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Environmental Technology and its Role in the Search for Urban Environmental Sustainability:

The Dynamics of Adaptation

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Cover art

Armando Paez says that scarcity is not inherent to nature, but it has emerged from the tendency of looking at everything in terms of domination and submission, from the misunderstanding of the relations between humanity and the rest of nature. This cover expresses how close humans are to nature, even when they insist on distancing themselves from it. The reticulate patterns in this leaf resemble the streets and waterways of a city. In nature, this structure works in a way that ensures that every single cell has access to water and nutrients. Cities are places for everyone and they should work in the same way, providing everything their inhabitants need: clean air, water and soil, food, spaces for social interaction, and security. The foundations for more sustainable cities are laid; perhaps we need to improve our cities' ability to adapt to the nature that supports them. Can environmental technology help?

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Abstract

The aim of this thesis is to analyze the role that environmental technology plays in the solution of environmental problems in cities, and discuss models and conditions that can facilitate the processes of selection, implementation and use of environmental technologies in and by cities.

The technological component is perhaps one of the most important characteristics of modern cities. The dependence of humans on technology is in most cases a given, something that is not ignored in the sustainability debate. The development and implementation of new, "better" technologies is however hindered by the inertia that modern societies have and the influence of the dominant systems (e.g. economic systems based on growth, extraction of natural resources and environmental disturbance). So-called environmental technologies are not always able to efficiently compete against other technologies that are embedded in societies by lock-in mechanisms, e.g. learning by doing and using, scale economies, subsidies, and network externalities.

Even with the "right" technologies, an exclusively techno-centered approach to sustainability can result in other problems, and it might reduce the sustainability debate and the cities' role in it to discussions of an administrative nature. The actual role of local actors and their agency must be also considered in the models and frameworks directed at understanding sustainability transition processes. It is thus important to analyze the dynamics of technology selection, implementation, use and diffusion in cities from a stakeholders' perspective as well.

Not only is the availability of technology of interest for understanding the impact it has on the environment, but also the intensity of its use. This has resulted in increased attention from politicians and scholars on the so-called global cities (e.g. London, New York, Tokyo), which are characterized by their intense use of e.g. transport, security and surveillance, and information and communication. Paradigmatic models of sustainability can however be contested when the role of local actors, power and agency are considered in detail and not isolated from the context. Some authors recognize the need to address what they call "ordinary cities", since focusing on the cities' comparative level of development (be it political, economic or technological) hinders the possibility of bidirectional learning. In the end, sustainability is a "collective good," which means that it is in everyone's interest to coordinate efforts and learn from the best practices, regardless of where they come from.

This thesis focuses on "ordinary cities," and promises to offer conclusions that can contribute to a better understanding of how societies can learn from each other and how environmental technologies can have deeper and better results when implemented in different contexts than the ones where they were developed. Two questions related to the process of environmental-technology adaptation are addressed in this thesis: How do technology adaptation processes for the solution of urban environmental problems take place in cities? And how do cities benefit from environmental technologies?

It is found that environmental technology is not only seen as a solution to environmental problems in cities, but every day more as a component of strategies to attract attention and compete for

resources in national and international markets. Cities have different adaptation and learning strategies. This means that technological solutions have to be flexible and adaptive to local conditions, and allow for vernacular knowledge and past experiences to enrich their performance by facilitating their connection to existing systems. Learning between cities is important and necessary for global sustainability transitions. When it comes to environmental technology, this process is facilitated by strong proof-of-concept projects. Such projects are not only expected to be able to show their technical ability to solve a problem, but must also offer contextual connections to the problems faced by interested cities or potential implementers.

Keywords: Technology Adaptation; Governance Mechanisms; Spread of Technology; Stakeholder Involvement; Proof-of-concept; Environmental Technology Suppliers; Urban Imaginaries.

Populärvetenskaplig sammanfattning

Fler och fler väljer att bo i städer och städerna underlättar mycket av vår moderna livsstil. Detta leder dock till många olika miljöproblem. Till exempel uppskattas städerna bidra med mellan 75 och 80 % av de globala utsläppen av klimatpåverkande gaser. Allt mer intresse riktas därför mot stadsutveckling och hur miljöteknik kan bidra till städers hållbarhet och ekonomiska tillväxt.

Flera städer runt om i världen har varit framgångsrika att utveckla och använda teknik som hjälper dem att bekämpa luft-, mark- och vattenförorening, att förbättra medborgarnas hälsa och att bättre organisera livet i staden. Spridning av denna kunskap och teknik anses som ett av de viktigaste sätten att lösa de utmaningar som klimatförändring och annan miljöförstörelse utgör. Men kunskapsöverföring och speciellt tekniskspridning är svårt, och även där det har skett, är det inte självklart att teknik på ett effektivt kommer att lösa sätt de problem som finns. Detta beror på många olika saker, men för miljöteknik utvecklad för att lösa urbana problem gäller att den ofta är framtagen under speciella omständigheter och inte enkelt kan flyttas utan problem med anpassning.

I den här avhandlingen studeras ett antal städer i Latinamerika som försöker förbättra sin miljö och sina medborgares liv genom att använda miljöteknik såsom olika former av kollektivtrafik, avfallshanterings- och energisystem. Speciellt fokus är på Medellín i Colombia. Avhandlingen svarar på två frågor:

- Hur sker olika processer för teknikanpassning av lösningar av miljöproblem i städer ut?
- Vilken nytta kan städerna få av att använda sådan miljöteknik?

Slutsatserna från avhandlingen bidrar till förståelsen av hur städerna skapar sina mål, dvs. en idé av vad hållbar stadsutveckling betyder för dem, och mekanismer för att nå de uppsatta målen. Till exempel konstaterades att miljöteknik inte bara ses som en nödvändig lösning på miljöproblem, utan också som en viktig del av städernas strategi för ökad internationell uppmärksamhet och att bättre kunna konkurrera om resurser med andra städer (t.ex. utländska investering, professionell arbetskraft och turism). Därutöver visas att olika städer har olika anpassning- och inlärningsstrategier, vilket betyder att miljötekniklösningar måste kunna anpassa sig till det lokala sammanhanget och att lokal kunskap och tidigare erfarenheter tillåts att berika dess prestanda och anslutningsmöjlighet till andra befintliga system. Slutligen visas att lärande mellan städer är viktigt för att möta globala hållbarhetsutmaningar. I det sammanhanget framgår att spridning av miljöteknik underlättas av olika demonstrationsanläggningar och det förväntas att sådana anläggningar inte bara visar tekniska lösningar, utan också hur dessa kan anpassas till de problem och förutsättningar som mottagande städer möter.

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Devoting so many years to one's own education is, at least partly, a selfish decision. Even if I made that selfish decision, there are a lot of people who have stood by my side to make sure I get the support I need to finish what I started. And I am profoundly grateful for that.

I had the fortune to have been born in a supporting and united family. My parents Gustavo and Claudia had the patience needed to raise a very restless child, and teach me as much as they have. My sisters María Paulina and Mónica, my babysitters and first math, geography and art teachers, probably had no option but to take care of me when I was a child, but still did it with love and dedication. Without my family's support, I would have never made it to Sweden in the first place. Thank you from the bottom of my heart; the idea of coming back to you has helped me to overcome those lonely winters (especially the last one). I was also fortunate to cross lives with Christer and Gloria, my parents in Sweden. They were always there when I needed them, and I know will always be in the future. Things would have been very different without them around. I am so glad that we will continue to live on the same side of the Atlantic.

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Last, but definitely not least, I want to thank Marce, *mi Pulguita*, who had little doubts of joining me when I asked her to leave everything on hold back home. We have grown together, but I am sure I took the best share. You are an important contributor to this thesis, as we share the same interests, from different perspectives, and I have benefitted immensely from your knowledge, opinions and experiences. I am glad you will now have your chance to shine.

To my father, whose curiosity about how things
work turned out to be an inheritable trait.

Great doubt: great awakening.
Little doubt: little awakening.
No doubt: no awakening.
Zen Koan

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1. Introduction

In this chapter, the research topic is introduced. A discussion about the relevance of the research is presented, as well as its potential to contribute to science in particular and to society in general. The aims and scope of the research are also reviewed in this chapter, together with a discussion of the limitations.

1.1. The role of cities in sustainability transitions

Although the concept of city has undergone changes with time (e.g., regarding the size of its population or its physical boundaries), it has been a central concept throughout the history of civilization (Portugali, 2000). Cities have always been important to humans because they concentrate wealth, power, people and commerce, and what is most important to this thesis, technology. As Gandy (2005) claims, technology might be one of their main characteristics and what makes them particularly attractive to many. More than the availability of technology, it is the intensity of its use that characterizes modern cities (compared to rural areas or other cities, for example).

Different problems like pollution, noise and overpopulation have long been a concern to local and international authorities. However, Bulkeley and Betsill (2005) claimed that it was not until 1987, with the Brundtland Report, that the central role that cities play as a means to address sustainability challenges was considered. They also stated that the ground that this discussion had gained was mostly rhetorical, and that the actual meaning of sustainable cities and communities was not clear in practice.

During the last decade, cities have gained attention, considering their role in facilitating social movements (Nicholls, 2008) and their strong influence on transitions into a greener economy (Puppim de Oliveira, 2013). With growing scientific and political consensus on the impact that human activities have on i.a. climate change (see e.g. Cook et al., 2013; Intergovernmental Panel on Climate Change, 2014; The Stockholm Memorandum, 2011; Tol, 2014), cities have drawn more attention due to the intensity of technology use within them and the impact this has on the environment. Numerous sources estimate that cities contribute from 75% to 80% of global greenhouse gas emissions (Marceau, 2008; Satterthwaite, 2008). This is exacerbated by the size of modern cities: while there were two megacities in 1970, i.e., cities with more than ten million inhabitants (United Nations, 2012), that figure reached twenty-eight in 2014, and it is estimated that it will be forty-one in 2030 (United Nations, 2014). These behemoths are perhaps the clearest cases of urbanization and concentration, but it is important to also acknowledge that there are around three thousand cities with a population of less than five million inhabitants (concentrating almost 80% of the world's urban population), a figure that is expected to become 3,500 in 2030 (United Nations, 2014). All this sends an unequivocal signal regarding the importance of putting cities at the center of the sustainability debate. Uncontrolled urbanization represents problems of an environmental, logistic and economic nature (Johnson, 2001; Keiner and Kim, 2007). Thus, physical concentration alone cannot be seen as the solution to achieve sustainable cities (some modern megacities are living proof of this).

The dependence of humans on technology is in most cases given (see e.g. Gandy, 2005). This dependence is not ignored in the sustainability debate. Some believe that technology should not be the most trusted solution when addressing the sustainability challenge, and that the conditions for its use must become stricter (see Ayres et al., 1998; Huesemann and Huesemann, 2011). For others, technology is the key to solving many of the problems humans face today, although it is recognized

that many of the current technologies must undergo a radical change (see e.g. Jackson, 2009). The development and implementation of new, "better" technologies (i.e., in comparison with existing technologies) is however hindered by the inertia that modern societies have and the influence of the dominant systems (e.g. economic systems based on growth, extraction of natural resources and environmental disturbance). So-called environmental technologies are not always able to efficiently compete against other technologies that are embedded in societies by lock-in mechanisms, e.g. learning by doing and using, scale economies, subsidies, and network externalities (Geels et al., 2008; Geels and Schot, 2010). However, it is important to realize that it is those dominant systems that have created the context under which new technologies can develop in order to achieve desired transitions, without causing profound destabilizations of the current system (Boonstra and Joosse, 2013).

The emergence of the "entrepreneurial city" (see e.g. Furlong, 2014) and the harsh competition of cities for resources on an international scale, has justified the upgrading of cities, in most cases via technological change (Bulu, 2014). However, even with the "right" technologies (e.g., less polluting or more energy efficient), an exclusively techno-centered approach to sustainability can result in other problems. It might reduce the sustainability debate and the cities' role in it to discussions of an administrative nature, e.g. architectural design (e.g. for energy efficiency in buildings), traffic management and the use of renewable energies (Bulkeley and Betsill, 2005; Hodson and Marvin, 2010). It might also lead to a society where technocratic knowledge replaces legal or ethical considerations, and to governments that are inaccessible in terms of political decisions (Montoya Brand, 2005). The actual role of local actors and their agency must be also considered in the models and frameworks directed at understanding the sustainability transition processes (Smith et al., 2005). It is thus important to analyze the dynamics of technology selection, implementation, use and diffusion in cities from a stakeholders' perspective as well.

Socio-technical Transition Theories recognize the need to focus on the interactions between technology and society, and the role that certain actors play in the alignment of resources and elements necessary for technological development (Geels and Schot, 2010). In particular, the Multi-Level Perspective (MLP) has gained popularity in the transitions debate (see e.g. Smith et al., 2010). The MLP, among other things, offers a framework under which transitions can be analyzed at different levels, defined according to the scale and the number of actors involved in them, which influence the possibility of orienting change at each level (Geels, 2002; 2011). Special attention is put on the interactions happening between and within them. This framework is relevant and useful for the analysis presented in this thesis, although some authors consider that the MLP does not give actors, power and agency the attention they deserve (Geels, 2011; Smith et al., 2005). On a higher level, Transition Theories have also received criticism. One of these criticisms is central to this thesis: Hodson and Marvin (2009; 2010) claim that Transition Theories underplay the role of cities in sustainability transitions. These issues will be addressed in subsequent chapters.

Not only is the availability of technology of interest for understanding the impact it has on the environment, but also the intensity of its use. This has in part resulted in increased attention from politicians and scholars on the so-called global cities (e.g. London, New York, Tokyo), which are

characterized, among other things, by their intense use of transport, security and surveillance, and information and communication technologies (see e.g. Hodson and Marvin, 2009; 2010). Paradigmatic models of sustainability can however be contested when the role of local actors, power and agency are considered in detail and not isolated from the context (see e.g. Hult, 2013). Hodson and Marvin (2009; 2010) recognize the need to address what they call "ordinary cities," and McFarlane (2006) says that focusing on the cities' comparative level of development (be it political, economic or technological) hinders the possibility of bidirectional learning. In the end, sustainability is a "collective good" (Geels, 2011), which means that it is in everyone's interest to coordinate efforts and learn from the best practices, regardless of where they come from. In this sense, although competing visions of sustainable cities can emerge due to the diverse nature and composition of groups and collective goals (Guy and Marvin, 1999), competition is less important when cities share ideas for sustainability transitions, since they all have the same goals (Keiner and Kim, 2007).

How does this process of sharing ideas and solutions take shape? Geels and Schot (2010) highlight the importance of bricolage for socio-technical transitions, i.e. vernacular constructions and interpretations that rely on the resources that are available to a certain society. However, it is clear that in many cases those societies that have not had the resources to develop their own technological solutions must rely on those who have. This obviously represents a good opportunity for technology suppliers to exploit international markets, since in many cases their own markets could easily be saturated (Kanda et al., 2015). In a sort of endless cycle, foreign providers have to consider local actors, ingenuity and vernacular knowledge, since trying to find magic-bullet solutions diverts attention and resources from other more fundamental problems (Katz and Altman, 2007). Therefore, both implementing cities and technology suppliers must ask themselves if cities can simply adopt technologies that have been developed under different contexts when urban sustainability is the goal. It is also important to consider the ability of technological solutions to adapt to the cities' needs and realities. For this, cities and technology providers must find a meeting point somewhere in between. These discussions will be central to this thesis.

