the construction of an electric tram is being added, which covers other areas of the city and is complemented by feeder buses and cable cars, and is linked to the city's public bicycle system [52].

Figure 2. Metrocable Line L station, Source: own elaboration, 2019

Figure 3. Metrocable Line L and rehabilitation of public space, Source: own elaboration, 2019
The idea of introducing a semi-massive transport system such as the metro cable in the suburbs of the city arose from a technical-economic need of the Medellin metro, inaugurated in 1995, whose main line runs through the city from north to south. There were problems to build access roads to its stations due mainly to the difficult topography of some sectors of the city [53].

The Metrocable was included in the 2001-2003 Medellin Development Plan entitled Medellin Competitive and its objective was to fight uncompromisingly against crime, poverty, unemployment and the shortage of public space. The first Metrocable line (K) was constructed in the northeast area of the city, connecting Metro line A with city districts Commune 1 (Popular) and 2 (Santa Cruz). Both sectors have a difficult, steeply sloping terrain that prevents the construction of railway lines, which gave a good reason for the installation of an aerial cable car system to enable access to these areas. (Figure 4).

![Figure 4. Metrocable passenger station, Source: own elaboration, 2014](image)

Metrocable started operations in 2004 and four years later the second line (J) was added, which crosses city districts Commune 7 (Robledo) and 13 (San Javier), in the western central area. In addition, Line L, incidentally the only one designed for tourist transport, was opened in 2010 and managed by Empresa de Transporte Masivo del Valle de Aburrá Limitada, the public corporation for massive transportation of the Atrurra Valley. Currently, the city is preparing the technical studies to expand the metro through “Metro de la 80”, a second longitudinal subway [50].

The Metrocable, which was initially thought of as a semi-massive public transport solution, became the spearhead for the next major urban transformation in the sector. Although the situation was complicated in the case of the popular peripheries of Medellin since restoring the presence, control and legitimacy of the State required challenging powerful illegal organizations and partially suppressing an extensive underground economy, the Metrocable offered an alternative for stable and secure mobility, not only for residents of the included sectors towards the rest of the city, but also to facilitate access to the peripheral sectors by state institutions and encourage these areas to become formal branches of the local economy [53].

Today the Metrocables are part of the Medellin Metro public transportation system, which consists of elevated train lines and overhead cable cars (Figure 5). Compared to other urban transport systems, cable systems can be built in a relatively short time and at comparatively low costs because they involve a limited number of lots of land to be purchased. A disadvantage of the system is that technically you cannot exceed 3,000 trips per hour without incurring high additional costs [54]. The Metrocable system can be considered a mitigation project in the face of climate change, because it is contributing to reduce
the emissions of CO2 into the atmosphere; furthermore, the public corporation for massive transport of the Aburra Valley (ETMVA), decided to apply one of the instruments created by the Kyoto Protocol, the Clean Development Mechanism (CDM), to the six metro cable lines. The CDM guarantees Parties of Annex B of the Kyoto Protocol that financed projects in developing countries, the concession of certified reductions of GHG emissions (in kilograms of CO2eq) assimilated to the GHG reductions obtained through this project [55].

![Figure 5](image_url)

**Figure 5.** Intermodal station lines K and L (center) and Library Park (right), Source: own elaboration, 2014

4.2. Adaptation project: Green Belt

The city of Medellin is preparing to face the effects of climate change. According to studies conducted by the IPCC 2010, in the metropolitan region of the Aburra Valley, there will be an increase in rainfall during this century. For this reason, the Municipality signed the municipal agreement 070 of 2013 by means of which the guidelines of the environmental policies for the city are taken up again, and where the technical, methodological, legal and normative instruments for the environmental management of the city were established for Medellin. With the update of the territorial ordering plan POT for 2014, the municipality incorporated new objectives to control climate change through mitigation and adaptation strategies. In 2015, during the mandate of Mayor Gaviria, two projects were proposed in this sense, the protection and increase of the protected areas, the metropolitan Green Belt project.

