Diffusion of Environmental Technology in a Megacity.
A Case Study of Mexico City

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Foreword

This study is financed by the Swedish Agency for Innovation Systems, VINNOVA. It started as a response to a call to study megacities as potential markets for Swedish environmental technology.

The initial proposal included two megacities: Mexico City and Cairo. However, due to 2011’s political turmoil in Egypt, it was difficult to complete the planned activities for Cairo. A year later, an exploratory round of interviews took place, but there was not enough time to include it in this thesis. However, several experiences and observations from this trip reaffirmed some of the findings in Mexico City regarding stakeholder involvement and technology adoption. A subsequent part of this study will hopefully include learning and conclusions from an eventual continuation of the project in the city of Cairo.
Abstract

In a world recently declared urban, each day technology plays a more important role in society. A majority of people seem to believe in technology not only for solving everyday problems and for supporting the current production and economic systems, but also for the redress of environmental problems that are caused to a large extent by the same technology that has driven society to the current standards. In this direction, megacities (i.e. cities with more than ten million inhabitants) represent a valuable example of both the problems caused by high urbanization rates and the possibility of solving them using technology. However, the mere development of technology does not guarantee its immediate adoption and successful implementation by a given society.

In this thesis, one of the largest megacities in the world (i.e. in terms of population) was chosen as a case study for the analysis of the adoption and diffusion of environmental technology. Mexico City is studied through a set of interviews with local stakeholders from academia, government, industry and other external organizations such as non-profit organizations and international institutions. This approach resulted in the identification of different obstacles to the adoption and implementation of technologies, but also led to a successful case of technology adoption that allowed for the understanding of important traits that facilitated not only such adoption, but also the subsequent diffusion and spread to other cities.

Although the thesis has a strong focus on the demand side (in this case Mexico City), the supply side (in this case the Swedish environmental technology sector) is also considered and analyzed. By using statistical data of common enterprise and economic nature, the composition of the sector was described and analyzed with the intention to identify important areas and behavioral traits that could give insight into the hindrances that the sector faces when exporting its offerings. Given the interest that the Swedish government has put in the sector for contributing to the country’s economic growth, the different studies commissioned for the assessment of the sector are also discussed in this thesis. The different conclusions and suggestions made by the different agencies entrusted with this task are shown and analyzed.

Conclusions are drawn regarding the need for designing strategies that consider local conditions, that are flexible and adaptive to a highly dynamic environment and that pay particular attention to the development of strong demonstration projects that facilitate overcoming the distrust normally created when new technologies are introduced in a society.
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I must have done something very good in my previous life, because in this one I have always had people standing next to me, giving me their support, sharing my good moments and understanding the not-so-good ones. This is something for which I am greatly thankful. Many will not be mentioned here, but all are in my heart and mind.

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List of appended articles

Article 1 – Megacities: turning ten million faces at Swedish environmental technology (Presented at the R&D Management Conference, Norrköping 2011).

Article 2 – Lessons from the spread of Bus Rapid Transit in Latin America (Published in the Journal of Cleaner Production – Special issue on Advancing Sustainable Urban Transformation).

Article 3 – Diffusion of environmental technology: an analysis of export strategies in Sweden (Manuscript to be submitted for publication).


My contribution to the articles

Article 1: Major contribution; both data collection and writing.

Article 2: Major contribution; writing and shared contribution for data collection.

Article 3: Major contribution, both data collection and writing.

Article 4: Shared contribution; both data collection and writing.

Related publications


Definitions

The following terms appear throughout the thesis. They are in one way or another, necessary for understanding the descriptions and discussions presented. This section describes them in the context of this research.

**Bottom-up approach:** This approach not only analyses the evident conditions of a certain place, but also the needs, wishes and requirements of those who will be directly affected by any intended solution and their own perception of any given problem.

**Demand:** Outside the traditional economics definition, in this case demand does not necessarily include the willingness to pay a price for a good or service. Rather, it refers to the identified, potential recipients of technology that is not locally available.

**Environmental challenge:** An environmental condition identified to affect, at present or in the future, the ability of ecosystems and their components to maintain life without unwanted effects.

**Environmental technology:** In this thesis, the definition provided by the Swedish Ministry of the Environment will be used: “goods, systems, processes and services that offer clear environmental advantages in relation to existing or alternative solutions, seen from a life-cycle perspective.”

**Lock-in:** Refers to the difficulty of changing a system that has become embedded in society due to popular and technical acceptance, not to mention the economic difficulties of changing the supporting (expensive) infrastructure in case it is not compatible with the new system.

**Megacities:** A commonly accepted definition is the one provided by the UN (2008), which refers to the number of inhabitants. A megacity is a city that has more than ten million inhabitants.

**Technology push:** In this case, the identification of a market opportunity is the main driver for proposing solutions based on already existing or pre-designed products or systems and based on the local experience of the eventual supplier, not that of the actual customer.

**Socio-technical regime:** This concept refers to the ruling set of relations between a society and the technical systems that support its activities at a particular point in time. The importance of the different networks that are built – intentionally or unintentionally – is addressed when analyzing these regimes.

**Stakeholders:** Each person or group that might have certain interest and connection to a particular event or decision, whether they actively participate in it or not.

**Supply:** From an economics perspective, supply refers to the amount of product that is available in a particular market. In this study, supply is understood as the set of potential technological solutions to environmental challenges in megacities and their suppliers.

**Technological transition:** The shift from one socio-technical system to another.
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Chapter 1: Introduction

1. Introduction

The world was recently declared half-urban (UN, 2008). This happened during a time when most
governments throughout the world were discussing environmental protection and remediation as
necessary actions in order to reduce the impact of human activities on the natural world.

It is in cities that most human activities are concentrated, e.g. economic, technological, academic,
industrial, political, military, and many more. Historically speaking, they started as meeting points for
trade, so it is fair to say that they have always been attractive places for humanity. Although the
services they provide have changed as technology and social relations have changed, their basic
functions have remained the same. Cities facilitate human life by gathering a population in a
geographically close area. Public services like drinking water, energy, sewage and health care have
been around for some time. New services, needed in order to serve the modern activities and to
respond to the exponential growth in most urban agglomerations, have become common traits of
modern cities (i.e. communication, transportation, recreation, education, etc.). Their attractiveness, the
abandonment of the countryside and other numerous social problems have created unprecedented
migration into cities. Whereas there were two cities with more than ten million inhabitants in 1950
(i.e. New York and Tokyo), there are twenty-three today, and it is expected that by 2025, there will be
thirty-seven (UN, 2012).