1.2. Aim and Research Questions

When discussing sustainability transitions, it is important to understand how the processes of technology selection, implementation and use take place. This thesis analyzes how a problem is understood and a collective goal such as environmental sustainability is formed in cities, and how local actors might influence the direction of their transition into a more sustainable state. The aim of this thesis is thus to analyze the role that environmental technology plays in the solution of environmental problems in cities, and discuss models and conditions that can facilitate the processes of selection, implementation and use of environmental technologies in and by cities.

Two research questions (RQ) support this aim by making it possible to explore deeper and gain a closer understanding of the problems being dealt with. In the end, by answering these questions it

will be possible to conclude on the aim of and discuss some of the implications found to be relevant for this research, now and in the future.

Acceptance of environmental technology solutions

The processes of selecting, implementing and using technology can differ greatly among cities, even if located closely in geographical, political and/or cultural terms. The emergence of popularly elected local governments, decentralization processes and the extensive access to information that the inhabitants of many cities have today, have created conditions under which technology selection, implementation, and use have become more complex (Robinson, 2011).

Cities face a myriad of problems and have perhaps even more technological options to address them, considering modern technological development, globalization and the ability to ship technology overseas, and the enormous competition that liberalized markets have created (Simmie, 2003). It is possible that not all cities have the knowledge or ability to solve the problems that emerge. This suggests the need to understand why certain solutions, even if implemented and proven in real-life conditions, are rejected (or not considered as a solution) by some cities that could benefit from them, and have the resources required to acquire them. Also, what values facilitate or complicate the implementation of a particular technological solution by a potential city-customer, i.e., a city that has a problem and is looking for a technological solution to solve it (Hult, 2013; Pierre, 2005; Smith and Stirling, 2008). These are the foundations for the first research question.

RQ1: How do technology adaptation processes for the solution of urban environmental problems take place in cities?

It is important to understand how these processes work and how initiatives to implement certain technological solutions emerge. As will be discussed in Chapter 3, this thesis mainly relies on a case study methodology for the analysis of the necessary conditions (besides their actual technical capability) for those solutions that make up part of a city's everyday life and help it to solve the environmental problems it faces. By focusing on the similarities rather than on the peculiarities, the cases are expected to contribute with conclusions and solutions that could be applicable to a wider variety of cases. For instance, groups of cities within certain geographical areas share similar or the same solutions to a problem they all face. By following the development of these solutions, it is possible to understand how their similarities work in favor of successful technology implementation. In this way, it is possible to identify critical turning points and characteristics that can facilitate or complicate the implementation and use of technological solutions. Also, it is possible to address this question by focusing on local actors and the interactions among them and with technology. Findings can also be strengthened by focusing on characteristics that could be more inherent to technology as such, rather than to the potential implementing venues. This can be done by discussing similarities among different cases of technological solutions.

The benefits of environmental technology

Modern cities are finding benefits from improved environmental performance, besides health and livability. Globalization and the free movement of people, capital, industry and goods have created similar conditions that are shared by different cities; i.e., some sort of standardization phenomenon has taken place in some spheres of city life. Because of this, new values have emerged: many cities see themselves as companies; they have become entrepreneurial and are competing for resources in national and international markets (Butu, 2014; Furlong, 2014; Hodson and Marvin, 2009; 2010; Simmie, 2003). City governments acknowledge the environment as a crucial point for their attractiveness and the kind of attention that they get from abroad, and thus for their ability to secure better living conditions for their citizens (Hodson and Marvin, 2009). These concerns are considered by the second research question.

RQ2: How do cities benefit from environmental technologies?

In this sense, it is important to understand how cities direct their sustainability transitions with the help of technology, in which sectors of city life they focus to lever these transitions, and which actors are central to this process. Findings from the case studies can be used to influence transition strategies or to better understand ongoing processes in other cities.

1.3. Environmental Technology: Establishing the boundaries

The term "environmental technology" is widely contested (Guziana, 2011). Although this will be the term used in this thesis, other terms used to refer to the same or similar technologies can be found in the literature, e.g. "cleantech," "cleaner technology," and "green technology" (see Guziana (2011) for a discussion). This is in part because virtually any technological innovation can be considered as environmentally friendly, since it is inevitably compared with previous versions of this technology or with a different technology designed to address the same problem.

The term can be deceiving and may even express environmental intentions where there are none; it can be easily used to label traditional innovations (Markusson, 2011). For example, an engine or a component that makes a vehicle consume 50% less fuel than its predecessor can (and most likely will) be considered as environmental technology. That does not solve the problem of emissions, non-renewables depletion, and non-conventional fossil-fuel extraction techniques. Another example could be software that helps to optimize energy consumption in a steel mill. Compared to previous production processes, this tool could help to decrease energy-related emissions and maybe material use. But that does not solve the problem of emissions and ecosystem disturbance from material extraction in the long term, or necessarily direct this sector into absolute decoupling of emissions from production. The divide between optimization technology and environmental technology can thus be blurry.

On a similar note, utility companies are also seen as "environmental technology companies." For example, Statistics Sweden (i.e. the governmental agency responsible for producing official statistics) includes their activities in their report about the environmental technology sector, as they are classified following the same codes as private companies (Statistika Centralbyrån, 2015). Although the services they provide are not normally labeled "eco", "green", or "environmentally friendly" (e.g. drinking water, heat, and electricity), the technical systems they use for transformation or distribution are (Montoya Brand, 2005). Can these systems be called "environmental technology" without comparing them to the available alternatives? This is a tough question. The Swedish Government (2014), for example, defines environmental technology as "[...] goods, systems, processes and services that offer clear environmental advantages *in relation to existing or alternative solutions*, seen from an ecocycle perspective" (emphasis added). This example is relevant to this question since Sweden is considered in many spheres to be at the forefront in the development and implementation of environmental technologies (see e.g. World Wildlife Fund, 2014).

Perhaps even more complicated, a technology that is classified as environmental today (e.g. because it solves a problem of the present) might be found to be detrimental in the future (e.g. because new problems emerge), or simply replaced by a "more environmental" alternative. A good example of this can be motorized vehicles, which solved the problems of noise (e.g., from horses' hooves) and waste (e.g., manure and carcasses) in cities (see Morris, 2007). Today, motorized transportation is criticized for high fatality rates and as one of the main contributors of pollution (ironically, including noise pollution) and climate change (see e.g. International Energy Agency, 2013). This is called the Collingridge Dilemma: efforts to control technology development face first an information problem, since impacts cannot be easily predicted until the technology is developed and used, and second a power problem, since once the technology has become embedded, change or control are difficult (Tannert et al., 2007). One arrives again at the concepts of problem shifting and unintended consequences, but from a different starting point.

These are just examples, but many can perhaps identify the difficulties of agreeing on what environmental technology is. The term is deceiving in the sense that by hearing it, one gets the impression of being able to find examples and classify technological innovations as environmental (Markusson, 2011). But in reality, it is quite challenging to objectively and unequivocally define such a category (Guziana, 2011). For this reason, this thesis will handle environmental technology as any type of technology that aims at solving or reducing the impact of a specific environmental problem (regardless of the cause), or that resulted in the solution or improvement of an environmental problem (regardless of the original intention).

1.4. Approach of this study

This thesis will not discuss prioritization between the different spheres that commonly comprise sustainability models, i.e. environmental, economic and social (see e.g. Ayres et al., 1998). Instead, the

attention is devoted mainly to the environmental sphere, especially from an urban perspective. This means that mostly environmental problems will be alluded to (e.g. air, water or soil pollution, emissions of greenhouse gases, deforestation, biodiversity loss, etc.) when talking about sustainability or sustainability transitions, and attempts to address them by using technology. However, these problems will not be quantified or discussed in detail, as the focus will be put on environmental problems as a general concept. Different cities face different environmental problems, and the interest of this thesis is to focus on the dynamics of the process of adaptation of technology that can help to solve them.

There are numerous relevant discussions about the rebound effect of technology (see e.g. Druckman et al., 2011; Greening et al., 2000), and the actual effect of e.g. some energy efficiency measures on emissions targets. It is also important to acknowledge that material and energy efficiency measures and technologies, although leading to relative decoupling (e.g., in terms of economic output, ton-CO_2/USD), do not necessarily lead to absolute decoupling (see e.g. Andreoni and Galmarini, 2012; Giljum et al., 2005). However, unintended negative consequences are not addressed in this thesis unless considered necessary to illustrate a particular point. Problem shifting and the rebound effect will be thus excluded from the analysis.

Social (e.g., inequality, poverty, and health) and economic (e.g., employment, growth, and development) issues will certainly be used to support many of the claims (especially as encountered in the case studies) because they cannot be disconnected, and affect or are affected by the other spheres. However, these issues will not be examined in depth, but only with an illustrative purpose or as scaffolding for supporting the construction of the analyses presented.

1.5. Thesis outline

This thesis is divided into two parts. **Part I** is comprised of five chapters and represents what is called *kappa* in Swedish, and can be called *cover essay* in English. The idea of this part is to discuss and summarize the research process and the conclusions in detail, and to connect the different appended articles. **Part II** contains five scientific articles in different stages (i.e. published or under review). These articles contribute to each one of the research questions, and ultimately, to the aim of the thesis. Table 1 provides an overview of the two parts and their contents.

Part I starts with the Introduction, which provides a short discussion on what the value of the topic is for research, describes the aim and the research questions, and delimits the study by discussing the scope and the limitations. The theoretical background is provided in **Chapter 2**, which discusses theories and models considered to be relevant to address the aim and frame the analysis and the discussion of the results. Once the theoretical background has been laid, **Chapter 3** explains the methods used for the realization of this thesis. The methodology section explains and discusses the methodological choices, the justification of these choices and possible limitations and shortcomings.

Next, **Chapter 4** presents the findings from the five appended articles and discusses each article's connection to the aim and the research questions defined in Chapter 1. **Chapter 5** then presents an in-depth discussion of the results, their connection to the theories analyzed in Chapter 2, and their contribution to knowledge in this field. This discussion is followed by the conclusions, and a reflection on future research possibilities based on the experience of this thesis. Part I ends with a list of the **References** used in this thesis and an **Annex** that provides a list of additional publications produced during the research education process, and that are closely related to this thesis' topic as well.

Table 1: Structure of the thesis.

	Chapter/Article	Content/Title
Part I	1. Introduction	Introduction to the thesis, description of the aim and research questions, definition of the scope and limitations.
	2. Theoretical Background	Description and discussion of theories and models used.
	3. Methodology	Description of the methodological choices.
	4. Adaptation: Learning and the Role of Intermediaries	Findings and description of the contribution of the articles to the aim and research questions in this thesis.
	5. Discussion and Conclusions	Discussion of the research results, conclusions, and reflection on future research possibilities in relation to this thesis.
	References	List of references used in the cover essay.
	Annex	List of publications produced during the research education process.
Part II	Article 1	Governmental export promotion initiatives: awareness, participation, and perceived effectiveness among Swedish environmental technology firms.
	Article 2	Lessons from the spread of Bus Rapid Transit systems in Latin America.
	Article 3	Protecting socio-technical regimes for advancing urban sustainability transitions.
	Article 4	A city's utility company as an axis for its sustainable development - A case study of EPM of Medellín, Colombia.
	Article 5	Exporting the Swedish Model for Sustainable Urban Development: What has changed?

Part II presents the five articles produced during this research process. Two of them are published and three are under review in different scientific journals. Each article contains its own discussions and conclusions, which means that no additional discussion or in-depth analysis of the articles is presented in this part.

2. Theoretical Background

In this chapter, relevant theories and models for the advancement of this thesis are discussed. Three fields are of particular relevance to this thesis, namely Transition Theories, Diffusion of Innovations, and Governance. These fields, their terminologies, and their models provide the foundations for subsequent discussions as well as strengthen the rationality and verifiability of the claims and analysis presented in subsequent sections.

2.1. Introduction to this chapter

This chapter discusses tools provided by different research fields and their relevance to the aim and research questions presented in this thesis. Most importantly, the intention is to highlight the connection among them and how they can be used to better understand the environmental technology adaptation process in cities.

This connection is presented in a circular manner, i.e. the departure point becomes the arrival point. Discussed will be how the goals concerning urban sustainability are defined collectively in cities, how these goals require orientation and the understanding of the different actors, conditions and processes influencing change, and which tools operationalize action in order to achieve the traced goals. In the following sections, this discussion is presented in more detail. However, Figure 1 offers a schematic depiction of the reasoning presented in this chapter.

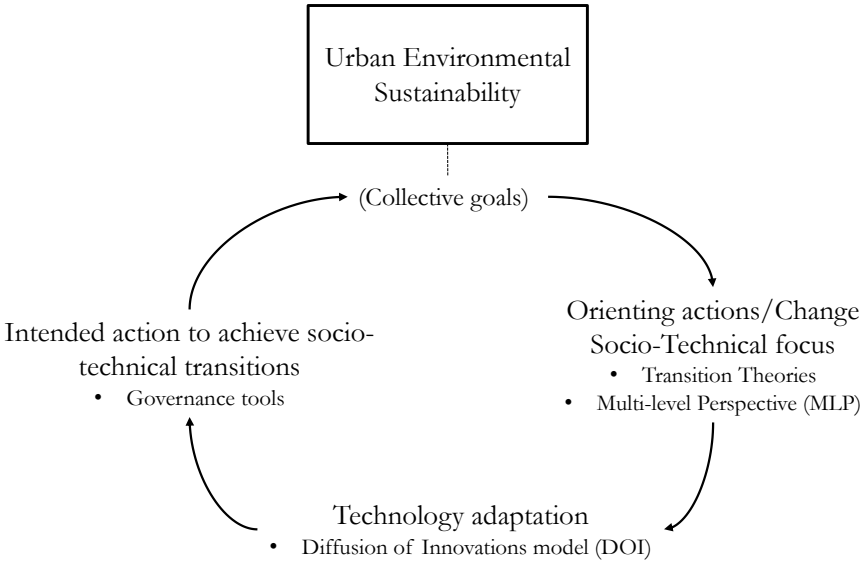

Figure 1: Schematic depiction of this thesis' theoretical framework.

Before looking at the different fields and tools in detail, it is important to discuss why knowledge-sharing between and among cities is important for the achievement of the greater goal of global sustainability, and why cities play such an important role in this process.

2.2. Sharing solutions to urban problems – Local or global sustainability?

In this thesis, cities, environmental technology, and environmental sustainability are not seen as separate, independent concepts. On the contrary, the intention is to highlight the connections between them and analyze the dynamics of technology adaptation needed to address many of the collective environmental problems we are facing. The concept of adaptation is central to this thesis because it is recognized that knowledge sharing between different social groups is an important component of global sustainability transitions, especially if one considers the urgency with which some of these problems need to be tackled (see e.g. German Advisory Council on Global Change, 2011). However, this thesis highlights that this sharing process is far from being straightforward, and that a plug-in approach to technology implementation faces tremendous obstacles. The need to understand the dynamics of technology adaptation is thus seen as crucial to facilitate global sustainability transitions.