One of the strategies proposed as mitigation against climate change is the preservation and increase of the protected areas of Medellin that represent 44.39% of the total surface of the municipality and in this sense, the Green Belt project promoted by the Mayor Gaviria, in the Development Plan "Medellin a home for life" 2012-2015, was proposed to regulate the use of the land, avoiding the expansive growth of the city towards the slopes of mountains and valleys, and also to preserve the natural areas. At the same time, in the context of the Green Belt and of a more academic nature, pilot projects are being developed with strategies that reduce risks through monitoring and early warning systems, drainage improvements, micro-agriculture, afforestation on slopes, and through the development of service-provided sites located in low-income settlements in the mountainous urban periphery.

The Metropolitan Green Belt project is a long-term integral planning strategy that aims to organize the territory in the meeting zone between the urban and the rural, through programmes and projects promoted by the Mayor's Office of Medellin and the municipalities that make up the Aburrá Valley. The first pilot project to be carried out is called the Circunvalar Garden of Medellin, which began to be built jointly with the community through a pedagogical urbanism. This project has been built in the sector of the Commune 8 of the city of Medellin, with the consolidation of trails, bike paths, ecological parks, and some amenities [56].
4.3. Discussion
The research set out to review how urban projects can be transformed into projects for mitigation and adaptation to climate change on an urban scale for the specific case of Medellin, drawn upon an integrative framework on sustainable transitions theory and the interrelation of mitigation actions and adaptation for climate change. The integrative theoretical proposal enables recognizing in the case of Medellin that mitigation and adaptation actions were developed in a context where climate change agendas had not yet been adopted and were subsequently inserted into the ad-hoc plans. This ex-post practice is not exclusive to the Medellin case, it had already been visualized in other experiences [38]. Urban projects with mitigation and adaptation goals are distinguished by their objectives, time horizon, scale, intersectoral relationships, and whether they operate in built-up areas or with the intention of controlling the expansion of habitable areas [34]. These projects are born as experiments in the niches of the Mayor's Office and EDU and have taken advantage of contingent or local events. As the characteristics of the third generation of urban projects that were born in the 90's with the singularity of large urban projects and urban acupuncture are surpassed by the challenges of climate change at a declarative and factual level, we visualize that, in the case of Medellin, a fourth generation would be emerging. Although the latter respects the definition of Solá-Morales [19], it exhibits a new seal of sustainable development within the context of the 2030 Agenda that addresses the objectives of curbing the flow and stock of GHGs and improving the resilience of the inhabited sectors, especially spontaneous settlements forming neighborhoods on the steep slopes around the city. Thus, we propose an expansion of the evolution of urban projects, incorporating this fourth generation that is oriented to tackle climate change through urban projects of adaptation and mitigation.

5. Conclusions
The article explored how urban projects can be transformed into mitigation and adaptation projects to reduce the impact of climate change at an urban scale for the case of Medellin, based on the theory of sustainable transitions and contributions on urban projects.

Medellin, as a case study, represents a Latin American case of an intermediate city that has managed to free itself from the stigma of the most dangerous city in the world through a process of change that occurred over a period of two decades and at different levels. In the Mayor's Office, windows of opportunity were taken advantage of that promoted the construction of a transportation system (Metro) that triggered new transformations that go beyond the merely mobility objectives. Macro-level pressure, especially the growing population in new peripheral neighbourhoods which are exposed to natural hazards, economic growth, democratic processes and impulses for citizen participation, has an impact on regimes that give in and deviate relatively from the usual practices or routines, taking advantage of the lower level, niches such as the Mayor's Office or the EDU to innovate and experiment. Through the case study, a new generation of urban projects is proposed, the fourth generation, which is distinguished by the seal of sustainable development and within which different levels of complexity are recognized. The mitigation and adaptation projects to climate change are developed for the case of Medellin in a long-term effort of urban planning, a municipal management with continuity and mayors’ leadership, a decisive support from the EDU and with citizen participation of the democratic period of Colombia.

These contributions enrich the sustainable transition approaches of cities where progress is made towards the analysis of micro or niche levels, urban projects within the great problem of climate change where cities play a determining role. The research could be expanded in terms of comparing other cases with the purpose of discovering empirical patterns or typologies, without omitting the particularities and neglecting the replicability limitations. Thus, to generalize the proposal of the fourth generation of urban projects and the complexity alternatives, it is necessary to submit it to verification in other cases. The research also invites to broaden the debate among planners, researchers and decision makers on public policies on the role of urban design as a tool that incorporates mitigation and adaptation projects for climate change.
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