Cities have relied on technology for the solution to many of their problems (e.g. aqueducts, sewage,
security and defense systems). In fact, technology is one of the cities’ most attractive and self-evident
components (Gandy, 2005). On the other hand, many environmental problems have been related to
the use of technologies. As an example, cities are responsible for 70% of the global CO₂ emissions
(IEA, 2008), which is to large extent an effect of their energy and transportation sectors (IEA, 2008;
ITF, 2010).

The world’s urbanization rate poses serious challenges, especially to those regions that do not have the
ability to respond in time to this trend. Most regions in Africa and some parts of Asia remain rural in
percentage terms, but they also have the highest urban growth rates (UN, 2012). Other regions, such as
Latin America, have already reached high urbanization rates, comparable to those of Europe or North
America (UN, 2012). This trend has more or less stabilized after tremendous growth during the second
half of the twentieth century.

In addition, the relatively recent attention that cities have gained regarding sustainability issues has
created a lot of opportunities for innovative solutions, technology adoption and transfer and the
migration into a “greener” economy (Jackson, 2009). Countries that have – to some extent – solved
environmental problems because of historical, economic or social reasons, have realized that cities
offer great opportunities, both for contributing to global sustainability and for supporting the growth of
their economies through the export of environmental technologies (The Swedish Government, 2011). Such
opportunities seem to magnify when talking about megacities. Conscious of these opportunities,
different governments have appointed teams for the analysis of conditions and the definition of plans
and strategies for the promotion of their technological solutions (Kanda et al., 2012). In particular, the
case of Sweden is of special interest for this study, since it is the author’s residence and where the
research funds come from.
A first phase in the process of promoting exports usually consists of assessing one’s own, local situation (i.e. companies in the sector, products/services they produce/offer, characteristics of the companies, etc.). Then, after identifying strengths and weaknesses locally, the demand side is analyzed (i.e. how do international markets for environmental technologies work, what solutions are needed in different areas and which areas could match their offerings). Finally, a strategy is defined looking to create the right conditions for the successful export of environmental technologies. An important connection must then be created not only with foreign markets, but also with the actual companies and entrepreneurs to which the strategies are directed. Their condition, needs and characteristics should play an important role in the actual definition of any strategy.

As mentioned above, an extension of this process is to identify potential markets for the implementation of locally-developed environmental technology and the subsequent international expansion. There are numerous factors that could attract governments, salespeople and researchers to study the potentiality of a venue; some examples are market size, income per capita, geographical location, political and economic and/or environmental situation. For the sake of this study, population and marked environmental challenges justify the interest in megacities, and in particular Mexico City. The term “megacity” refers specifically to the total population in the city and its metropolitan area (i.e. more than ten million inhabitants), and provides an idea of its vast geographical extension, the complex interactions among its inhabitants, and its pressure on environmental services. Interestingly enough, the fact that cities in general, and megacities in particular, are considered to be “obvious” markets for environmental technology solutions, brings about the risk of generalizing and therefore missing important characteristics for the successful implementation of any given technological solution. Generalization can be a delicate practice, especially when talking about environmental sustainability.

In particular, environmental technology developers and providers create solutions to problems based on their experience, the particular milieu in which they perform their everyday activities, the particular laws and cultural practices of their surroundings and the characteristics of the actual environment they pretend to preserve or redress. Science provides accurate descriptions and explanations of problems that occur all over the world; based on this, technology offers a specific solution. However, problem-solving is not only about the availability of technology, but also about the way it is understood, used and applied to a particular problem. A problem can be embedded in a far more complex context than an isolated laboratory or a particular city or town. This is why new technological solutions, of any kind, can encounter distrust and rejection, even if technically adequate.

In particular, when analyzing the specific case of Mexico City, one must ask things like: How is a problem understood? Who is actually defining the problem? Who is affected – positively or negatively – by any proposed solution? In summary: Whose problems are to be solved and from which perspective are they being defined? These questions are of great importance, not only when looking at megacities as potential breeding grounds for sustainable solutions, but also as platforms for the successful deployment of strategies for the promotion of foreign environmental technologies. This study aims, on one hand, to provide answers to these questions and to provide a solid understanding of the relation among local stakeholders and between local and foreign actors. On the other hand, the analysis of individual export initiatives and strategies will help to understand how missing connections could result in unsuccessful implementations. The following section provides a deeper description of these issues.
Chapter 1: Introduction

1.1. Aim

The aim of this thesis is to study and analyze megacities as platforms for the diffusion of environmental technologies. The particular case of Mexico City is selected as a case study due to its position as a megacity (highly urbanized settlement), its importance in the region, the environmental challenges it faces and the availability of local contacts to facilitate the research process. The analysis will have an environmental sustainability focus, although social and economic sustainability issues might be used in order to support some of the arguments.

An important characteristic of this study is a strong focus on the demand side, i.e. Mexico City as recipient and user of any potential environmental technology coming from abroad. This focus is referred to in this thesis as a bottom-up approach, highlighting the fact that local needs and conditions are prioritized over offerings and possible, potential solutions and purely economic market opportunities. This type of approach is expected to provide a solid contribution to existing studies on technology diffusion, in particular within the environmental technology area. Although an emphasis is put on the demand side, supply is unavoidably considered and included in the equation by analyzing the market situation in Sweden, both from the government’s as well as from the companies’ perspective. The aim will be supported by the following specific research questions (RQ):

RQ1: What are the main environmental problems faced by Mexico City, and to what extent can technology help to solve them?
RQ2: How do different stakeholders in Mexico City perceive, understand and use technology to solve environmental problems?
RQ3: How do technological solutions permeate a city and diffuse to other cities, and how is this diffusion and adoption process characterized?
RQ4: What strategies is the Swedish government using for the promotion of environmental technology exports, and what are these strategies based on?
RQ5: To what extent do environmental technology companies participate in export activities, and how do they perceive governmental export promotion strategies?

1.2. Limitations

As mentioned in the introduction, the particular contexts that are under scrutiny when talking about urban sustainability allow very little room for generalization. However, analyzing specific cases can bring about interesting and relevant examples of how particular problems are understood, who is involved in their analysis and solution and how these experiences can be applied to approach contextually similar cases, or to develop flexible solutions that adapt to the surrounding environment.
On the other hand, human arrangements are in general very complex structures composed of numerous connections and relations among different kinds of actors and stakeholders. It is virtually impossible to individually map and track all the interactions. It is necessary, therefore, to approach interactions, relations and roles with a broad perspective, understanding the overall picture and the details involved, but keeping enough distance in order to be able to conclude about any stated question.

That being said, this thesis is framed within the following limitations:

- Although different tools and instruments are recognized and mentioned as important components of a city’s search for sustainability, this thesis will focus on the role that technology plays in this sense. Throughout the thesis, political, social and economic initiatives could be mentioned and highlighted as undoubted contributions to problem-solving. However, an emphasis will be put on the technological component and the conclusions will be based on a technical approach.