Cities are seen as unavoidable elements in the pursuit of global sustainability (Bulkeley and Betsill, 2005; Marceau, 2008). However, a strict focus on the notion of urban sustainability is inevitably biased towards a geographically defined area (i.e., the city). This area-bounded application of the term is problematic for three reasons. First, sustainability is a collective good. Its achievement strongly depends on coordination, and especially on the agreement of the goal and the direction (something that has proved difficult, as experienced in global climate negotiations so far). This is because unilateral changes often have a small chance of success (Hansson, 2010). Second, there is no agreed-upon definition of what "sustainability" means, and certainly no transnational urban sustainability language, as this is largely dependent on temporal and spatial perspectives (Hansson, 2010; Hult, 2013). Third, sustainability efforts are dependent on existing social structures. In particular, the dominant economic system creates very strong incentives/demands on cities to compete in international markets (Bulu, 2014; Hodson and Marvin, 2009; 2010; Simmie, 2003), a competition directed at innovation and economic growth (Marceau, 2008; Simmie, 2003), which many times leads to increased consumption and environmental disturbance.

It is impossible to consider the role of cities in sustainability transitions and ignore their technological component; technology *makes* the modern city (Gandy, 2005). In many cases, in fact, the upgrading of cities is thought of first in terms of their technology (Bulu, 2014). However, the decision of which technology to focus on is not free of challenges, considering the long development times and large investment requirements, the sometimes long period of time required to see the benefits, and the numerous actors involved in or affected by such a decision (Alkemade and Suurs, 2012). This is an interesting and relevant process to analyze and understand, because cities are offered a myriad of solutions to their problems, many times coming from foreign technology suppliers and their governments, who see a potential market opportunity (Kanda et al., 2015). By understanding the adaptation process, both the potential implementer and the supplier can benefit. The former, on the one hand, can benefit from a better understanding of the role of the different actors involved, and as a result, a better use of governance tools that can facilitate the selection of the most appropriate technological solution to their problems. The latter, on the other hand, can benefit

by being able to make better-informed decisions, designing more flexible and adaptive solutions, and identifying the obstacles their solutions face in order to approach them accordingly. Successful implementation thus relies on bidirectional adaptation: both potential implementers and suppliers must acknowledge the need to translate socio-technical considerations between contexts.

In summary, when studying urban sustainability an important question must be considered: how can cities, collectively, contribute to global sustainability? However, it must also address the dominant economic system, which relies on competition and innovations (Simmie, 2003). In this thesis, those questions are dealt with by analyzing how ideas that address sustainability problems in cities can spread between contexts, and what conditions facilitate or obstruct this process. Environmental technology diffusion is seen as an important first step to reach global sustainability (del Río González, 2009; Kanda et al., 2015; Vollebergh and Kemfert, 2005). It is evident that some cities will benefit economically from other cities acquiring their solutions, but the main intention in this thesis is to focus on the adaptation process and the positive impacts of environmental technology diffusion between and among cities for local and global environmental sustainability. Different theories and fields address these concerns. In this section, the ones used in this thesis will be discussed. In any case, the decision of a city to "go sustainable" has to start with the establishment of a goal, a state that society wants to achieve. In other words, change has to have an orientation.

2.3. Orienting transitions

Modern societies have become extremely complex, particularly compared to earlier civilizations such as small groups of nomadic hunter-gatherers or medieval societies. As human groups stopped wandering and settled, new challenges arose, many of them leading to the specialization of their members. Villages would become cities and would require coordination and internal organization in order to avoid collapse. An important component of this internal order is what can be described as *collective goals*. This is not to say that small families or groups in the past did not share goals, but the scale and the need for coordination has never been as great as in modern times (Hansson, 2010). Spatial closeness and the need to rely on others for the satisfaction of basic needs (because of specialization) result in a feeling of togetherness, in the impression that an agreement on what is the proper way to preserve or improve our quality of life has to be reached. This agreement requires two conditions: first, the recognition and definition of particular problems or threats to that way of life, and second, the definition of what is the expected state to be achieved once it is solved or overcome. Hillman et al. (2011) describe these two conditions in terms of the *cognitive* (i.e. the framing of the problem) and the *normative* (i.e. what society wants) mechanisms.

These conditions are conjoined together in a process that is nurtured by different societal actors. The first one, for instance, can result from a collectively experienced event (e.g., a drought, a financial crisis, or an increase in crime rate), or from experts or individual citizens who want to alert the rest of society (e.g., climate change). The second condition can be influenced by cultural values

embedded in the society (e.g., environmental protection and social cohesion) or also by individuals and their personal values (e.g., politicians, industrial leaders, academicians or social leaders). In any case, these characteristics are particular to each society and are embedded in it. Many may be aware of the difficulties of trying to influence these values externally, and of relying exclusively on this type of interventions to achieve results that are beneficial for the society in focus (Hodson and Marvin, 2009). It will be later discussed how important this is for the intentions of addressing urban environmental problems with technology. For now, the focus will be put on the actual characteristics and internal components of the process mentioned at the beginning of this paragraph.

Socio-Technical Transition Theories try to address the cognitive and normative components of sustainability transitions. They discuss how societal change, or better yet, transitions into better socio-technical systems, can be influenced into a desired path (Grin et al., 2010). From the perspective of Transition Theories, it is better to talk in terms of transitions instead of change. This is because it is understood that a particular collective goal must be achieved through a set of subsequent, reinforcing and connected changes (Meadowcroft, 2009), not one single event. From this discussion something that is central to Transition Theories becomes evident: the recognition of the interaction between society and technology. This is to a great extent explained by the fact that Transition Theories have their roots in Science and Technology Studies (STS), for which such interaction is central (Geels and Schot, 2010). In fact, Bijker (2001) talks about a "technological culture," referring to how modern societies are constituted by science and technology, and the fact that the different resources and components, and their roles, have to be considered when trying to understand such transitions. It is through technology that social interaction takes place, and through societal institutions that technologies can function (Bijker, 2006).

Although Transition Theories have been recently used to analyze transitions from current states into more sustainable states, or "sustainability transitions" (Smith et al., 2005), Rotmans et al. (2001) claimed that they do not propose a specific transition, but rather explore how governance tools can help *any desired* change (more about governance tools will be discussed in Section 2.5). It does so by focusing on long-term thinking, on multiple domains, actors and levels, and on feedback learning mechanisms (Rotmans et al., 2001). Influenced by systems theory, Transition Theories relate long-term developments to stocks and short-term developments to flows, and analyze them by dividing social structuration into three different levels: micro, meso and macro. This division will be discussed in more detail in the following section.

2.4. Structuration of local practices: The multi-level perspective approach

The focus of Transition Theories on three different levels of social structuration has been mentioned above, and will be discussed in the subsequent sections. From the simplest definition of the micro level being composed of individuals, the meso level composed of networks and communities, and the macro level composed of conglomerates (Rotmans et al., 2001), this framework has evolved to

consider more complex relations within and among the levels. An approach that has become particularly popular for the analysis of socio-technical transitions is the Multi-level Perspective (or MLP; see e.g. Geels, 2002; Smith et al., 2010).

This framework kept the multi-level approach native to Transition Theories, but included a deeper analysis of the intra and inter-level dynamics. The three levels of societal structuration were re-baptized into socio-technical landscape (macro level), socio-technical regime (meso level), and niche-innovations (micro level). These levels are depicted as horizontal and parallel constructions, whose rigidity, and thus the difficulty to influence them, depends on how structured their activities are (Geels and Schot, 2010).

The MLP relies on a term that describes the dominant values and activities at the meso level: regimes. The concept of regimes is a somewhat controversial one (some critiques to this approach will be addressed below) and refers to the stability of the activities and interactions happening between and among different societal components and the actors involved. These activities are dynamic, but governed and stabilized by the dominant practices of the current regime. However, eventual shocks to the social system create opportunities for the levels to interact, e.g. a war, an extreme weather event, or global negotiations on climate change (Geels, 2002). (It must be noted that the MLP has received criticism for the way in which it addresses the origin of these shocks, i.e. the landscape level; see Geels, 2011.) Developers, supporters and other actors at the micro level (i.e., where most innovations emerge and are protected in a sort of niche, see Smith and Raven, 2012) find an opportunity to try their innovations at the meso level, where they can be tried for compatibility and acceptance. Regimes are thus a process, not a fixed state. Their dynamism or stagnation depends on what is happening on the remaining levels of structuration and, as it will be discussed in Chapter 5, on their interaction with other regimes.

The concept of regimes, central to the MLP, has received substantial criticism. Markard and Truffer (2008), for example, mentioned that their delineation is challenging due to this concept's suitability for the analysis of many empirical cases at different levels (e.g., it can be molded to analyze a complex sector at the sectoral or at sub-sectoral levels, with the same results). Furthermore, Jørgensen (2012) says that the concept of regimes is not clear in regard to their existence and emergence, and the extent to which they address power structures. Walker and Cass (2007) criticize the original framework for being deliberate and hierarchical, and Hodson and Marvin (2009; 2010) highlight the fact that cities are not given the attention they deserve by the framework, which is relevant for this thesis considering that cities are where most interactions between societal actors and technical systems take place in modern societies (i.e. the arenas where regimes emerge, remain and undergo transformation).

Despite these criticisms, the MLP has been widely used to analyze and describe numerous cases of socio-technological transitions (see e.g. Fallde and Eklund, 2015; Konrad et al., 2008; Raven, 2007; Smith et al., 2010; Söderholm and Wihlborg, 2014). The popularity of this framework can be explained to a large extent by the first point of criticism mentioned above, i.e. its malleability and applicability to numerous empirical cases. What the MLP has created is a common language: a set of

terms that many people understand and use, and thus find as a platform for the discussion of sustainability transitions (Smith et al., 2010). This is not something new, as exemplified by older terms such as "sustainability" and its variants (e.g., urban, social, environmental and economic sustainability). This being good or bad depends on the assumptions and the academic style, as Geels (2011) comments. The MLP framework and its terminology will be used in this thesis. More than focusing on the actual framework and theories, it will be used as a platform in which to support the discussions, making use of its "common language." This does not mean that the criticisms will be ignored, though; when Transitions or MLP terminology are used, an explanation of what it means or in which sense it is used will follow.

2.5. Technology adaptation: The social acceptance of technology innovations

The question of how innovations diffuse is an important question. It has been a very popular research topic, especially after World War II, when Schumpeterian economics took off and the idea of economic growth became a strong driver for governments (Sarkar, 1998). Schumpeter (2003[1943]) claimed that institutions, technological progress and innovators were the promoters of economic growth. This is not just any claim, as it has to a large extent justified the reliance on innovations, mainly technological, for the improvement of nations during the last seventy years. Although the processes of invention and innovation are central to the development of new technology, the process of diffusion is what actually determines the extent to which this technology will be put into productive use (Sarkar, 1998).

It has been discussed that Transition Theories and the MLP framework touch upon this topic, because these frameworks consider technological innovations being tested and implemented at the socio-technical regime level as central for transitions, and particularly sustainability transitions. In this sense, the MLP tries to explain how technical innovations emerge in environments (called niches) where they are protected by e.g. their developers or a particular social group that believe in their benefits. These protected innovations are however not part of everyday life (i.e. socio-technical regimes), and will not be until they get a chance to prove their relevance and usability in mainstream social activities.

There are numerous theories and models of innovation diffusion and social acceptance, some of them dating back to the 1950s (Sarkar, 1998). According to Sarkar (1998), there are three dominant types of models in the literature of diffusion of technology: epidemic models, neoclassical equilibrium models, and neoclassical disequilibrium models. The first group is characterized by the assumption that the number of adopters of a certain technology increases as non-adopters get in contact with those who have already adopted it, or when they gather information about the technology. Here, potential adopters are assumed to be "passive recipients" as they do not actively seek information. The second group of models describes the diffusion process as a dynamic process; i.e., consecutive shifts in equilibria due to a given stimulus and the consequent adjustments of

adopters. The third group treats diffusion as a selection process in which the characteristics of the technology, the behavior of the adopters, and the conditions of the environment determine the diffusion of emerging, contesting technologies. These models have been vastly used for the modeling and forecasting of the diffusion of technology, with a strong emphasis on economic growth. Meade and Islam (2006) provide a summary of the nature and frequency of references to studies in this area, with a marked dominance of marketing and forecasting.

The second group (i.e. neoclassical equilibrium models) has been widely adopted by e.g. the corporate world due to their intra-firm approach (see e.g. Chuttur, 2009). One reason why this group has received so much attention from this sector might be its focus on individual choices and organizational issues. One criticism is that these models tend to focus on a very specific group of individuals, with very particular characteristics: they all perform a specific task in relation to a specific technological system and belong to a homogenous group (i.e. the professionals working in that sector or with that particular type of technological system). This makes sense to the corporate world, because a diffusion model tested on people that will probably never be exposed to that particular technology will surely generate ineffectual results.

However, that is not the case for other technologies that are used by more diverse groups of people, have different uses (think of e.g. transport or wastewater treatment technologies), have different goals, and do not necessarily follow hierarchical power structures, as is many times the case in organizations. In organizations, hierarchical arrangements and authority structures are particular, which is why this group of models will not be used here. In this thesis, it is necessary to consider models that offer a wider vision of the context and the influence that society has. In cities, hierarchies can be blurrier and stakeholders more numerous; there is a social contract, rather than a professional one. Societies themselves decide how to control that this contract is being fulfilled, at least the most democratic ones.

The MLP can be considered as a model belonging to the third group, i.e. neoclassical disequilibrium models, because of the attention it gives to the characteristics of technology, the behavior of the adopters, and the contextual conditions affecting the emergence and diffusion process. In MLP terms, some concept of "levels of structuration of activities" takes shape in this approach. In neoclassical disequilibrium models, technological diffusion is defined by the interaction between three levels (Sarkar, 1998): the micro level (i.e., the competitive advantage of different technologies), the meso level (i.e., behavioral attributes of agents, or *regimes*), and the macro level (i.e., the economic and institutional environments). In this sense, neoclassical disequilibrium models address criticisms that earlier approaches had and that abstracted diffusion and technological changes from important contextual conditions such as culture, values, and the ecological system (Sarkar, 1998).

The disadvantage of using neoclassical equilibrium approaches for this thesis' goals is its strong emphasis on individual choices and hierarchy. Epidemic models offer an abstraction of this approach in order to analyze more easily the aggregate phenomenon of diffusion (Geroski, 2000). Geroski (2000) claims that this simplification is useful when externalities and competitive effects are created by the density of use (intensity, in the case of cities), something that was discussed in Section 2.1.

The Diffusion of Innovations model (DOI) is a good example of an epidemic model. It was originally developed with a focus on the diffusion of innovations within the agricultural sector, but began to be used in other fields over time (see e.g. Bertrand, 2004; Rogers, 2002). This model is more flexible and offers a wider picture of societal acceptance, without such a marked influence of personal choices. With this, it is not meant that the model does not address individual choices, but that, in comparison to other models, more importance was given to external influences, and to the dynamics of the innovation being introduced and the systems already in place (N.B. not only **technical** systems).

These dynamics are expressed by Rogers (2003) through five factors that define the innovation's rate of adoption:

- **Relative advantage**, or the degree to which an innovation is perceived as better than the system it supersedes.
- **Compatibility,** or the degree to which an innovation aligns with existing values and past experiences.
- **Complexity,** or how difficult a solution is perceived to be.
- **Trialability,** or the degree to which an innovation can be put to test on a limited basis.
- **Observability,** or the degree to which the results are visible to others.

The MLP and DOI are not only compatible, but also complementary. It can be noticed that Rogers' DOI does not explore in depth the emergence of innovations, but their acceptance and diffusion. The MLP offers a more detailed picture of this emergence process. On the other hand, the MLP does not focus very much on explaining diffusion or modeling it. It describes the process of innovation insertion into the mainstream activities (i.e. socio-technical regime) following a window of opportunity that opens up due to some great event at the socio-technical landscape level, but not the actual process of acceptance or rejection. (It does however touch upon alignment with the dominant regime and mentions that some innovations fail and some succeed, as represented by small arrows in the MLP model; see Geels and Schot, 2010.) Figure 2 provides a schematic explanation of how the MLP and DOI complement each other, from the perspective of this thesis. Although the original MLP model describes three parallel levels of structuration of activities, the adaptation process of interest in this thesis occurs between the micro and meso levels, and this is why the macro level is not depicted. DOI provides tools to better understand the process of adaptation of innovations emerging under the protection of niches, or developed under different contextual conditions. This process is represented by the dotted circle in Figure 2.

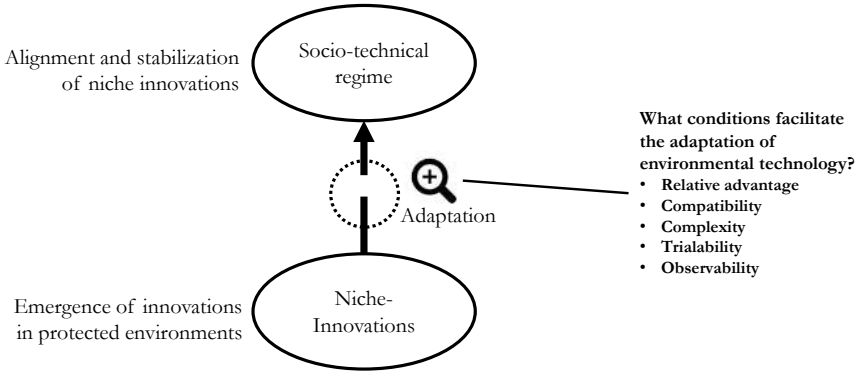

Figure 2: The contribution of the Diffusion of Innovations (DOI) model to this thesis (based on Geels and Schot, 2010).

Models of the emergence, acceptance and diffusion of innovations, and of societal processes that can be influenced towards a desired direction (e.g., a more sustainable state) have been described. There is however an important aspect to add, and that is the actual mechanisms that motivate society to mobilize in any given direction (i.e. in the sense of pursuing collective goals through action or non-action), and facilitate or hinder the acceptance and implementation of certain technological concepts and solutions (see e.g. Baas, 2005). This will be discussed in the following section.

2.6. Governance: A central concept for successful technology adaptation in cities

Governance brings the adaptation discussion to a full circle (see Figure 1). Fukuyama (2013:350) defines governance as "a government's ability to make and enforce rules, and to deliver services, regardless of whether that government is democratic or not." He deliberately leaves out democratic accountability from the definition since he claims that democracy and governance are not always mutually supportive, adding that "[a]n authoritarian regime can be well governed, just as a democracy can be maladministered" (Fukuyama 2013:351). However, due to the nature of this thesis and the topics involved, the focus is instead put on a broader set of actors, and on a specific, collaborative type of interaction. Therefore, governance is understood in this thesis based on a broader, participatory definition. Van der Heijden (2014:6) provides such a definition: governance is "an intended activity undertaken by one or more actors seeking to shape, regulate or attempt to control human behaviour in order to achieve a desired collective end." Two mechanisms that support the pursuit of collective goals in society (i.e. normative and cognitive) are conjoined in a process that is addressed by Transition Theories, which analyze how governance tools can influence change (Rotmans et al., 2001). Figure 3 is a continuation of Figure 2, and provides a schematic description of the contribution of governance tools and mechanisms to the understanding of technology adaptation, as a complement to DOI.

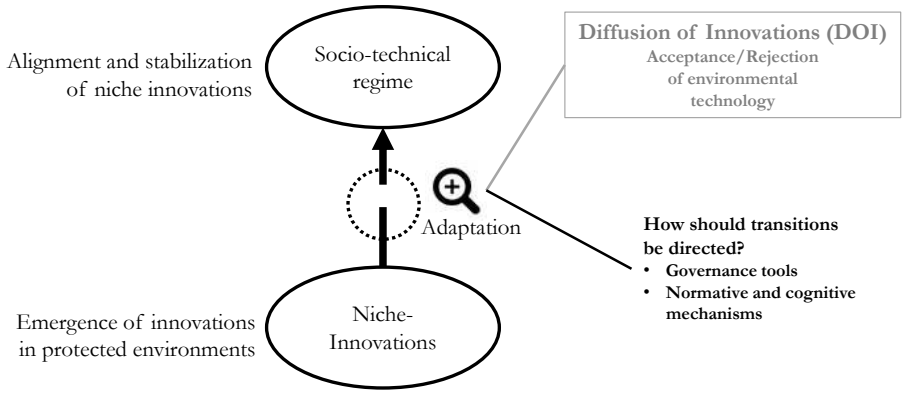

Figure 3: Contribution of governance tools and mechanisms to the understanding of technology adaptation (based on Geels and Schot, 2010).

In line with the definition of governance adopted in this thesis, Peñalosa (2011) says that cities are expected to be places for the practice of democracy, and for the construction of social equality and inclusion. Here democracy, more than a strict term referring to political representation by a majority, refers to participation, to the possibility of taking part in the shaping of the place where one lives (see e.g. Walker and Cass, 2007). Geels and Schot (2010) claim that interpretation and creativity are important components of technological development and acceptance by socio-technical regimes, a process they call "bricolage." Such components are better exercised through involvement and participation.

Due to the shared nature of the urban environment, governance is central when talking about urban sustainability (Hillman et al., 2011). According to Hillman et al. (2011), social initiatives are an important driving force for transitions into sustainability, many of these initiatives happening outside traditional policy instruments and taking a bottom-up shape. Smith et al. (2014) provided examples of such initiatives in their study of grassroots innovation movements, while Baas et al. (2014) showed the importance of these movements for the promotion of energy independence and renewable energy systems.

In cities, agency is facilitated by participation, as well as collective experimentation and learning (Smith et al., 2005; Voß and Bornemann, 2011). This claim reinforces the theoretical cycle mentioned at the beginning of this section, since Transition Theories receive criticism for underplaying the role of agency (Geels, 2011). Governance tools can facilitate the implementation and use of innovations by allowing societies to understand their compatibility (or incompatibility) with existing values (Rogers, 2003), and the further building of networks that can speed the process of spreading crucial information for the diffusion of innovations (Rogers et al., 2005).

Modern cities have the possibility to access a vast amount of information thanks to the extensive networks that information technologies have facilitated (Rutherford, 2011). This has been beneficial for many cities that have learned from the experience of others, both good and bad (World Business Council for Sustainable Development, 2009). Rutherford (2011: 22), for example, understands the city as "an assembled space of parts of other places." How is this process of learning taking place? First, locals agree on a particular problem that needs to be solved. Second, they have to agree on a way to solve it, and on the networks they need to build and the knowledge they have to gather in order to do so (Hillman et al., 2011). Similarly, Loorbach (2010) discusses the "transition management cycle," and mentions the additional need to undertake experiments, monitor and evaluate these experiments, and "adjust the vision, agenda and coalitions" based on the results. However, not all technological transitions can follow this pattern. For example, large technical systems (which are central to Transition Theories) pose challenges when it comes to experimentation and adjusting. Not only is it expensive for cities to do this, but also highly impractical, due to the rigidity of existing infrastructure (see e.g. Wallsten et al., 2013). Again, looking into other cities to see how they have dealt with the same or similar problems seems to be a natural first step.

The fact that cities are looking for solutions to their problems has created strong competition in the international markets, not least in the "sustainable city market." Cities compete for skilled professionals, cheap resources and even tourists (DiGaetano and Strom, 2003), and look for ways to make it to the top of city-ranking indexes (Bulu, 2014). They inevitably see technology as a way to position themselves positively (Bulu, 2014; Hodson and Marvin, 2010); in other words, cities need to publicize themselves (Timms, 2011). The emergence of the "entrepreneurial city," a competitive entity that sees technological change and innovation as one of its main concerns (Simmie, 2003), raises the need to develop new governance tools to respond to external pressures from these markets (Hodson and Marvin, 2009). This is particularly important when talking about urban sustainability, since market pressures can often leave little room for long-term environmental conservation goals (Polk, 2011), particularly for those that are shaped locally.

Cities must respond to growing international concerns about the role they play in global transitions to sustainability. This is relevant to this thesis since pressure comes many times in the form of paradigmatic ideas on sustainability–of abstractions of values and norms from dominant socio-technical models (Pierre, 2005) (e.g. from "global cities" or what McFarlane (2010) calls "the usual suspects"). Such ideas normally include certain technological innovations that are in line with these ideas and are inevitably attached to them, but that can be alien to the society implementing them (Hult, 2013; Wangel, 2013).

There is a limited number of so-called "global cities." Most cities are in fact what Hodson and Marvin (2010) call "ordinary cities." Many cities outside the global cities group have found and developed numerous solutions to common urban/societal problems, although it is common that only when globally attractive cities (e.g. Western and Northern European or North American cities) implement them, other cities follow suit (Peñalosa, 2011).Whereto are "ordinary" cities to direct their attention in their process of seeking ideas to solve the problems they face? Groups that are more compatible facilitate the emergence of the networks needed for learning and experimentation, and

the overcoming of obstacles to the transmission of information (Rogers et al., 2005). Innovations are first shaped by social processes, which means that users (in this case cities implementing them) play a central role in the analysis of socio-technical transitions (Shove and Walker, 2010).

Governance tools (e.g. negotiated agreements and covenants, partnerships and networks, and development and implementation processes; see van der Heijden, 2014) allow societies to define whose visions should construct the cities people want to live in, and which social interests and expectations produce such visions (Hodson and Marvin, 2010). They also facilitate the understanding of where the vehicles for achieving them should be found (Smith et al., 2014). In other words: governance tools support the process of understanding how transitions are to be directed. The interaction between existing systems (be it political, economic, social or technological) and new technologies must change in order to respond to local needs (Dolata, 2009) and align with vernacular common goals such as environmental sustainability. In fact, users of the new system inevitably try to "make sense" of it based on their experiences with and knowledge of the system being replaced, or those coexisting with the new one and serving a similar purpose (McLoughlin et al., 2000). Even with a technocentric approach to urban sustainability, the analysis of cities and their interaction with technology is fruitless if people, space and time are left out (Rutherford, 2011).

3. Methodology

In this chapter, the methodological choices are explained and their relevance to this thesis highlighted. The reliability of the sources and the collected data is also discussed in this chapter.

3.1. The research journey

This thesis is mainly the result of the second phase of my research education. The first phase focused on studying two megacities (i.e. Cairo and Mexico City) as arenas for the diffusion of environmental technology, and resulted in a Licentiate thesis (Mejía-Dugand, 2013), three conference papers (Kanda et al., 2012; Mejía-Dugand et al., 2011; Mejía-Dugand et al., 2012), a report to the funding agency (Mejía-Dugand et al., 2013a), and a scientific article (Mejía-Dugand et al., 2013b), which is included in this thesis (Appended Article 2).

The first stage of this research focused primarily on the recipient cities and local stakeholders; it had a clear bottom-up approach (see Mejía-Dugand et al., 2013a). However, making use of additional information collected about Swedish environmental technology suppliers during the first stage, a transitional study was performed with the intention to learn about the supply side before embarking on a second stage. This study was presented at an international conference and resulted in the publication of a scientific article (Kanda et al., 2015), which is appended to this thesis (Appended Article 1). The results from this study were useful for the second stage, which was designed to apply the knowledge acquired to actual cases of companies planning or running implementation projects abroad. With this in mind, a joint project was proposed together with Envac AB (a company within the waste management sector) and Tekniska Verken AB i Linköping (a municipal utility company). Envac, besides having vast experience in international markets, had recently opened a satellite office in São Paulo (Brazil) and was starting negotiations for implementation of its system in Medellín (Colombia). Tekniska Verken had long shown interest in exploring international markets, especially regarding its waste-to-energy technologies and know-how.

Given the experience acquired during the first stage and the ease of access to information, Medellín was suggested as the case to study. The city seemed a promising case of technology adaptation due to its recent improvements in social and environmental aspects and the strong role that technology played in them, and offered the opportunity to study the implementation of a particular technology (i.e. Envac's waste collection system) and the subsequent process of adaptation to the city's dynamics. In addition, this city as a case study was expected to provide relevant information on the phenomenon under study, in terms of quantity and quality, due to its contextual and temporal uniqueness. Flyvbjerg (2006) claims that this is a common strategy for the selection of cases.

The articles included in this thesis complement each other. The order in which they are appended suggests successiveness and facilitates the presentation of the discussions and conclusions in the cover essay:

- Article 1 studies Swedish environmental technology firms and governmental initiatives to promote and support their exports.
- Article 2 focuses on a technological solution (Bus Rapid Transit systems) in a particular geographical area (Latin America).

- Articles 3 and 4 focus on the city of Medellín and its utility company.
- Article 5 is based on UNHABITAT's World Urban Forum 7 and the Swedish delegation that attended the event.

The different studies will be discussed in more detail in subsequent sections of this chapter, but it is important to first describe the process that led to them, and to the writing of this thesis and the appended articles. A list of other publications produced during the research education process that are relevant to this thesis as well is provided in the annex.

3.2. The cover essay

The cover essay has the aim to summarize the research process and connect the different appended articles by presenting a joint analysis of findings and conclusions from these articles, summarizing conclusions and suggestions for further research. The writing process of this cover essay consisted of an additional literature review on the three main fields presented in the theoretical background and on case study methodology, the subsequent discussion of the different findings from the articles, and the conclusions in relation to the aim and research questions defined for this thesis. The cover essay provides a synthesis of learnings, findings and conclusions resulting from the research education process, and offers a joint analysis of the different results obtained in different studies and projects that comprised this process.

Article 1 was useful to understand how important the environmental technology sector is for promoting global sustainability and at the same time supporting economic growth. It was also useful to identify and analyze some of the obstacles that actors at the niche level find when trying to test their solutions under real-life conditions, or in a different context than the one where they were originally developed. The results from a survey sent to almost 700 environmental technology suppliers in Sweden were useful to get a picture of the export-oriented nature of this sector, as well as the difficulties of operating in highly competitive and saturated markets. It was also possible to identify the obstacles that governmental initiatives to promote exports face, and how the companies to which they are directed perceived their effectiveness in increasing their exports. This article gave useful foundations for answering RQ1 (How do technology adaptation processes for the solution of urban environmental problems take place in cities?). Discussed was how the Swedish government confronts the challenges posed by market failures by providing suppliers with different initiatives aimed to facilitate their export process. Among them, the need to develop new business models that can respond to opportunities in different regions, and the provision of communication channels that help companies to find collaboration partners, were found useful as foundations to address RQ1.

Article 2 gave important insights for the understanding of the processes of selection, implementation, and use of a particular technological innovation, i.e. BRT systems. By analyzing the historical development of the concept in the region, and highlighting the characteristics that

facilitated and boosted its spread throughout Latin America, it was possible to understand how this particular innovation overcame the barriers normally faced by technological innovations in general and environmental technologies in particular, as reported by several studies. It was also possible to identify key points that seem to have influenced the diffusion process. Regarding the research questions, this article addressed RQ1 (How do technology adaptation processes for the solution of urban environmental problems take place in cities?). It was discussed how modern cities are increasingly paying more attention to local conditions and the actors involved in any implementation project.