- The commonly accepted model of sustainability (i.e. the intersection of the social, environmental and economic spheres) is not contested in this thesis and the discussion of the importance or limits of each sphere is not addressed. The basic concept is used (i.e. three components) as a foundation for the discussions and the design of the case-studies. However, the main focus will be put on the environmental component. This component has common roots with the social and economic spheres, but those connections are outside the analyzed system’s boundary and will only be used for supporting particular arguments, or when unavoidably needed.

- As mentioned in the introduction, generalization is difficult, especially under the urban context. This thesis is based on a case study of one megacity, Mexico City. The discussions and conclusions included, unless otherwise indicated, are based on the information collected in this venue or its surrounding region.

- The analysis that this thesis provides is based on basic supply and demand reasoning. As mentioned in the aim, a bottom-up approach will be used. This means that a stronger emphasis will be made on the demand side, filtered through a “sustainability sieve”. Supply (i.e. environmental technology providers) is seen as an important component, but will be approached from a general perspective. This means that the sector is studied and its most important characteristics identified, described, and considered for the analysis of the conditions for technology implementation, but e.g. marketing or “push” strategies will not be considered.

1.3. Outline

This thesis is divided into seven chapters. An outline is presented below with the intention to provide the reader with an overall image of the thesis’ structure and to highlight each chapter’s main contribution.

In Chapter 1 the introduction is presented together with the aim, research questions and limitations. This chapter provides an initial discussion about urbanization and the challenges it presents; about the
role of technology when talking about environmental sustainability in megacities; and about the fact that such cities represent potential platforms for environmental technologies.

In Chapter 2, the scope is depicted in order to clarify the reach and limitations. The theoretical framework is presented including discussions about the theories chosen and their relation to the aim of this study.

Chapter 3 describes the methods used during the development of the research activities and the appended articles. The contribution of the articles to the aim of this thesis is also explained in this section.

From a more empiric perspective, Chapter 4 provides a discussion about the different views of stakeholders on the condition of the city. Here, material obtained during the numerous interviews in Mexico City will be shown and discussed. A specific case of a complex solution and the conditions for its successful adoption, implementation and further diffusion is shown based on Bus Rapid Transit (BRT) systems. In addition, Appended Articles No. 1 and No. 2 support this chapter and provide deeper analyses on the topic.

Furthermore, the Swedish environmental technology sector and the governmental strategies for its promotion in foreign markets will be addressed in Chapter 5. An initial description about the sector and important characteristics will provide a foundation for the subsequent discussion about the different attempts by the government to promote environmental technology exports. This has the intention of analyzing strategies, approaches and the reasons behind them. Part of this discussion is continued in Appended Articles No. 3 and No. 4. In addition, export activities among companies within the environmental technology sector in Sweden are analyzed, as well as the companies’ perception of governmental export promotion initiatives and their effect on actual exports of environmental technology. Appended Article No. 4 discusses this in more detail.

Chapter 6 presents the analysis and discussion of the results by directly answering the research questions. Finally, Chapter 7 presents the conclusions by providing and analysis of the conditions necessary for understanding megacities’ environmental challenges and the role that technology plays in facing them. This discussion is presented by analyzing the mechanisms that influence different processes involved in the acceptance, adoption and implementation of technological solutions. Here, features like contextualization, flexibility, adaptation, demonstration and the ability to make the most out of windows of opportunity are particularly addressed. This chapter ends with recommendations for further research.
2. Research framework

This section depicts the research framework of this study. The limitations discussed in Section 1.2 are included together with the theories used and the stakeholders considered. Due to the complexity of cities and connections among the manifold stakeholders involved, this will facilitate the understanding of the study’s approach. The theory used as reference is discussed below with the intention of laying the foundation for the discussions in subsequent sessions and the appended articles.

As mentioned above, the study of cities is a complex task, given its many actors, networks and connections involved and the manifold possible results of these interactions. However, given this study’s aim, scope and limitations, a set of theories can be found to be useful to analyze environmental problems from a technological perspective, without forgetting the important role of the remaining components. A strong emphasis is put on the demand side. This means that it is of particular importance to understand the components, networks and interactions that have a direct or indirect influence on the way technology is understood, adopted and successfully aligned with existing structures. In this direction, Transition Management (TM) theories provide a clear description of socio-technical transitions, and analyze how these transitions are influenced into a desired path (e.g. sustainability goals) (Grin et al., 2010).

In addition, since this thesis has a technological approach and sees at innovation as an important contribution to sustainability in urban settlements, the Diffusion of Innovation Model (DIM) is considered as an important tool. The study of innovation addresses how technology emerges and diffuses (enters the market) and analyses the communication channels and the actors involved. These theories will be discussed in more detail in the sections below. Figure 1 shows a conceptual map of these theories, with the intention of giving a broader understanding of their influence on this thesis.

![Conceptual map of theories included in the analysis.](image-url)
2.1. Transition Management: socio-technical transitions and the Multi-level Perspective

A transition can be seen as subsequent, reinforcing and connected changes happening in major societal subsystems (Meadowcroft, 2009; Rotmans et al., 2001). In particular, the Transition Management (TM) approach seeks to orient these changes, happening in the long-term (Meadowcroft, 2009). TM has its roots in Science and Technology Studies (STS), which focuses on interactions between technology and society (Geels and Schot, 2010) and on how technology is understood by a particular society. This will influence the development, implementation, adoption and diffusion of technological concepts within and among societies. A particularly important characteristic of STS is that it contests the linear model of technology forming without external influences and having little influence on social changes (Bijker, 2006b). It does so by following actors and their interactions (Geels and Schot, 2010), and understanding technological development as the confluence of manifold heterogeneous resources and components (Hughes, 1986). It is through technology that social interaction takes place, and through societal institutions that technologies can function (Bijker, 2006a). An additional contribution comes from Geels and Schot (2010), who highlight creativity and bricolage as important components of technological development, which is also related to the use of technology by a particular society.

TM does not propose a specific transition, but analyzes in an exploratory manner how governance tools can help to reach certain desired change (Rotmans et al., 2001). There are five components that characterize the TM framework (Rotmans et al., 2001): long-term thinking; multi-domain, multi-actor and multi-level thinking; focus on feedback learning; bringing system innovation alongside system improvement; and keeping a large number of options. Particular importance is put on analyzing change as a result of the interaction between the manifold actors in different levels, who are influenced by changes and at the same time influence further changes (Kemp et al., 2007). This is an important feature of the TM approach. Since it has roots on systems theory, TM uses stocks and flows. This behavior will influence the relation between long-term developments (stocks) and short-term developments (flows), which are analyzed by dividing social organization into three different levels, with the intention of tracking changes and comparing developments (Rotmans et al., 2001):

- Micro: composed of individuals (persons, companies, environmental movements).
- Meso: comprises networks, communities and organizations.
- Macro: conglomerates (nations or federations).