Article 3 contributed with the analysis of how technology, in the form of large technical systems, has helped the city of Medellín to achieve substantial improvements in its social, economic and environmental conditions. Also, it describes, explains and discusses how the city has managed to protect stability, maintain the direction traced in the past, and rely on the use of technology to promote further advancement in other aspects of city life. The article addresses both RQ1 (How do technology adaptation processes for the solution of urban environmental problems take place in cities?) and RQ2 (How do cities benefit from environmental technologies?). It discusses the definition of collective goals from an early stage in the city and the emergence of mechanisms that would ensure good coverage, the further development of its utilities, and resources for the improvement of its environmental performance.

Article 4 contributed with insights on how a city like Medellín, with its 2.5 million inhabitants, administers its large technical systems (i.e. water distribution, wastewater collection and treatment, energy transformation and distribution and telecommunications) for the improvement of its living and environmental conditions. Regarding the research questions, this article addressed both RQ1 (How do technology adaptation processes for the solution of urban environmental problems take place in cities?) and RQ2 (How do cities benefit from environmental technologies?). It discusses how the ruling elite trusted the city's modernization on the provision of reliable public services, and how the expansion of the utility company administering them has nurtured the city's entrepreneurial spirit.

Finally, Article 5 presented a case of technology implementation and discussed the conditions that can influence the decision of implementing certain technological solutions. It discusses how the export of technology inevitably drags along the export of values and social systems that can represent an obstacle for successful implementation. The article addressed RQ1 (i.e., How do technology adaptation processes for the solution of urban environmental problems take place in cities?). By being part of the audience during the whole-day presentation by the Swedish delegation, it was possible to witness the reception of urban imaginaries by locals as they were explained by the presenters. The article discussed also some of the conditions for locals to engage with new technological concepts, especially when coming from foreign actors.

The process of writing the cover essay is based on the different approaches used during this research. Case study methodology is the main methodological choice, supported by different data collection strategies. These strategies will be explained in more detail. For now, Table 2 summarizes the relation

of each article to the research questions presented in Chapter 1, the methodology used for each of them, and the data collection strategies used.

Table 2: Appended articles and their relation to the research questions of this thesis

Appended article	Status	Research question(s) addressed	Methodology*	Data collection strategy
1. Governmental export promotion initiatives: awareness, participation, and perceived effectiveness among Swedish environmental technology firms	Published in the Journal of Cleaner Production	1	Survey	- Literature review - Database building - Web-based survey
2. Lessons from the spread of Bus Rapid Transit in Latin America	Published in the Journal of Cleaner Production	1	Case study (instrumental)	- Interviews - Database analysis - Field studies
3. Protecting socio-technical regimes for advancing urban sustainability transitions	Under review. Submitted to the journal Cities	1, 2	Case study (instrumental)	- Interviews - Literature review -Field studies
4. A city's utility company as an axis for its sustainable development - A case study of EPM of Medellín, Colombia	Under review. Submitted to the journal City	1, 2	Case study (intrinsic)	- Interviews - Archival work - Field studies
5. Exporting the Swedish Model for Sustainable Urban Development: What has changed?	Under review. Submitted to the Journal of Urban Technology	1	Case study (instrumental)	- Interviews - Direct observation - Participant observation - Field studies

***** More information about instrumental and intrinsic case studies is provided in Section 3.6.2.

3.3. My contribution to the articles

Article 1: My contribution consisted on the original idea of building a database of Swedish environmental technology suppliers and designing a survey to learn about their perception of governmental initiatives aimed to promote exports. I participated actively in the design of the survey and the analysis of the results, and contributed to writing and reviewing the article.

Article 2: My contribution consisted of the original idea of studying the pattern of the diffusion of the Bus Rapid Transit (BRT) concept along Latin America, and most of the writing. Coauthors from the division contributed to the analysis and conclusions sections, and with several revisions of the manuscripts. The external coauthor, from the Institute for Transportation and Development Policy (ITDP), contributed with the collection of data central to the analysis, and with revisions and additions to the original manuscript.

Article 3: This article was written together with two coauthors from the division. I collected all the data, performed the interviews and wrote the text. The coauthors contributed to the analysis and conclusions sections, suggested literature and references, and performed several revisions and additions to the original manuscript.

Article 4: I was the only author of this article. I collected the data, performed the interviews and wrote the text. I received very valuable contributions from colleagues at the division on the original manuscript.

Article 5: I was the only author of this article. I collected the data, performed the interviews and wrote the text. However, I received numerous and valuable contributions from my colleagues at the division.

3.4. A discussion of the implications of the methodological choices: Reliability, transferability, and replicability

In this chapter, the intention is to discuss how the methodological choices can help achieve a better understanding of the process of technology adaptation, which is the focus in this thesis. This discussion will be presented by focusing on three important aspects that support the validity of the chosen methodology, the data obtained, the findings, and the conclusions offered in this thesis: reliability, transferability, and replicability.

3.4.1. Reliability

Two different methodologies were used for writing the articles appended to this thesis. Appended Article 1 was written using a survey methodology, while the remaining articles followed a case study methodology (Table 2). The survey used for Article 1 followed a non-random sampling strategy, i.e., it was targeted to a specific group. A questionnaire was sent to roughly 700 companies, previously classified in a database following the categories suggested by Statistics Sweden for the environmental technology sector. A depuration of the entries in the original database (which contained around 1,020 records) helped to eliminate companies that, although involved in the environmental technology sector, were not directly involved with exports, which was the main focus of the study (e.g., investment companies, municipal companies, committees and marketing associations). The questionnaire contained mainly closed questions, although respondents were given the opportunity to add thoughts or impressions in the end, which was very useful for the analysis and conclusions presented in the article.

The invitation to participate in the survey was sent to the companies' CEOs when their contact information was available, or included a request to forward it to a knowledgeable person that could answer the questions. This was done in order to guarantee better quality of the answers from the survey and more reliable results. However, the responses were kept anonymous, which means that it was not possible to know which companies answered the survey. The response rate was around 25% (172 companies), which is considered to be a normal response rate for this type of survey (Kelley et

al., 2003). After a second reminder was sent, no more answers were received, so it was decided to close the survey. Data was analyzed using the survey tool, and consisted mainly of percentages. The results from the survey were also analyzed manually, and in the case of open questions grouped into different categories. The article offered a discussion about possible reasons for other companies not responding the survey, e.g., outdated contact information or inadequate formulation of the invitation email's subject.

Regarding the case studies, a commonly used approach to assure the convergence and thus reliability of the collected data is called triangulation (Berg, 2009; Eisenhardt, 1989; Yin, 2009). Triangulation refers to the use of multiple sources of evidence (Eisenhardt, 1989; Yin, 2009), but also to multiple interpretations through e.g. different investigators, methods and theories (Berg, 2009). The idea of varying approaches is to assess and confirm the reliability of the sources, the accuracy to describe a problem, and the validity of the collected data and the interpretation. In this research, different types of triangulation were used: data, investigator, and theory triangulation.

Data triangulation

Multiple interviewees contributed with information about the same phenomena, each from their own perspective. In each of the case studies, actors belonging to academia, industry, government and civil society were interviewed. The aim with this approach was to combat bias and obtain a clearer picture of challenges that affect each sector in a different way, and that are given different priorities by different actors or groups of actors. In addition, the triplet academia-industry-government was central to this thesis' aim because of its role in the processes of technology emergence, implementation and diffusion (Etzkowitz and Klofsten, 2005), and in particular in sustainability transitions (Etzkowitz and Zhou, 2006). Other actors, such as non-governmental organizations (NGOs) and other types of civil organizations, have been found to contribute greatly to the proper functioning of this triplet's interactions (Leydesdorff and Etzkowitz, 1998).

In Article 2, for instance, semi-structured interviews and personal communication with e.g. BRT operators, local authorities, NGOs, and other stakeholders influenced by or influencing the implementation and use of this solution in different cities provided additional data about the evolutionary process leading to the modern version of the system and its spread from city to city. Articles 3 and 4, on the other hand, focused more on actors from government and industry, since the main interest was not a particular technology or system, but the city as a whole and the role of large technical systems in its infrastructure transitions. The city's utility company was found to be central to this process, as were actors directly involved with its management and operation. Article 5 included additional sources of information. In this case, data was not only collected from the interviewees, but also from participants at the World Urban Forum 7, which was the main setting for the realization of the study that led to its writing. Information about other interviewees, who were relevant for this thesis but are not included in the articles, can be found in Mejía-Dugand (2013) and Mejía-Dugand et al. (2013a).

Besides interviews, other sources of information were useful for the collection of relevant data. While Article 2 relied on the database of the Institute for Transportation and Development Policy (ITDP) for the collection of quantitative data regarding the emergence and diffusion of Bus Rapid Transit (BRT) systems in Latin America and globally, Articles 3 and 4 relied strongly on local libraries and local universities for the collection of historical data on the city under study and its utility company. Article 5 relied mainly on scientific literature as an additional source of information.

Finally, when the particular case, aim and questions allowed it, different strategies were used for the collection of data. At least three different data collection strategies were used for each of the five articles appended to this thesis. All articles relied on interviews and field studies as strategies for the collection of data. However, each article relied on additional, different strategies. Article 2, for example, makes use of an extensive database containing detailed information about the system under study. This database was analyzed in order to understand the emergence and diffusion of BRT systems in Latin America, and to build a chronological map depicting the geographical spread of this solution since its first implementation in Lima in 1972. It was also used to create two graphs, one showing the cumulative trend of diffusion in terms of kilometers of BRT lanes built, and the other the number of cities implementing them over the time period studied (1972-2011).

Article 3 uses a literature review to contextualize the case under study and the contribution of the paper to Transitions Theories. The article addresses gaps that were found in the literature and some criticisms raised by different authors. Article 4 was written supported by archival work performed in local libraries and with the help of local universities in the city under study. This data collection strategy was found appropriate for the type of study being conducted and to address the aim of the article. Finally, Article 5 takes a different approach by using direct observation and participant observation as data collection strategies. These strategies were found useful considering the environment in which data was to be collected and the aim of the study that led to writing the article. The different strategies used in the articles are summarized in Table 2.

Investigator triangulation

This research has been performed under the umbrella of larger projects, in which other researchers have been directly involved. The research group can be said to be interdisciplinary, at least when it comes to the professional and academic backgrounds of those involved (i.e. natural sciences, engineering and social sciences). The group not only met regularly to discuss and analyze data, but all members participated actively in the collection of data from the survey and during the field trips. This approach provided wider possibilities for data interpretation and enriched the analyses and conclusions.

Such mixed participation is reflected in the articles. Articles 2 and 3, for example, were written together with other researchers involved in the different projects leading to this thesis, and an external author in the case of Article 2. Although Articles 4 and 5 have a single author, inputs and collaborations from other researchers involved in the projects were important for the final outcome.

Theory triangulation

It is difficult to find a single theory that fits the problem under study perfectly. This is why it was decided to use complementary theories for the development of this thesis. When one theory was found insufficient or inadequate to address the questions under study, another theory would prove to be useful to fill the gap and provide a different perspective.

Three fields were central to this thesis most of the articles supporting it: Transition Theories, Diffusion of Innovations, and Governance. These fields were useful for writing Articles 2 and 3, which used their models, terms and concepts for the analysis of sustainability transitions. However, they were used differently, as Article 2 focused on a particular technology solution (i.e. BRT systems), while Article 3 concentrated on an entire city and on a set of technology solutions (i.e. utilities). Article 4, on the other hand, took an historical approach to the evolution of utilities in the city under study and their impact on the city's sustainability transitions. No particular theories can be highlighted in this article, as it is based mainly on archival work and interviews with different stakeholders. Finally, Article 5 makes use of different fields, such as Comparative Urban Studies and Diffusion of Innovations, and relies on findings from two studies from the field of Social Psychology for the analysis of data and the formulation of the conclusions.

3.4.2. Transferability

Generalization can be of two types: statistical and analytic (Flyvbjerg, 2006; Yin, 2009). The first type refers to inferences about a population emanating from empirical data collected from a sample. Although Article 1 relied on a survey methodology, it did not present an in-depth statistical analysis of how the results could be extended to a greater population. The discussions and conclusions were focused on the particular group that was being studied and the answers from the respondents, without further statistical inferences. However, it was also discussed that the studied group represented an important sector, and that other companies that were not included in the study for different reasons, could benefit from the results. In particular, an important recipient of the results was the Swedish government, which could benefit from the findings presented in the article. Results from this study provide relevant information for the design of strategies and programs to reach a higher number of environmental technology companies interested in export, and to facilitate their operation abroad.

Regarding the remaining articles, cases were chosen as with the aim to reach conclusions that could be applied to a greater population, i.e. other cities (see Flyvbjerg, 2006), it is clear, and in fact central to this thesis (as can be seen in the following sections), that contextual conditions will always be a crucial component of any intended analysis of technology implementation and use in and by cities. The case study methodology is a controversial topic within certain scientific spheres (Berg, 2009; Flyvbjerg, 2006; Yin, 2009). Flyvbjerg (2006) claims that this controversy emerges many times as a result of different misunderstandings about the nature of this methodology, such as the impossibility

of generalizing based on individual cases, the bias towards preconceived notions, and the difficulty of developing general theories based on specific cases. However, predictive theories or universals might not be suitable when context-dependent knowledge is sought after (Flyvbjerg, 2006; Yin, 2009), something that will be discussed later and is central to this thesis.

According to Berg (2009), well-undertaken case studies should provide understanding about similar groups or social phenomena, as "few human behaviors are unique, idiosyncratic and spontaneous" (Berg, 2009:330). However, it cannot be realistically expected to obtain a one-fits-all model from the data obtained. Instead, different theories were used as templates to compare the empirical results, or what Yin (2009) calls "analytic generalization." This, as Yin (2009) states, can support replication when two or more cases are shown to support the same theory.

Second, there are different types of case study methodologies that can be used in order to better understand how the results can be transferrable to other cases. For Article 4, for example, a methodology that Stake (1994, 1995; cited by Berg, 2009) calls an *intrinsic case study* was used. This type of study is undertaken in order to better understand a particular case. The aim when choosing this methodology was to learn from the particular case of a municipally-owned utility company, not because it represented other cases, but because of its contextual uniqueness. Unique cases are selected based on expectations about their information content, and the potential contribution to debates or theories due to their uniqueness (Flyvbjerg, 2006). For Articles 2, 3, and 5, a methodology that Stake calls an *instrumental case study* was used. In these cases, the research interest emerges from one single concern (e.g. urban sustainability), and one or more study cases are identified to have the potential to illustrate these concerns or a plausible solution. According to Berg (2009), the researcher will better understand a theoretical question or problem by relying on these cases.

3.4.3. Replicability

The survey study presented in Appended Article 1 can be easily replicated, as the questions and information of the respondents are recorded and saved in the survey tool used. It is however not possible to guarantee that the results will be the same, since they depend on the response rate and especially on which companies agree to participate. The survey was answered anonymously, which means that it is not possible to know which companies participated in it. Also, since the survey was conducted in May 2012, the characteristics of the companies and the sector could have undergone changes as well, which could also have an impact on the results.

Social phenomena are quite dynamic. This is particularly true for this thesis, considering the human-technology relation under study and the reliance of the dominant economic system (i.e., capitalism) on constant evolution rather than on the stagnation of technical systems (concepts such as *economic growth*, *innovation, continuous improvement* and *planned obsolescence* are good illustrations of this point). This is of uttermost importance when relying on a case study methodology. Yin (2009) highlights that when researchers want to replicate a study that followed this methodology, they must conduct the

same study all over again, i.e. not try to look for the same results in a similar/different case study. Good practices (case study in particular and scientific in general) are to properly document the procedures and the sources of data used for the sake of transparency, criticism and replicability. In this research, procedures, transcriptions and collected data are available for scrutiny and repetition, documented in a report (e.g. Mejía-Dugand et al. 2013a), a licentiate thesis (e.g. Mejía-Dugand, 2013), and in the articles appended to this thesis.