This division plays a central role in the study of socio-technical systems and has a strong influence on the study of sustainable transitions, and in particular on the multi-level perspective.

The Multi-level Perspective (MLP)

An isolated analysis of a particular technology is counterproductive when seeking to expand the scope to the urban level. The manifold interactions between this technology and the system context in which it is embedded demand a systemic approach. In this regard, the multi-level perspective (MLP) offers a
plausible framework for the understanding of the dynamics of technological transitions and socio-technical systems.

MLP describes three different levels of structuration of activities in the local practice. Such structuration will define the complexity of the social networks that interact within each level and thus the difficulty to influence them (Geels and Schot, 2010). As mentioned above, the influence of the TM framework can be seen in the mentioned levels of social structuration:

- **The micro-level (niche-innovations) – Low structuration of activities:** disorganized and uncoordinated activities take place at this level. Innovations arise because of small networks that share visions and expectations. These innovations happen under protected environments and are supported by enthusiasts or risk-takers. However, there is uncertainty and distrust because of the lack of proof-of-concept or large-scale demonstration projects.

- **The meso-level (socio-technical regimes) – Medium structuration of activities:** dominating practices in everyday life dictate the direction of activities and technologies used. Different components and the actors involved (i.e. the hexagon in Figure 2) are supposed to determine the status quo and possess certain power over the resources that influence what happens. At this level, activities are dynamic, but stable.

- **The macro-level (socio-technical landscape) – High structuration of activities:** landscapes are the most difficult levels to influence, because they are composed of rigid and complex structures. It represents a broad context under which decisions are made, normally on a global scale. Examples can be oil prices, financial crises, environmental crises, and collective goals formulated at a confederated level (e.g. climate negotiations). Disruptions at this level are less frequent, but inevitably cause the opening of windows of opportunities that allow innovations from the micro level to enter the meso-level (e.g. oil prices making alternative fuels economically competitive). Figure 2 provides a graphic illustration of the different levels and the flows and stocks within each one.

![Figure 2: The MLP framework: structuration of activities vs. time (Adapted from Geels and Schots, 2010).](image-url)
As mentioned in the introduction, the (more or less) recent interest in environmental protection and remediation globally (macro-level) has triggered the seeking of opportunities to make the most out of emerging, environmental technologies. This is something that is given as granted for this study and will only be discussed when mentioning opening windows of opportunity. Thus, the main focus lies in what are defined as socio-technical regime (meso-level) and niches (micro-level). At the micro-level, there are numerous innovation activities happening under a very dynamic environment, although in isolated and experimental manners. Innovations constantly emerge, but face difficulties when — and if — they manage to step into the meso-level and have to interact with the existing regime. At this level, changes take more time and occur in an incremental way and cannot be forced, since this could create strong barriers and generate opposition from stakeholders (Perrels, 2008).

Once windows of opportunity open (e.g. global climate awareness and negotiations, good financial situation, political support from higher government levels, etc.), innovations from the micro-level encounter a chance to step in and enrich practices that might be embedded in the meso-level. Actors at the micro-level hope for radical changes that modify or replace the existing regimes embedded in society due to economic or technological lock-ins (see e.g. Baas, 2005; Geels, 2002). It is disturbances occurring at the meso-level that provide the opportunity for innovations from the niche level to step into the socio-technical regime (Geels, 2005; 2002). However, although on a smaller scale, such innovations bring with them disturbances, due to the fact that they are new and unknown. To a large extent, the magnitude of this disturbance will define the ability of an innovation to align with other connected subsystems of the regime, since these subsystems are protected from excessive disturbance by suspiciousness and distrust (Rogers et al., 2005).

In summary, MLP helps understanding where innovations emerge, and how they manage to be considered by the networks operating in the socio-technical regime when a window of opportunity opens. What is left now to analyze is how such innovations survive, i.e. how they stay and become functioning solutions to particular societal problems. First, the aggregated level (STS) was discussed, followed by the analysis of systems, actors and interactions among them. After talking about the components of socio-technical systems, it will now be analyzed how technical solutions emerge, mature and find their way into the regime, where some fail and some stay and become innovations (i.e. they compete in the market or become complementary to other existing solutions).

### 2.2. Innovations: emergence and diffusion

As mentioned above, when having in mind the MLP framework, innovations emerge in the micro-level. This process of emergence can be depicted as having four different phases (Robertson, 1967): identifying a particular problem, setting the stage (cf. opening windows of opportunity), finding the solution, and analyzing the actual practicability of the solution. An interest in studying innovations and their diffusion can be traced back to post-World War II era, when the environment motivated the emergence of innovations and the economic model started to strongly rely on them (Abrahamson, 1991; Meade and Islam, 2006). Such reliance has not changed much, especially in the case of developed economies. In particular, the growing attention to environmental challenges has motivated a race for the development of cleaner technologies (e.g. renewable energy, energy-efficient technologies, etc.). This justifies the interest in the analysis of innovations and their diffusion process for the case of environmental technologies in megacities.
As mentioned previously, the case of megacities is especially complex due to the complicated relations and interaction among different actors and the networks they might belong to. Having in mind this complexity is important because it facilitates the understanding of the difficulties to influence certain systems when they are connected to so many other systems and subsystems. This is not new for scholars in the diffusion of innovations field. Some signs of this can be seen in Robertson’s work (1967), who classifies innovations as continuous (i.e. low disruption on existing practices and structures); dynamically continuous (i.e. more disrupting but do not alter established patterns), and discontinuous (i.e. establishment of new ways and new practices).

A natural extension to the study of innovations is the process of diffusion. The diffusion process refers to an innovation that is spread through communication channels over a period of time to members of a social system (Rogers, 2003). This process might be difficult to model due to the numerous variables involved. However, Rogers (2003) proposes a diffusion curve based on the normal distribution, in which adopter categories are classified according to the time when individuals adopt an innovation. Figure 3 shows the normal distribution curve and the cumulative distribution curve, respectively.

Figure 3: Adopters’ categories based on time of adoption. The bottom graph represents the normal distribution (i.e. sequential adoption), while the top graph represents cumulative adoption (adapted from Meade and Islam, 2006; and Rogers et al., 2005).

This model is interesting because it shows the different types of adopters and their different nature, and each individual/group’s willingness to accept or reject risk. It is this diversity that makes diffusion possible (Rogers, 2003). Most interesting to this study is not only to understand how the diffusion process looks, but also to analyze how it is delayed or dynamized. The diffusion of innovations model (DIM) has been used in different fields. Particularly, the field of health has used the model for the analysis of innovations diffusion, for example for the prevention of diseases like HIV/AIDS and the diffusion of preventive innovations (e.g. Bertrand, 2004). Rogers (2002) defines five factors that determine an innovation’s rate of adoption:

- **Relative advantage** refers to the degree to which an innovation is perceived as better than the idea it supersedes. In particular, adoption and diffusion of an innovation happens more rapidly when it is seen as a sign of prestige, convenience or satisfaction. Environmental issues include

1 Note that this reference is to the source’s 5th edition. Rogers started to develop this model already in 1962.
a complicated contradiction. On the one hand, especially lately, cities compete over which one is the “greenest” or the most sustainable. One way of achieving this is through environmental technologies, i.e. technologies that decrease the city’s impact on the environment. On the other hand, however, the current economic system hinders the adoption of any technology that is monetarily non-efficient, i.e. that is more expensive to acquire, more expensive to maintain and/or does not show short-term economic benefits.

- **Compatibility** is the degree to which an innovation aligns with existing values and past experiences. In the case of cities and environmental technology, given their complex and rigid systems, this also has to do with the innovation’s compatibility with existing infrastructure and socio-technical systems.

- **Complexity** is how difficult a solution is perceived to be. Complexity here does not only refer to the actual functioning of a technological solution, but it is closely related to the previous bullet point (i.e. compatibility). An innovation that is simple to understand and use in an isolated matter can be complex to use when non-compatible with existing, connected systems.

- **Trialability** refers to the degree to which a technology can be put to test on a limited basis (chronologically speaking). In this case, it might be one of the most (if not the most) problematic factors hindering diffusion. Environmental technologies, especially those on a large-scale (i.e. those considered and/or adopted by cities) are expensive. Both producers and adopting cities cannot afford implementing e.g. a transport system for a trial period, not to mention how impractical it would be. This poses an enormous hindrance to new, untested technologies, which would require risk-takers (innovators and early adopters in Rogers’ terms) in order to prove their solutions. Even so, cities might be reluctant to try solutions that might seem implemented under contexts perceived as distant or incompatible.

- **Observability** is the degree to which the results are visible to others. The problem here is not that results are not visible, but that in most cases these results can take years to become evident. In particular, this can become a political problem, since decision-making is numerous times a process affected by political visibility, i.e. mayors and politicians want the results to show during their time in office and are generally not willing to let other politicians enjoy the recognition. Times in office vary from place to place, but they normally lie between three and six years. Many environmental technologies show results in the long-term, especially at large scales, e.g. air pollution, underground water restock, biodiversity recovery and soil remediation. Added to this, most citizens want their problems solved now, even if that is virtually impossible in many cases.

As it will be shown, these conditions are directly or indirectly discussed by the interviewees in each of the case-studies. For now, they are shown here to provide a theoretical support to the study.

Different approaches to the relation between society and technology are shown here and adopted as a framework for subsequent analysis. It has been shown how the interactions between society and technology can be studied from different perspectives, and a focus is put on analyzing actors and their interactions, the structuration of their activities and how innovations are a part of socio-technical systems. All these traits will be seen and discussed from an empirical perspective in the following section.
3. The research process

The different methods used to develop this study are described in this section. Such methods include the selection of the case study, literature reviews, identification of stakeholders and field trips including numerous interviews with selected actors. In addition, the contribution of the appended articles in relation to the aim and the research questions mentioned in Section 1.1 is described and discussed. As was touched upon in the introduction, and will be looked at more deeply below, the intention of analyzing cities as platforms for the diffusion of environmental technologies is born from the fact that cities are identified by different actors as potential markets given their numerous environmental problems. Cities with more than ten million inhabitants, i.e. megacities, are particularly interesting from this perspective. This is given the self-evident difficulties of providing good environmental conditions in highly-urbanized areas because of their complexity and the high pressure they put on their surrounding environment, and on those environments they rely upon for their everyday functioning.

3.1. Selection of Mexico City as the case study

In 2009, The Swedish Governmental Agency for Innovation Systems (VINNOVA) launched a call for the analysis of megacities as potential business arenas for Swedish environmental technology. Megacities have been described by different scientific articles and governmental and journalistic reports as problematic places, with uncontrolled growth and numerous environmental challenges. Mexico City was proposed as a case study, for the reasons presented below.

When planning to study the complex dynamics of these large towns, it is important to have access to quality information and reliable sources. A first mapping of the stakeholders thought to provide valuable and accurate information about the cities’ situation was made. Existing contacts, cooperation programs and previous joint projects with different actors in Mexico City allowed the selection of this venue as a feasible case study. In addition, the regional importance of this city (i.e. its position in Latin America) was an additional fact that influenced the decision. The political, economic and social weight of this city and its flows of people, knowledge, information and technology were thought to facilitate the understanding of environmental technology diffusion, adoption and implementation.

Finally, based on their current growth rates and their capability to respond to environmental challenges, cities can be classified into three groups (Gareth Lothhouse, Economist Intelligence Unit, 2004): emerging, transitional and mature. There are fewer megacities in the developed world, and although they fall into the category of highly urbanized – and thus allegedly problematic areas – they are considered to be more prepared and capable to respond to environmental challenges, at least from a technical and economic standpoint. In comparison, these cities have solved many of their environmental problems and have throughout the years provided the right environment for the local development of solutions, and the subsequent possibility of exporting them. On the other extreme, emerging cities have large growth rates which they struggle to cope with. These cities have a variety of problems that must be prioritized over environmental protection, which might leave little room for considering the implementation of many environmental technologies.
Transitional cities, on the other hand, present more stable growth rates and even a decline in some cases. They have managed to organize more properly and are starting to generate more resources that can be directed toward environmental protection and remediation. Mexico City can be considered to be within this last group (Economist Intelligence Unit, 2011). Many of the environmental challenges that are now in these cities’ administration agenda represent good opportunities for environmental technology providers looking to expand their current activities and for venues that might not only require their products/services, but that might also be willing to implement them and become platforms for the further diffusion of their offerings. Figure 4 summarizes the case selection process.

Mexico City provides therefore an interesting case study, given the type of questions and the aim defined for this study, as the case study methodology is useful for analyzing contemporary events for which relevant behaviors cannot be manipulated (Yin, 2009). By directly observing events being studied and by performing interviews with those involved in them, it can be possible to understand the conditions for the current environmental situation, how the challenges are faced by local stakeholders and what have been the results of different processes addressing environmental issues over different periods of time (Yin, 2009; Berg, 2009).