4. Adaptation: Learning between cities and the important role of intermediaries

In this chapter, the most important findings from the five appended articles are presented. A discussion on how each article contributes to the thesis' aim and research questions is also presented.

4.1. The diffusion of environmental technology between cities

The diffusion of environmental technology is seen as a fundamental contribution to global sustainability transitions (del Río González, 2009; Kanda et al., 2015; Vollebergh and Kemfert, 2005). It is thus important to understand the conditions facilitating or hindering the diffusion process. Article 1 provides a useful background for the understanding of this process, as it focuses on the micro-level, i.e., where environmental technologies originally emerge. Highlighted was the importance of the environmental technology sector in the search for global sustainability and economic growth, and the need to facilitate the process of insertion into the meso-level, i.e., where they will be tested and implemented. It was found that a high percentage of the respondent companies were export-oriented, which can be attributed to two reasons. First, the market in which they operate is small and thus easily saturated. This condition motivates them to look for external markets. Second, many of them realize the demand from other markets for their solutions, as these markets experience the same or similar problems as the local one, and in many cases do not have the knowledge or technology to fight them.

It was also found that companies that want to export face numerous problems. For instance, many of them are not willing to invest in the collection of information about foreign markets since they recognize the risk of information spill-overs, i.e., their competitors benefitting from their efforts. The government, therefore, has to intervene and fight market failures such as this one, in order to provide information to all the companies interested in exporting on an equal basis. Conclusions reached by different groups appointed by the government to evaluate the environmental technology sector and suggest strategies to promote its exports were also discussed. Particularly relevant for this thesis are recommendations focused on the need to develop new business models that can respond to opportunities in different regions, and the provision of communication channels that help companies to find collaboration partners. These recommendations rely strongly on the characteristics of the recipient markets, on the use of vernacular knowledge and on the understanding of past experiences regarding environmental problems and the use of technology.

To better understand how the implementation and diffusion processes happen in those markets that are recipients to technological solutions, Article 2 focuses on a particular technological solution, i.e. Bus Rapid Transit (BRT), and its diffusion pattern throughout the Latin American region. Although BRT systems had been studied from numerous different perspectives (e.g., institutional, social, technical, urban planning, and environmental), there was a lack of studies analyzing the connection among the implementing venues, the transmission of the ideas among them, and the impact that incremental improvements had on the concept's geographical diffusion pattern.

Discussed was that innovations find resistance and distrust, due to e.g. technological and economic lock-ins, and the disturbance to existing systems that they bring. The magnitude of these disturbances will define the ability of the innovation to be accepted by the mainstream regimes. When barriers to innovation emerge, governance tools are useful–especially at the urban level–due to the shared nature of the environment. Governance tools outside traditional policy instruments allow

these barriers to be overcome by fostering participation, experimentation and collective learning. Bottom-up approaches facilitate the understanding of innovations and their relevance to the particular problem under scrutiny, since the compatibility of the innovations with existing systems and values are made more explicit.

The use of cognitive and normative mechanisms (Hillman et al., 2011) to shape the idea of a sustainable city is also discussed in Article 2. The process of defining a problem, building networks to deal with it, and establishing the goals a particular society wants to achieve takes place through the adaptation of concepts to local conditions and requirements, which are made explicit through governance tools. BRT systems were found to be a good illustration of these mechanisms and the impact they have on the diffusion process of certain innovations. The historical pattern of diffusion was described and a map was built to illustrate how the concept travelled throughout the region (Figure 4).

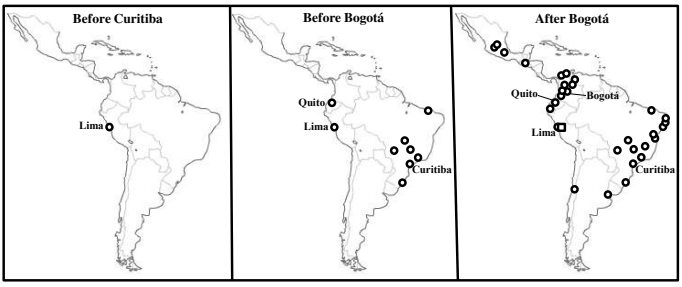

Figure 4: BRT's geographical diffusion map. Three important waves are highlighted (Mejía-Dugand et al., 2013b).

Figure 5a shows the incremental growth of the system in terms of the kilometers of segregated lanes built in the different implementing cities through time. It is possible to see the impact that particular implementation projects had on the diffusion process and pinpoint the cities that were key to the overcoming of barriers faced by this particular innovation. Lima (Peru), Curitiba (Brazil), Quito (Ecuador) and Bogotá (Colombia) were found to be crucial implementation projects for the diffusion of the concept in the region, but also globally (Figure 5b shows the evolution of built kilometers globally). These cities contributed with both incremental and radical improvements that proved to be adaptive to the needs and contexts of other similar cities. In addition, it was found that diffusion was facilitated by the existence of strong demonstration projects, especially in places where other cities could see possibilities of adaptation to their own contexts. Concepts that are flexible and allow for local innovations to enrich them will be appreciated by cities, which are looking to attract regional and international visibility.

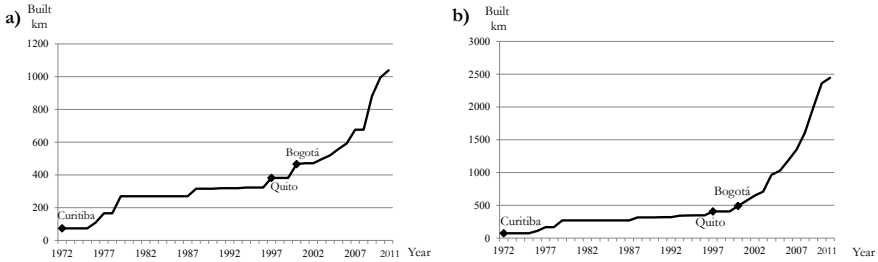

Figure 5: a) Cumulative built kilometers of BRT, Latin America (1972-2011). b) Cumulative built kilometers of BRT, globally (1972-2011) (Mejía-Dugand et al., 2013b).

Figures 6a and 6b show the concept's dissemination in terms of implementing cities, in Latin America and globally.

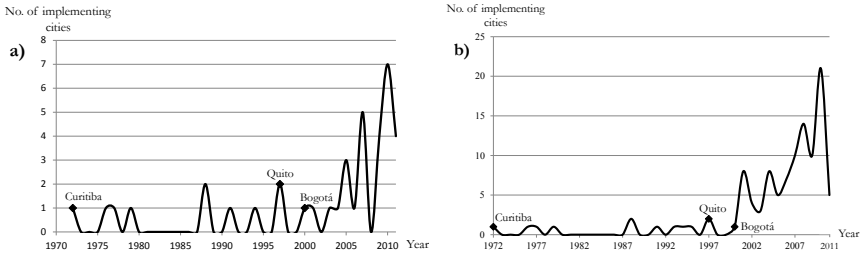

Figure 6: a) Number of cities implementing BRT, Latin America (1972-2011). b) Number of cities implementing BRT, globally (1972-2011) (Mejía-Dugand et al., 2013b).

Article 5 reports similar findings. In this case, it was found that potential recipients of new technology or concepts related to urban sustainability find it difficult to understand how some of these concepts or systems could be applied to their local situation. In particular, the article focuses on a Swedish diplomatic/commercial delegation to the World Urban Forum in Medellín (Colombia) and found that its message of holistic urban solutions was difficult to grasp for locals. This was not because some sort of complicated technical language was used, but because attendees did not feel familiar with it. Findings from the field of social psychology, in particular from the work of Oettingen and Mayer (2002) and Kappes and Oettingen (2011), were used for the analysis of how "imposed" imaginaries result in poor understanding of their benefits for the potential implementing city and in less energy put into achieving them. This is because these imaginaries are not based on past experiences, but on different values and environmental conditions.

Foreign imaginaries that do not align with local cognitive and normative mechanisms find resistance and disinterest. Similar to Article 2, a particular case was of interest to Article 5. A waste

management technology supplier (Envac AB) seemed better prepared to address concerns and doubts about the feasibility of implementing such a system locally. This case was interesting because it demonstrated the importance of proof-of-concept projects in which the potential implementer can rely on where connections or possibilities for adapting a particular technology solution can be identified. Discussed in the article was that while the Swedish Government and its Trade Council rely strongly on Hammarby Sjöstad as a showcase (an old industrial area in Stockholm transformed into a residential area where symbiotic relations are facilitated through the use of technology), Envac can rely on other implementation projects, such as Barcelona, where the system was implemented in the 1990s. It is claimed that cities, in this case Latin American cities, find it easier to understand the functioning of the system by looking at a city closer to them in terms of culture, politics/regulations, and even urban planning directives. In a similar way, it is probable that other cities in the region that might become interested in the future first look at Medellín (the host city for the Forum) instead of Hammarby Sjöstad.

Relying on Hammarby Sjöstad as a showcase might be inevitable for Sweden. Although it has received criticism locally (e.g. Pandis Iveroth, 2014; Wangel, 2013), it is indeed a good example of how technology can contribute to more sustainable cities. It was found that the delegation is aware of the problem of disconnected contexts and seems to have included strategies to address it. The message that the delegation conveyed during the World Urban Forum 7 changed in comparison to what was reported in previous studies. Although it is clear that there continues to be a strong commercial intention, the message has lost rigidity and allowed for bottom-up considerations to enter the discourse.

This change in strategy can be beneficial for Swedish environmental companies. It was found in Article 1 that roughly 80% of the respondents were already exporting or planning to do so in the near future, although 62% of them were not aware of governmental initiatives that fit their particular needs. Although many of these companies mentioned their preference for financial support programs, it was discussed as well that they need access to useful information about markets, local actors, and networks. Such information can facilitate the process of technology adaptation and be beneficial for companies that can offer environmental technology solutions.

Such solutions must thus be flexible and adaptive, i.e. able to align to existing social, economic and environmental systems. Article 2 suggested a model as a tool to classify different transportation innovations and how they influence the social, economic and environmental spheres in the city (Figure 7). In this model, transportation innovations are classified according to their alignment with existing systems (i.e. cognitive mechanism) and by the desired impact from implementation (i.e. normative mechanism). Full BRT systems, for example, were said to be an example of the best case, due to their capacity to align to existing systems (i.e. economic, technological and social) and their positive impact on the social, economic and environmental spheres in the implementing city.

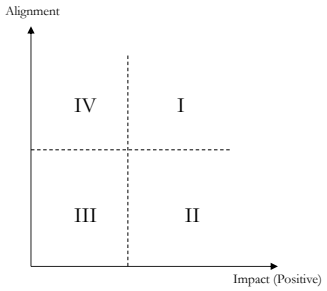

Figure 7: Impact on existing regimes vs. alignment with current systems (Mejía-Dugand et al., 2013b).

Different barriers to the diffusion of environmental innovations between cities were also identified in Article 2. The BRT's approach to these barriers was discussed with the intention to show possible reasons for the successful diffusion of the system. For example, the fact that the system proved to be profitable and independent from subsidies in a relatively short time, its up to 10:1 cost ratio (compared to a subway, for example), and its use of existing infrastructure, are suggested as advantages of the BRT concept when dealing with barriers to environmental technology diffusion.

Such learnings can be useful for environmental technology companies that are exporting or thinking of doing so, as well as for those that are indecisive (a total of 83% of the respondents in Article 1). Those who already have experience in exporting might have realized the need for a better understanding of the conditions under which their solutions will operate. Other companies might be exporting to markets that are similar to their local markets (e.g., to Nordic or Northern European countries) and could lack crucial information that could help them to explore other markets. It is not clear from the survey's results what the reasons are regarding why some companies are indecisive about exporting. However, it is possible that one of the reasons is that they lack information about local conditions or potential markets for their technology, or which advantages their technologies have over other systems already operating in those markets, or other technologies these markets are presented with.

4.2. Key intermediaries: pursuing collective goals and coordinating actors and activities for advancing sustainability transitions

Key intermediaries are seen as important actors in sustainability transitions (see e.g. Hodson and Marvin, 2009; Söderholm and Wihlborg, 2014). This is also the case in this thesis. In particular, the case of a utility company in Medellín was found to be a good illustration of this claim.

Article 3 offers a general understanding of how the city's utility company has contributed to infrastructure transitions that, in the end, have nurtured sustainability transitions. This is because a

wide coverage of electricity, sewage collection and treatment, solid waste collection, etc., contributes to the control and reduction of the environmental impact that the concentrated life in the city creates. It is highlighted that cities establish their own visions and goals of what a sustainable city should be and develop their own ideas of how to achieve them. In this line of thought, it is discussed that the local administration has been found to play an important role, and that key intermediaries can help to create these visions and build the networks required to achieve them.

By following the case of Medellín, the emergence of a central actor (i.e. the city's utility company, EPM) is highlighted. An historical description of the environment under which the company emerged, and the development of mechanisms that have allowed it to grow and become central to the different transformations the city has gone through, makes it possible to identify two crucial events. These events are understood as shocks to the stability of the utilities sector in the city. It is discussed that embracing external shocks as opportunities reflects more an entrepreneurial than a public approach, and this can be contradictory when collective goods such as sustainability are pursued. It is claimed that these shocks do not always represent opportunities to exert change, and with particular attention to the case of Medellín, they are treated as threats more than opportunities. This is because such shocks could destabilize the regimes and affect the collective goals established in the past, i.e., expanding coverage and securing a source of revenue for further city development. Figure 8 summarizes the most important events affecting the utilities sector, as described in the article.

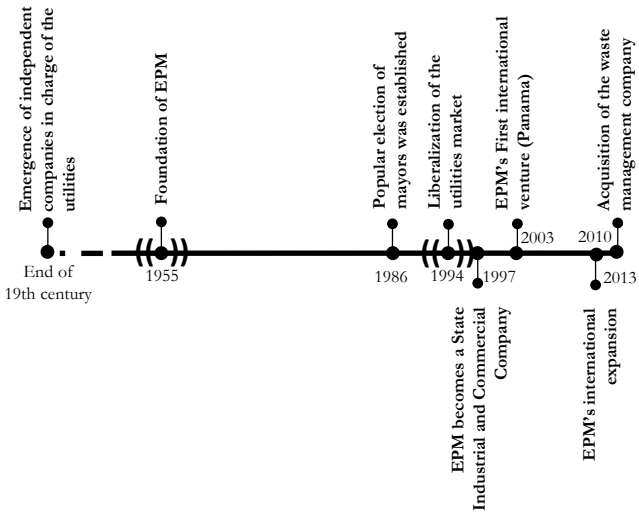

Figure 8: Timeline summarizing important events in the history of the city's utilities. Brackets depict the events considered as shocks to the existing regimes (Appended Article 2).

The role of the utility company of stabilizing the regimes and coordinating the exchange of information among the multiple actors involved is highlighted, and it is claimed that by protecting the socio-technical regimes from these shocks the city has been able to retain key-assets, expand its utility coverage, and rely on a constant source of revenue useful to advance further infrastructural transitions.