![Figure 4: Schematic description of the selection of Mexico City as the case study.](image.png)

3.2. Literature research on Mexico City

Cities like Mexico City have been considered attractive places from a historical perspective. Most recently, however, the attention has been on their rapid growth and its consequences. There are numerous academic studies and reports describing the different characteristics of these cities and their historical traits. From an environmental perspective, the past and current problems of megacities, as well as their challenges, have been widely described and critically analyzed (see e.g. Toufexis, 1989; Baas, 2005; Burdett and Sudjic, 2007; Mejía-Dugand et al. 2011).

Initial desktop research provided extensive knowledge about the current environmental situation in the city and the history behind that situation; its administrative structure and the possible hindrances to implementing different environmental initiatives; and its preoccupations, projects and focal areas regarding environmental protection or redress, among other more specific details about life in this city.
Chapter 3: The research process

Although it is classified under the label “megacity”, its differences and context were identified and understood having in mind its own characteristics. Historical, geographical, political and social differences provided a clearer image of the role that different stakeholders could play within their city. Such background research would provide the foundations for the theoretical image created prior to eventual field visits and interviews with stakeholders in the city.

3.3. Selection of stakeholders

As mentioned above, access to quality information and reliable sources is an indispensable requirement for a case study. The definition of stakeholders mentioned above was emphasized after selecting the city for study. In order to ensure relevant and reliable results, Yin (2009) and Berg (2009) suggest triangulation as a valid strategy. This concept refers to the process of looking for information about a phenomenon by combining several lines of sight; i.e., with different parties influencing, being influenced by or involved. Taking an analogy from the military, this strategy can provide a more approximate and accurate result on the object of study. Therefore, based on local experience (i.e. in Sweden) on the application of technologies, the decision-making process and the communication flows needed to facilitate environmental technology implementations, the triple-helix model for decision-making (i.e. academia-industry-government) was selected as the strategy to follow.

The choice of a triple-helix approach was completely a methodological decision (cf. a theoretical decision). In modern, knowledge-based societies, innovation is expected to emerge equally from academia, government and industry, and collaborative relationships and the interaction among the three are expected to produce proper innovations (Etzkowitz and Klofsten, 2005). All three major institutional spheres must work transversally, or as Etzkowitz and Klofsten (2005:245) state, “take the role of the other”. Innovation is stimulated at the intersection between the three spheres, contrary to the statist model (i.e. industry and academia under control of the State) and the laissez-faire model (i.e. the three spheres are independent and interaction is limited or non-existent) (Etzkowitz, 2007). In fact, the intersecting spheres’ model has been expanded to include a sustainability dimension (Etzkowitz and Zhou, 2006). A particular interpretation of the triple-helix model describes mediating organizations that facilitate interaction among the spheres and that have been known to have played key roles in technology transfer (Leydesdorff and Etzkowitz, 1998). Such organizations, in particular supra-governmental organizations and non-governmental organizations (NGO), were thus included in this thesis.

Different representatives from each group were contacted and asked for an interview. These representatives were informed in advance about the objectives of the research project in order to direct the discussions specifically toward environmental concerns.

3.4. Field studies: interviews with stakeholders

Once the different stakeholders were identified and prioritized, field visits were planned with the intention of confirming the data collected through the desktop research, as well as to personally collect
the impressions and opinions of the different actors influencing and influenced by the environmental challenges of the city. These visits were held in two phases: one exploratory, one in-depth. More detail is provided below.

**First round of interviews: an exploratory approach**

In December, 2010, once information regarding the selected venue was collected and the stakeholders were selected and contacted, a field trip was made to the city. Through semi-structured interviews it was possible to corroborate what was found through the desktop research, increase and deepen the knowledge and expand the contact network. Table 1 provides a more detailed look at the interviewees in Mexico City.

**Table 1: Interviewees in Mexico City and their role (first round).**

<table>
<thead>
<tr>
<th>Ref. No.</th>
<th>Type</th>
<th>Organization/Institution</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Academia</td>
<td>Center for Urban Studies, Universidad Autónoma de la Ciudad de México (UACM)</td>
<td>Generate research within the urban phenomenon, particularly in Mexico City. Communicate its results through seminars, colloquia and publications in cooperation with other universities and governmental bodies.</td>
</tr>
<tr>
<td>2</td>
<td>Academia</td>
<td>Energy Department - Universidad Autónoma Metropolitana (UAM)</td>
<td>Generate knowledge and develop sustainable environmental technologies in line with the problems that society faces regarding the efficient use of the planet’s energy sources.</td>
</tr>
<tr>
<td>3</td>
<td>Governmental</td>
<td>Metropolitan Environmental Commission (CAM)</td>
<td>Define, coordinate and monitor legislation, projects and actions regarding environmental protection, preservation and restoration of the ecological balance within the urban area.</td>
</tr>
<tr>
<td>4</td>
<td>Governmental</td>
<td>Waste Commission of the Federal District</td>
<td>Propose and define mechanisms and criteria for the coordination of issues regarding generation, handling, treatment, minimization, use and final disposal of residues within the Federal District.</td>
</tr>
<tr>
<td>5</td>
<td>Industrial coalition</td>
<td>World Business Council for Sustainable Development (WBCSD) – Mexican chapter</td>
<td>Participate in research, analysis and in the solution of problems related to sustainable development, and promote and provide training regarding sustainable development and eco-efficiency, all in cooperation with the different sectors involved.</td>
</tr>
<tr>
<td>6</td>
<td>Industrial coalition - Academia</td>
<td>National Council of Ecologist Industrialists (CONIECO)</td>
<td>Promote an ecologic culture in industrial processes and the efficient and responsible use of energy and water; participate in the creation, revision and analysis of the ecologic regulations for industry; and spread technical, economic and cultural information about pollution control.</td>
</tr>
<tr>
<td>7</td>
<td>Non-governmental organization</td>
<td>Institute for Transportation &amp; Development Policy (ITDP)</td>
<td>Influence policies and raise awareness of the role that transportation plays in sustainable development and advise local governments on the implementation of transport solutions for the reduction of pollution, poverty and the improvement of the quality of urban life.</td>
</tr>
<tr>
<td>8</td>
<td>Non-profit organization - Industrial coalition</td>
<td>Global Environmental Management Initiative (GEMI)</td>
<td>Guarantee legal stability for companies involved regarding environmental legislation; promote green supply chains; make environmental assessments; provide advice to industry, society and government; and benchmark best practices worldwide.</td>
</tr>
<tr>
<td>9</td>
<td>Supra-national initiative - Academy</td>
<td>Mexican Center for Cleaner Production (CMPL)</td>
<td>Deliver services to businesses, the government and other stakeholders for the implementation of cleaner production methods, practices, policies and technologies.</td>
</tr>
</tbody>
</table>
Chapter 3: The research process

Second round of interviews: a deeper look at technology

As mentioned earlier, the first round of interviews confirmed the knowledge previously acquired and provided a deeper understanding of the situation in Mexico City. A year later (i.e. November 2011), a follow-up visit was planned. This trip had two objectives:

- **To join a business delegation of Swedish companies traveling to Mexico City.** Different entrepreneurs (not only environmental technology providers) took part in a week of events directed to understand the local market and meet potential customers, in order to expand their activities. The delegation trip was organized by regional business organizations in Sweden (e.g. SINEC, SIEN and BNÖ) and the Swedish Trade Council (Exportrådet) in Mexico. The delegation took advantage of the visit planned to the city by the Swedish Minister of Trade, Ewa Björling. The intention with joining these entrepreneurs was to take part in the initial conversations and exploration of the market, in order to learn from the process.