An important discussion from this article is related to the emergence of innovations. As an example, it is discussed that transport solutions that have emerged in the city have been beneficial for the socio-technical regimes and for the city's international reputation. Most importantly, it is claimed that these and other innovations have not necessarily resulted "due to" to shocks from the landscape and the "windows of opportunity" they create, but rather from the ability of the city to protect the regime from these shocks and maintain the direction agreed upon to pursue goals established in the past.

The conclusions highlight the important role that the ruling elite and the utility company have played in the pursuit of the collective goals established by the city. It is also highlighted that external shocks that threatened these goals were faced with mechanisms that allowed the city to retain key assets while maintaining the utility's ability to compete in a liberalized market. The flexibility and autonomy given to the company, together with the society's protection against political involvement, have been crucial for its stability, its capacity to maintain or expand the coverage of its services, and its ability to produce the resources the city needs to advance infrastructural transitions.

It was also found that considering bottom-up change models can be sometimes detrimental to collective goals such as sustainability, because it assumes that innovations can only be motivated by external shocks that create instability in the socio-technical regimes. It was discussed that the case of Medellín is a good counterexample, since innovations have emerged despite the stability of the regimes, guaranteed by protecting them from the harmful shocks that threatened to disrupt them.

In this line, Article 4 provides a more in-depth analysis of the process of emergence and maintenance of the city's utility company. It discusses the unique case of this company, considering the way in which the provision of utilities in the country and the region has evolved during the last two to three decades. It was found that organized management of public utilities was already established in the end of the 19th century, although these utilities were provided to a great extent by private actors. However, as the city and its industrial sector began to expand, the ruling elite found it necessary to municipalize them in order to cope with that expansion. If the city were to provide an image of modernity, the ruling elite thought, it had to be based on the reliable provision of public services. Since individual providers lacked independence and operational freedom, they were constantly used as parafiscal resources by the city's administration. This fact led to the creation of EPM in 1955 which, after the proper authorization from the central government, united the public services of telephony, water, electricity and sanitation.

Three important decisions made when the company was established were found to be crucial for this process: the company should be of an apolitical nature, it would have administrative autonomy, and

it would be allowed to perform commercial activities outside the city's administrative boundaries. In particular, the article discusses autonomy as a central concept to the development of the company and with it, that of the city. Since then, the company has been able to operate and grow without major interference of professional politicians. EPM did not face major competition until the utilities market was open to the participation of the private sector in 1994, when a law was approved following a wave of privatization policies in the South American continent. Under this new framework, companies like EPM had to choose between becoming joint-stock companies and becoming what would be called State Industrial and Commercial Companies. Medellín decided to stick to the latter, which would allow it to keep ownership of the company, while governing it following private rather than public law. This decision was not only made with the intention to protect this key asset from privatization, but also to have the option of creating revenue for the city.

As the company grew, so did its contributions to the city's budget: between 1990 and 2010, EPM multiplied by a factor of 37 its transfers to the municipality, its sole owner. This has resulted in unprecedented investments in social projects, an increase of 129% since 2007 alone, including the remediation of the river, investment in public transportation and neighborhood improvement projects, and the indirect benefits from fighting economic migration from rural areas–and thus urban sprawl and the emergence of informal, impoverished settlements.

5. Discussion and Conclusions

In this chapter, a discussion of the findings of the research is presented in relation to the research questions formulated in Chapter 1. The conclusions of this thesis are also summarized and discussed. At the end, possible directions for further research on this topic are suggested.

5.1. Summary of the conclusions

This section provides a summary of the main conclusions of this thesis. Such conclusions will be discussed in more detail in Section 5.4, after addressing each of the two research questions. For now, the intention is to highlight them and facilitate the reading process.

i) Environmental technology is not only seen as a solution to environmental problems in cities, but every day more as a component of strategies to attract attention and compete for resources in national and international markets.

ii) Cities have different adaptation and learning strategies. This means that technological solutions have to be flexible and adaptive to local conditions, and allow for vernacular knowledge and past experiences to enrich their performance by facilitating their connection to existing systems.

iii) Learning between cities is important and necessary for global sustainability transitions. When it comes to environmental technology, this process is facilitated by strong proof-of-concept projects. Such projects are not only expected to be able to show their technical ability to solve a problem, but must also offer contextual connections to the problems faced by interested cities or potential implementers.

These discussions will be resumed again later. For now, it is important to provide the foundations by addressing each research question separately.

5.2. RQ1: How do technology adaptation processes for the solution of urban environmental problems take place in cities?

Technology adaptation processes can take different shapes. A transversal observation in this thesis and the appended articles is that many cities are gaining power that allows them to raise ambitions and set tougher demands regarding the inclusion of local considerations and vernacular knowledge in any technology implementation project (see e.g. Katz and Altman, 2007). This evolution has been facilitated by the wide availability of information and communication technologies that allow citizens and governments to be more aware of the conditions under which such processes have succeeded or failed elsewhere. They also benefit from accumulated knowledge that can give some certainty about the possible future effects of a particular technological solution (Rutherford, 2011). The conditions under which environmental technologies must perform and the demands that cities are setting on them are becoming tougher. This is an important fact that both governments and environmental technology suppliers must understand when designing strategies for exporting their solutions (see Appended Article 1).

Some cities are more attractive globally than others (see e.g. Hodson and Marvin, 2009; 2010), but their status does not necessarily affect the diffusion of technological concepts, as this seems to be more a matter of non-hierarchical connections, a horizontal rather than a vertical coordination of learning and adaptation activities (see Appended Article 2). In a vertical arrangement, those elements located in lower levels (i.e. less attractive or powerful cities) would inherit the features of those located in higher levels, which leaves the former with little or no degrees of freedom, and in most cases results in citizen discontent, rejection or non-use.

The increased ability of cities to set these demands rests, to a large extent, on the realization of their regional importance and/or their position as national or regional platforms for further diffusion of technological concepts (or the "politics of the showcase city;" see Hodson and Marvin, 2009). International competition on the "sustainable cities" market is harsh, due to the great importance that environmental issues are gaining in the global political and economic agendas (Bulu, 2014; Hult, 2013). At the same time, this market represents opportunities for countries or technology suppliers to export their solutions to urban problems to cities that are many times not able to cope on their own with the technology they have (see Appended Articles 1 and 5). However, many cities are suspicious about technologies that have not been proved at least under conditions they can relate to (e.g. another city in the region or one with some kind of historic, cultural, economic or political connection) (see Appended Articles 2 and 5). As knowledge and proof-of-concept conditions build up, the acceptance process is lubricated and distrust is overcome more easily.

It would be unfair to say that the main motivation for cities to set tougher demands on technological solutions to their environmental problems is the realization of the commercial advantages they represent to others. It is clear that cities emerged in the first place to facilitate and improve the life of their dwellers. Environmental conditions in the city have a profound impact on the ability of citizens to thrive and of society to prosper: for instance, polluted air and water make people sick, and thus in many cases unable to contribute their full potential to society. Both local and central governments have for a long time been aware of this, although most of them have given priority to economic growth, perhaps, even if unconsciously, expecting that once material wealth reached a certain level, environmental concern and redress would start to take place, as promoters of the environmental Kuznets's curve[1] normally claim (see e.g. Tierney, 2009; Mills and Waite, 2009). As knowledge about the effects of pollution and consumption on the environment has grown, so has the preoccupation of local authorities to reduce their impacts, mostly through the use (or banning) of technology.

Those cities that have managed to improve their environmental conditions have realized an additional and in some cases probably unexpected result (see Appended Article 2). In a globalized world, where materials, capital and labor are to a large extent free to move, cities are an obvious accumulator of these resources. The ability to attract these resources is a sign of competitiveness in the modern world order (DiGaetano and Strom, 2003). Cities now realize the effect that improved environmental conditions have on this attractiveness and on how others perceive life in them. In turn, foreign attention brings benefits such as interest from academia, foreign investment, political

[1] An inverted U-shaped relationship between per capita wealth and environmental protection.

cooperation and tourism (Bulu, 2014; DiGaetano and Strom, 2003). The observability (i.e. the degree to which results are visible to others) of environmental technology solutions is thus found to have a significant impact on the process of technology adaptation under the current world order, something that different actors in Sweden have realized, as it was discussed in Appended Article 1.

Finally, it is important to highlight an important process taking place in modern cities. Cities emerged from the realization of the benefits of proximity. For many years, the administration of cities consisted of managing internal resources, of facilitating the activities of their citizens and industry, and making sure they had the services they needed to do so. The main source of revenue for cities has historically been the collection of taxes from their inhabitants and from industry. In many cases, this revenue is not enough to cope with growing needs due to urbanization and migration from the countryside. Some cities realized the need of finding additional sources of income, leading to the emergence of the entrepreneurial city model (Furlong, 2014). Entrepreneurial cities exploit their assets to increase their revenues, as the case of Medellín shows (see Appended Articles 3 and 4). This is done to a large extent through the use of technology and large technical systems: energy transformation and distribution, water treatment and distribution, solid waste collection and disposal, and wastewater treatment and handling. Numerous societies have used this model around the world, something discussed by e.g. Furlong (2014) and seen in Swedish cities such as Linköping and Gothenburg, through their utility companies Tekniska Verken and Göteborg Energi, respectively (Kairento and Nygårds, 2014).

Acceptance and rejection of technological solutions

Imposed urban imaginaries, i.e. ideas of how a city should be, find tougher barriers compared to imaginaries built locally and based on previous experiences (see Appended Article 5). This is not to say that cities do not accept collaboration, support and ideas coming from abroad, but that those ideas must be designed and presented as flexible and adaptive to local conditions. It is understandable that technology suppliers develop their technologies under the particular context in which they operate, and in fact it is most likely this context that facilitated the emergency of their solutions in the first place (see e.g. Geels, 2002; Smith and Raven, 2012).

However, these solutions cannot always be extrapolated to a different context without deeper considerations (Hult, 2013; Wangel, 2013). This is a problem that some technology suppliers and techno-optimists face. Technology is sometimes believed to have an inherent value, and it is thus not perceived to have the same conditions and requirements as other non-technical systems, just technical requirements that can be easily fixed: the size and shape of the electricity outlets, the voltage, or the type of fuel it needs to operate (see e.g. Huesemann and Huesemann, 2011). However, there are two levels at which any new technology must connect and interact: with other technological systems and with human systems (see Appended Articles 2 and 5).

Touching upon the first level, it is possible to realize that cities are not a new invention; they have been around for a long time, and many of their modern technical systems have evolved from older systems (e.g. sewage systems, drinking water distribution systems, and road infrastructure). Other

systems are completely new, but are limited by existing infrastructure. Even those cities that have grown slowly in comparative terms (e.g. Swedish cities vs. Asian or Latin American cities), and which have had time to better plan the deployment and distribution of their technical systems, are locked-in when it comes to replacing old systems with new ones (see e.g. Wallsten et al., 2013). It is not difficult to see what a challenge it is for those cities that grew alarmingly fast due to economic migration or forced displacement from the countryside, not to mention their sizes (see e.g. Appended Article 4; Mejía-Dugand, 2013).

With this in mind, it is crucial to consider how any new technological system will align with existing systems or infrastructure. There are two possibilities. First, the new system will completely replace an old system (e.g. an underground waste collection system that will replace a superficial one). How easy is it to implement the new system considering what is already in place, and the disruption that implementing it will create? Talking strictly in physical terms, how deep is the old system buried in the city's underground? How much new space will have to be created by e.g. demolishing existing buildings and other systems that share the same space but serve a different function (see Appended Article 2)? The second possibility is a new system that will coexist with another system that serves the same purpose (e.g. a BRT system that will cover one area while regular buses or a light train cover other areas). These two systems have the same goal, which means that they cannot compete with each other or grow in a parallel manner. On the contrary, they must complement each other, since none of them is replacing the other. This is crucial to technological solutions implemented in cities, especially in large ones. Even if the new system will replace the old one completely, in such big places this process will be gradual, which means that at least at some point they will have to coexist. The extent to which they are able to do so will be central to the final acceptance of the new system. In Rogers' (2003) terms, the compatibility of the new innovation and its capacity to align with existing systems is crucial for the technology adaptation process.

The second level, i.e. the system's interaction with humans, is equally or more important. Geels and Schot (2010) highlight that it is the combination of human and non-human components that creates configurations that work. Technology being a central component of Transition Theories, it is seen as dependent on human agency, as if their destinies were tied together (Bijker, 2006). Modern technologies and automation have sometimes created an illusion of technology independent from human involvement. In fact, this illusion is perhaps responsible for the citizens' disconnection from the impacts that energy consumption and waste generation have on the hinterlands. This does not mean however that citizens and other users of technological systems in the city do not appreciate technologies they can easily understand and use (Rogers, 2002). The perception that they have on both the ease of use (complexity, in Rogers' terms) and the actual benefits that that use will bring considering experiences with the system that will be replaced (relative advantage, in Rogers' terms) are important components that facilitate or complicate the adaptation process.

Citizens take many of the technical systems that keep the city working for granted (see e.g. Graham, 2009). However, this does not mean that they do not directly interact with them, and just hides the fragility of modern lifestyles that depend so profoundly on them. It is important to understand the values (common goals) that have been the foundations for the implementation or development of

the technical systems that are in place, the new values that have emerged as a result of citizens' interactions with these systems, and the extent to which new systems disrupt these values (see Appended Articles 2 and 5; Geels, 2011; Hillman et al., 2011; Smith and Stirling, 2008). These are important issues to keep in mind when analyzing the validity of paradigmatic models of sustainable cities in certain contexts, and the barriers posed to strategies that are based on a market rationale, i.e. one that relies on the fulfillment of demands through technology implementation.

It is clear that no one knows better how these interactions function than those directly dealing with them, i.e. the potential implementer city (see e.g. Rutherford, 2011). In this line, Appended Article 1 discussed the need of designing more flexible business models, and of gaining access to reliable information about the target markets, which are facilitated when locals are involved. It is important to clarify at this point, however, that this does not mean that ideas, innovations and knowledge cannot come from abroad, and with "abroad" it is not only meant from another country, but also from another social group. This is particularly evident in highly segregated societies, where the wealthy want to impose their vision of modernity on the poor (e.g., Medellín; see Appended Article 4), or some ethnic majority on an ethnic minority (e.g., Cairo; see Mejía-Dugand et al., 2013a). In fact, many societies need fresh, external ideas to illuminate their processes. But how much are these ideas open for local scrutiny and able to adapt to the conditions under which they will actually have to operate? How much do actors rely on adaptation processes? In this sense, technological innovations at the urban scale face a tremendous challenge: trialability (Rogers, 2003). Trialability, as was discussed in Chapter 2, refers to the degree to which a technology can be put to test on a limited basis (e.g., an underground transport system, a sewage collection technology or a waste disposal technology). Even if cities had the resources to put these technologies to test, it would be highly impractical to do so.

Appended Article 1 discussed governmental initiatives that aim at providing demonstration grounds for Swedish environmental technology companies. This is corroborated by other findings from this research, which suggest that cities are not willing to implement innovative solutions unless there are other cities that can act as proof-of-concept cases (see Appended Articles 2 and 5). This is how humans operate in other aspects of their lives, unless there is a tremendous incentive to be the first to try an innovation. However, what is most important to highlight is the fact that it is not just any kind of city that potential implementers look into, but primarily cities they can relate to, or those in which they can see their own reflection (see Appended Articles 2 and 5). This connection is manifested through geographical, cultural, economic or political means, and is justified by a decrease in the effort necessary to transmit new ideas and concepts, to disseminate knowledge about the functioning and benefits of the new system, and to fight against resistance from future users or beneficiaries (see Appended Article 2; Rogers et al., 2005). Many times, even if a certain technological solution seems to solve a problem that two cities share, their differences (e.g. values, climate, political system) seem to have a higher weight on the implementing decision (see Appended Article 5). This is illustrated by the findings presented in Articles 2 and 5, and discussed in Chapter 4.

5.3. RQ2: How do cities benefit from environmental technologies?

There are obvious benefits from implementing environmental technology solutions in cities, e.g. the improvement of the actual problem they aim to attack. The actual attractiveness of modern cities comes to a great extent from their technological systems (see e.g. Gandy, 2005): not necessarily how many or how visible they are, but how available they are for the benefit of their citizens. It is no surprise that so-called global cities show an intense use of technology (e.g. transport technology, security and surveillance, energy, and ICT). The intention here has been to discuss an additional advantage that cities see from the implementation of technologies (environmental technologies in particular), and that is attracting international attention (see also Bulu, 2014; Hodson and Marvin, 2009; 2010). The focus of this thesis has been put on technologies that improve the life of citizens and visitors, urban technologies like transport systems, wastewater treatment, traffic management systems, energy transformation and distribution, and waste management. These technologies have been termed "environmental technologies" for the sake of this thesis.

The development of these technologies requires time and persistence, and they are usually complex in technical terms. The hardware, i.e. the components (e.g. machines and equipment) needed to keep them running, are most often not built by the cities implementing them. However, implementing cities have learned to procure them, manage them and improve them, which is equally or more important than the physical components. Mejía-Dugand (2013) discusses that this is the case of many Swedish municipalities, but highlights that this is seen as a hindrance in the Swedish context, since cities find obstacles to sell systems they do not physically produce. One reason is that the market in North and Western Europe is quite mature in the sense that cities are wealthy and experienced, and competition is harsh (see Kanda et al., 2015). There is internal collaboration within Sweden (a municipality's company serves nearby, smaller cities), although the competition is also harsh due to the ability of many municipalities to provide for their citizens on their own, and their maturity in terms of infrastructure. Some exchanges are also happening with neighboring countries (e.g. waste incineration), but international operations are not that common in the municipal realm, especially since Swedish municipal companies face harsh legal restrictions in this sense. Some attempts have taken place, but they seem to be more the exception than the rule. For example, Linköping's Tekniska Verken has had commercial exchanges with Malta and a failed venture in Bucharest (see Kairento and Nygårds, 2014).

On the other hand, the case of Medellín was exposed in this thesis. The city has profited not from the production of technical solutions, but from their installation, maintenance and operation, something that Swedish cities, as mentioned above, also look into. The context is however different and more feasible for this kind of venture. First, many Colombian and Latin American cities are lagging behind in terms of infrastructure and the ability to provide good-quality utilities for their citizens. Second, municipal companies in Colombia are allowed (depending on their legal constitution) to venture into international markets (see Appended Article 4). These two conditions, together with the management efficiency and reputation built through time, have facilitated the city's

utility company's expansion and financial growth in a relatively short time, and thus the ability of the city to improve its social and environmental conditions by relying on a powerful source of revenue.

This has in turn resulted in the benefit of attracting international attention. With an improved reputation and the improvement of living conditions through the use of large technical systems and well-planned social interventions aided by technology (e.g., a gondola lift and several coexisting and connected amenities), the city has benefitted from the renewed trust of investors, academicians, politicians and tourists. In some sort of continuous cycle, revenue increases for the entrepreneurial city, which can in turn continue to invest in the improvement of its infrastructure and its citizens' living conditions.

But these conditions are not only beneficial for the actual city implementing technological solutions. Technology suppliers also benefit from the attention and importance these cities are gaining in the region. This is a necessary condition for their business expansion in these regions, as other cities are not only looking into these "good examples," but also trust them when they see connections to their own contexts (see Appended Articles 2 and 5). The case of Envac's implementation of its waste collection solution in Medellín, and the city's close connection to Barcelona and other Spanish cities, shows that Medellín will very likely represent an important proof-of-concept example for Envac's further expansion in Colombia and Latin America, probably more influential than Hammarby Sjöstad in Stockholm and even Barcelona (see Appended Paper 5). This was also the case with Volvo's BRT buses (Appended Article 2), and later for Scania and Mercedes Benz, when Curitiba and Bogotá showed the benefits of such a system. Up to 2011, providers of BRT-related technology were supported by the thirty Latin American cities that had implemented this transportation system. Strong demonstration projects like Curitiba and Bogotá were crucial for the expansion of the system regionally and globally (Appended Article 2). In turn, these two cities have enjoyed international attention and the benefits that come with it.

5.4. Conclusions

This thesis focused on the implementation of technology for the solution of environmental problems in cities. To do so, different cities were studied with the intention to understand the process leading them to the identification of a problem, the mechanisms built to solve it, and the dynamics of selection, implementation and use of any given technological solution. It was also important to identify the actors involved in such process, the ways in which they interact and the networks they build to deal with the problem.

An important conclusion of this thesis is that besides seeing technology as an inherent characteristic of cities, a simple byproduct of urbanization, it is seen every day more as a necessary component of any strategy adopted by cities to create competitive advantages, and to attract or keep resources thought to be crucial for guaranteeing the well-being of their inhabitants. Through the use of technology, manifested mainly in the form of large technical systems, cities do not only guarantee

that their inhabitants have access to services they need to live a comfortable life, but also can benefit from the expertise acquired from their management (see Appended Articles 3 and 4). This has promoted the emergence of entrepreneurial cities, cities that act as an enterprise, participating in markets and competing with other cities and private companies to capture value for their shareholders (i.e., citizens).

Many cities are not able to, or simply choose not to, produce the technology they need to fight all the environmental problems they face (see Appended Article 1). This does not only have to do with the availability of financial resources or the expertise needed to do so: economic theory has for many years talked about comparative advantages when analyzing societal gains from commerce under a free-trade scheme. This is an important fact in this study, considering that a central concern is how foreign technologies can be more easily implemented (with a special–but not exclusive–focus on Swedish environmental technology). The implementation of technology in many emerging cities that represent interesting targets for foreign suppliers (e.g. Latin American cities) faces significant challenges. Such challenges include the common concerns about e.g. cultural barriers for trade. However, most important and central to this analysis are the challenges related to the actors involved in any decision to implement technological solutions on an urban scale and the power structures governing them. Each city has different adaptation and learning strategies. It is important, thus, to understand how these strategies are built, which values and socio-technical structures compose these strategies' foundations, and what cities focus their attention on when they want to influence or accelerate the learning process in order to solve a problem they are facing.

In this line of thought, two mechanisms highlighted by Hillman et al. (2011) are of particular interest: the cognitive and normative. Numerous cities are struggling to find their identity, a term that is not used here only in a figurative way, but has more to do with the speed with which they are growing, the uncontrolled conditions under which they have grown, and the increasing gaps between the groups that comprise them. For a better understanding of these dynamics, it is necessary to identify the problems they are facing, how they are to be prioritized, what the collective vision of the future is, and which solutions are depicted to achieve it. Modern technologies have facilitated widespread access to knowledge that was before previously only reserved for favored groups. This has in turn facilitated international comparisons among cities, e.g. the myriad lists ranking cities according to their livability, "greenness," ease to do business, etc. (Bulu, 2014), and what is perhaps more important, tougher demands from citizens on their governments, and from local governments on (foreign) technology suppliers (see appended Articles 2 and 5). In addition, decentralization processes in many countries have allowed city governments to better manage their resources (see Appended Article 4). These conditions have made it tougher for foreign technology suppliers to enter their markets, since local governments and citizens are more self-aware and have more negotiating power than before.

This leads to another important conclusion from this thesis: Technology suppliers have to be ready to adapt their offerings to local conditions and contexts, and allow for vernacular knowledge to enrich the performance of the solution and facilitate its connection to existing social and technical systems (see Appended Articles 2 and 5). This is beneficial for suppliers, not detrimental. Locals

understand better than anyone else the conditions under which any technological solution will perform; thus, they should be the ones laying the groundwork. This might sound like old wine in new bottles (cf. "the customer is always right"), but as it was discussed in Article 2, some suppliers have problems realizing the potential of some technological solutions in cities, even more if customization, or better yet, adaptation, is needed. They need not necessarily fear higher costs and thus a drop in their competitiveness: in many cases, when cities need a solution and decide collectively to pursue it, they will be willing to pay the price. For example, Curitiba's planners performed the feasibility studies by themselves and flew to Sweden to convince the company to deliver the buses for their system (see Appended Article 2). Medellín is currently facing a similar situation with the implementation of a tram with the help of Spaniards.

But not every city has the guts or financial muscle to embark on the risky decision of implementing a system which is new and largely untested, at least under conditions similar to theirs. Most cities want to see the system operating first in order to make an informed and safe decision (see Appended Articles 2 and 5). Although many suppliers offer showcases, these are many times difficult to understand due to the context in which they have developed and operate (see Appended Article 5). Thus, it can be concluded that foreign suppliers need to develop proof-of-concept projects that could help potential city-customers to overcome distrust and suspiciousness.

In reality, it is not the suppliers who ultimately decide which city implements their solutions. However, choosing a potential implementer is a purely strategic decision, one that many companies make all the time when they define target markets for their products. It is clear that the initial implementation in certain regions is challenging, since few cities dare to implement untested technologies, or those that do so are operating under seemingly different contextual conditions. Such a challenge can be faced in different ways. One is to use information gathered by embassies, diplomatic missions or business councils (as was the case of Medellín; see Appended Article 5) to identify cities looking to develop solutions to their problems and having the resources to do so. Another solution is to make use of international cooperation initiatives to gain access to testing grounds and resources to finance projects that will be useful in the future as showcases for other implementation projects in the region. Whichever strategy is chosen, it was discussed in this thesis that cities rely more on technological solutions operating under conditions they identify as similar to their own, and that show more clear benefits to the actual stakeholders to which they would be directed. For example, Latin American cities find it easier to relate to a particular solution implemented in Spain (because of cultural and political ties), than to the same situation implemented in Sweden (see Appended Article 5). This is of course even truer when the solution operates in another Latin American city.

The aim of this thesis, to recall, is to analyze the role that technology plays in the solution of environmental problems in cities, and to discuss models and conditions that can facilitate the processes of selection, implementation and use of environmental technologies in and by cities. This research suggests that adaptation is key to facilitate the achievement of more sustainable cities through the use of environmental technology. The correct and timely identification of the actors involved in the adaptation process will to a great extent influence the probability of successful

implementation. It is perhaps equally important to consider the conditions that shape modern cities, and how they look at other cities, both to learn from them and to compete against them. Urban sustainability requires collaboration and learning from the experiences of other cities. It is found that environmental technology solutions find less resistance among homogeneous groups of cities, since less energy is required to share knowledge, applications and advantages. The increasing level of education and access to information, and the emergence of participative tools accessible to citizens, allow them to shape their own cities, and what is more important, their collective sustainability goals. Who better than them to take the reins of their city?

5.5. Further research

Cities in general and urban sustainability in particular are very popular research topics today. The dynamic nature of modern cities, however, nurtures the constant emergence of challenges and interesting questions related to how to decrease their impact on the environment or to improve their inhabitants' lives.

In relation to this thesis and its focus on technology adaptation and use in cities, it is important to address concerns regarding the role they actually play in transitions into sustainability. Hodson and Marvin (2009; 2010), for example, highlight that cities are seldom mentioned by Transition approaches and that the MLP does not clearly include them in its framework. This is an important issue, considering that cities are obvious places to study and promote such transitions, and the popularity that Transition Theories and the MLP approach have gained among scholars focusing on transitions into sustainability. There are numerous issues that must be addressed, for example regarding the emergence of regimes and the power structures governing them (Jørgensen, 2012). Another important issue to address is the scope of MLP analyses. Markard and Truffer (2008) claim that the concepts of the MLP framework are not fully demarcated as to their applicability to different levels of analysis and the results they lead to. In the case of cities, this can result in the possibility of talking about different sets of micro, meso, and macro levels for each city that is analyzed using this framework. A better delineation of the different levels of structuration can be then an important contribution to the Transitions debate and in particular to the MLP framework, by making it more homogeneous.

In this thesis, the need to create proof-of-concept projects is discussed as a necessary condition for the diffusion of technological solutions in a particular region. It is discussed that diffusion in the studied cases has taken a horizontal, rather than vertical shape. This has in turn facilitated the emergence of networks of cities that ease the transmission of knowledge and ideas, helping to overcome fear and distrust and reducing the amount of energy needed to promote technological implementations. With this in mind, an interesting research direction is the study of the emergence and management of national, regional or international networks of cities and their influence, not only on the decisions to implement certain technologies, but on the results of doing so and their

connection to the actual network. Can international city networks facilitate the spreading of solutions to shared problems among cities? If so, under which conditions? How can all members benefit in the same way, regardless of the region where they are located and their degree of development? What, besides purely commercial interests, motivates cities to share their experiences and knowledge regarding their solutions to certain urban problems?

Finally, local learning processes are very relevant for the continuation of this study. In this direction, numerous possibilities emerge from some of the cases included in this thesis. For example, as it was discussed in Chapter 4, the case of the decision to implement a whole new system for the underground collection of solid waste in Medellín, which is one of the first cases of implementation in Latin America, is an interesting historic opportunity. By following the process from an early stage it is possible to track the development and evolution of this technological concept in the country and the region, similar to what was discussed in Appended Article 2. Defining a window of time to follow-up and analyze how the system takes off, how cultural change happens in a city where the system is completely new, and how the stakeholders are affected by or benefit from the system, could result in interesting findings and conclusions about the technology implementation process in cities. It could also contribute to strengthening Transition Theories and the MLP framework, and to the understanding of technology adaptation processes for the solution of environmental problems in cities.

References

This section offers a list of the references that were used in this thesis. Most of the list is comprised of articles that have been published in scientific journals, but, due to the nature of the research project and the availability of information, other sources such as books and "gray literature" were also used.

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Annex

Other related publications

This thesis includes and discusses five articles. However, a licentiate thesis and other reports and publications were produced during this five-year research education process, and are closely related to the findings and conclusions discussed here. Those publications are:

- Mejía-Dugand, S., Hjelm, O., Baas, L., 2011. Improving energy and material flows: a contribution to sustainability in megacities. World Renewable Energy Congress – Sweden; 8-13 May; Linköping, Sweden. http://dx.doi.org/10.3384/ecp110573169 [Accessed 04 April, 2015].
- Mejía-Dugand, S., Hjelm, O., Baas, L., 2011. Megacities: turning ten million faces at Swedish environmental technology. The R&D Management Conference; 28-30 June; Norrköping, Sweden.
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- Mejía-Dugand, S., Kanda, W., Hjelm, O., 2014. Analyzing city networks for the diffusion of environmental innovations: A study of five major Swedish cities. 17th European Roundtable on Sustainable Consumption and Production; 14-16 October; Portorož, Slovenia.
- Mejía-Dugand, S., Kanda, W., Hjelm, O., 2015. Analyzing international city networks for sustainability: A study of five major Swedish cities. Submitted to the Journal of Cleaner Production Special Volume for the 17th European Roundtable on Sustainable Consumption and Production.
- Mejía-Dugand, S., Hjelm, O., Baas, L., 2015. Urban imaginaries and the sustainable city. Sustainable City, 10th International Conference on Urban Regeneration and Sustainability; 1-3 September; Medellín, Colombia.

Articles