- **To collect empirical data about technology use and diffusion in the city.** For this purpose, different actors in the city involved in the development, implementation and diffusion of technology and science were interviewed. It is important to highlight that two of the interviewees from the first round were again interviewed in the second round; they are marked with (*) in Table 2, which provides a deeper description of the interviewees.

Table 2: Interviewees in Mexico City and their role (second round). Interviewees marked with (*) keep the reference number given in Table 1.

<table>
<thead>
<tr>
<th>Ref. No.</th>
<th>Type</th>
<th>Organization/Institution</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Academia</td>
<td>Research Group in Industrial Ecology (GIEI)</td>
<td>Provide a diagnosis that could help to reduce the negative environmental impact of industry. Look for material and energy exchanges among industries, upgrade waste materials and reduce the generation of waste.</td>
</tr>
<tr>
<td>11</td>
<td>Governmental</td>
<td>Institute of Science and Technology of the Federal District (ICyTDF)</td>
<td>Contribute to the strengthening of the scientific, technological and innovative capabilities of institutes and research centers located within the Federal District.</td>
</tr>
<tr>
<td>12</td>
<td>Industry</td>
<td>Green Momentum</td>
<td>Promote the development, implementation and commercialization of environmental technology by providing training, financial and market information, and business model support.</td>
</tr>
<tr>
<td>13</td>
<td>Foreign governmental agency</td>
<td>Swedish Trade Council - Mexico City</td>
<td>Provide all services required to establish a company and its products, services or ideas in new markets.</td>
</tr>
<tr>
<td>4*</td>
<td>Governmental</td>
<td>Waste Commission of the Federal District</td>
<td>Propose and define mechanisms and criteria for the coordination of issues regarding generation, handling, treatment, minimization, use and final disposal of residues within the Federal District.</td>
</tr>
<tr>
<td>7*</td>
<td>Non-governmental organization</td>
<td>Institute for Transportation &amp; Development Policy (ITDP)</td>
<td>Influence policies and raise awareness of the role that transportation plays in sustainable development and advise local governments for the implementation of transport solutions for the reduction of pollution, poverty and the improvement of quality of urban life.</td>
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</tbody>
</table>
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Data collection during the field trips

Two types of data were collected during the field trips. First, as mentioned before, qualitative data was collected through interviews. This data was transcribed, both when recorded and when notes were taken. Such data was used for describing the environmental situation in the city, the understanding and use of technology to solve environmental problems and the obstacles that technology faces for implementation. The second type of data collected was quantitative. With the help of the Institute for Transportation and Development Policy (ITDP) in Mexico, information about the development of Bus Rapid Transit (BRT) systems in the city (as well as on a global scale) was collected and analyzed. This was done with the intention of studying a particular case of technology adoption and diffusion, and analyzing lessons that could be reproducible by other types of technologies within the environmental sector (see Appended Article No. 2).

3.5. Analyzing the demand side

Two types of data were collected for the analysis of the environmental technology sector in Sweden. First, information was collected about companies in the sector. Field, area, products/services, location and contact information was collected and classified in a database. In addition, a web-based survey was sent to around 730 companies within the environmental technology sector. The survey aimed to analyze these companies’ involvement in export activities and their perception on governmental support systems for the promotion of exports. The results, which provided interesting conclusions about the sector, were presented at a conference in October 2012 (see Appended Article No. 4).

Furthermore, economic data about the environmental technology sector in general was analyzed by making use of publicly available data provided by Statistics Sweden (SCB). This agency defined the Environmental Accounts (in line with European Commission’s plan for the implementation of environmental technology - ETAP) and classified the sector’s activities in order to register its economic activities (e.g. turnover, exports, establishments and employment). This information allows a deeper analysis of the sector’s composition and economic behavior (see Appended Articles No. 3 and 4).

3.6. Contribution of the appended articles to the aim of the thesis

As shown in Section 1.1, the aim of this thesis is supported by five research questions. In this section, such research questions will provide the foundations for describing the contribution of each appended article to the general aim. Each article has its own contribution, incrementally covering the intended questions, as shown in Table 3.
Chapter 3: The research process

Table 3: Contribution of each article in relation to the research questions.

<table>
<thead>
<tr>
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<th>RQ1</th>
<th>RQ2</th>
<th>RQ3</th>
<th>RQ4</th>
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<td>Article 1</td>
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<td>Article 2</td>
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<td>Article 3</td>
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<td>x</td>
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<td>Article 4</td>
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Aim: The aim of this article is to analyze megacities as a potential market for Swedish environmental technologies. This is done by providing insight into the key dynamics for the successful up-scaling and diffusion of environmental technologies using a case study methodology.

Method: Through interviews with key local stakeholders, such as governmental and non-governmental institutions (NGOs), intermediary institutions, industry representatives and academia, a description of different barriers to environmental technology implementation is provided, keeping in mind the specific social and economic context of the venue and its inhabitants/government’s perceptions of their current environmental situation. These are the article’s research questions:

- What are the major environmental problems in megacities?
- What are the key dynamics for the successful up-scaling of environmental technologies in cities in emerging markets?
- What are the possible barriers to success?

Contribution: This article contributes with a more detailed analysis of the environmental problems of megacities, with a focus on Mexico City, along with different opinions from stakeholders and a description of hindrances mentioned by them, as well as some identified during the field trip. A model thought to facilitate the entrance of foreign environmental technology making use of local resources is suggested.

Article 2 – Lessons from the spread of Bus Rapid Transit in Latin America (Article Published in the Special Edition on Sustainable Urban Transformation of the Journal of Cleaner Production).

Aim: The aim of this article is to describe the diffusion dynamics of the BRT concept in Latin America and to identify and analyze the determinants of this behavior. This is done with the intention to provide foundations for learning about the diffusion and implementation process for other technology concepts.

Method: Information from the 30 Latin American cities that had implemented BRT systems by 2011 was collected with the help of the Institute for Transportation and Development Policy (ITDP) in Mexico. Such information included the name of the system, its opening date, the total length of the main lanes (trunk), the number of passengers transported, the peak throughput, the number of stations,
and the number of buses. The data were classified and filtered to construct a chronological map illustrating how the BRT concept was replicated and the diffusion pattern that it has presented since its first years. The theoretical structure of this article was founded on socio-technical transitions and governance theories. The research questions addressed by this article are the following:

- Are there any key points in the development path of BRT systems in Latin America that stimulated their diffusion in the region?
- What traits have been and could be further replicated to facilitate the spreading of other type of technology concepts?

**Contribution:** This article’s contribution is the description of the diffusion path of an urban mobility solution in the Latin American region. Although its development, adoption, improvement and subsequent diffusion did not happen as an environmental initiative from the beginning, the environmental benefits it has resulted in has caught wide attention in that direction. This article claims that other types of technologies, especially those that have an environmental focus, can learn from this process for the design of diffusion strategies in the future.

**Article 3 – Diffusion of environmental technology: an analysis of export strategies in Sweden (Manuscript to be submitted for publication).**

**Aim:** The aim is to describe the process of development of export promotion strategies for environmental technology in Sweden, and to discuss possible conditions for a successful international diffusion.

**Method:** Data collection was developed in two stages. In the first stage, information about the environmental technology sector was collected with the help of databases publicly available through Statistics Sweden and The World Bank. In the second stage, data was collected through the different agencies entrusted by the government to assess the sector and provide conclusions and suggestions for the development and deployment of strategies to promote the sector, locally and abroad. From a theoretical perspective, Governance and Diffusion of Innovation theories were used as a basis for the analysis of the different conclusions reached by the different agencies; for the discussions about possible obstacles that the sector faces in international markets; and for the suggestion of possible approaches to have in mind, considering the conditions of the sector and the characteristics of the different potential markets abroad.

The research questions for this article are:

- What is the current composition of the Swedish sector of environmental technology?
- What kinds of strategies is the Swedish government using for the promotion of the environmental technology sector internationally?

**Contribution:** This manuscript provides deep insight into the Swedish environmental technology sector, describing its performance in selected common enterprise indicators during the last decade. In addition, it summarizes the different findings and conclusions drawn by the different agencies and institutes commissioned for the assessment of the sector and for the development of action plans for the promotion of its offerings. Finally, it presents a discussion about the actual strategies and plans
deployed so far by the government from a theoretical perspective, and suggests adaptive approaches, depending on particular market characteristics.

**Article 4 - Environmental technology exports: Analyzing Swedish government and firms’ initiatives** *(Article presented at the Greening of Industry Network Conference, 2012 – To be submitted to the Special Volume of the Journal of Cleaner Production for the GIN Conference 2012)*.

**Aim:** The aim of this article is to assess the perception of the effectiveness of governmental initiatives for export promotion among Swedish environmental technology firms. In addition, the article addresses the internal initiatives of firms to reach potential foreign markets through the use of modern communication channels.

**Method:** The study consists of three parts. First, a database was built containing information about environmental technology companies in Sweden. Second, a web-based survey was sent to those companies that provided electronic contact information. Third, a desktop analysis of the firms’ web sites was performed in order to analyze the use they make of the Internet as a tool for reaching out to potential foreign customers, based on their presence on the Internet (i.e. own, functional web site), the provision of electronic contact information and the provision of language customization options. The research questions addressed by the article are:

- Do companies in the environmental technology sector participate in fitting governmental export initiatives? If so, what is their perception on these initiatives’ effectiveness?
- Are Swedish environmental technology firms making use of the Internet as a way of expanding their outreach to potential foreign markets?

**Contribution:** The article provides a view on the composition of the environmental technology sector in Sweden. A deep analysis looks at the reasons behind the governmental initiatives to promote exports and the different types of initiatives found in the literature for this purpose. Furthermore, with the results obtained from the survey, it is possible to gain insight over the perception that companies in this sector have on the effectiveness of the initiatives to reach good export results. On the other hand, private initiatives are mentioned as necessary, additional contributions to the export efforts. The use of the Internet and the provision of language options are suggested as a possible signs of these efforts.
4. Mexico City: stakeholders’ perspective on environmental challenges and environmental technology

As previously mentioned, the triple-helix approach (i.e. the academia-industry-government triangle) is used as a strategy for assessing the city’s environmental situation, and for understanding the role of some of the actors involved in environment-related issues and the networks they are a part of. Although it is not the aim of this study, it is important to devote a few lines to explaining the context of Mexico City.

Most human agglomerations in the Americas were, prior to the arrival of Europeans, small villages with few inhabitants and few connections among them. This was not the case of Mexico City. According to the City Hall, Mexico City (formerly Tenochtitlán) was founded in 1325 by the Aztecs. When the Spaniards arrived, the city had advanced sanitation systems which collected human excreta for use as fertilizer, and even a public lighting system. The local marketplace, Tlaltetolco, was the largest and most important in Mesoamerica, where local and distant merchandise was exchanged. All this highlights the regional importance of the city, even before it was “discovered”.

In 1824 the area was defined as a Federal District, i.e. a territory under control of the federal government. This, as it will be discussed later below, has implications on the flexibility and the entitlements of the city administration. The Federal District is composed of 16 boroughs, each one governed by a borough head, elected democratically. According to the National Institute of Statistics and Geography (INEGI) (2011), the last census of 2010 showed a population of 8.8 million. The whole metropolitan region (called Metropolitan Area of the Valley of Mexico) had a population of 20.1 million by that time, which accounts for almost 18% of the total Mexican population. This region is comprised by the Federal District, as well as by 59 municipalities from the State of Mexico (Secretaría de Gobierno, 2006). This poses numerous challenges to the administration, as coordination can be sometimes difficult. By 2010, according to INEGI (2011), 77.8% of the total Mexican population lived in urban areas. Figure 5 shows the location of the city and its political division.

Geographically, Mexico City is situated in the Valley of Mexico. In particular, a large part of the city is located on the basin of the former Lake Texcoco, artificially drained by the Spaniards to avoid flooding. While it solved the flooding problem, it also caused additional problems, due to the instability of the soil and the dust storms formed during the dry season (not to mention the loss of an efficient, ancient, transportation means for people and merchandise). In addition, the overexploitation of underground water has caused the collapse of soil layers, which has resulted in the sinking of infrastructure and the damage of e.g. water pipelines.
4.1. A conversation with different stakeholders in Mexico City.

The interviewees that participated in the first round of interviews in the city were mentioned in Table 1. In the present section, a summary of the different topics discussed is presented with the intention of providing a deeper understanding of the current situation and a closer look at how different actors see problems, solutions and the networks involved. The section will be divided in three parts, each of them addressing a different topic. Data obtained from the interviews with the stakeholders will constantly appear in this section. They will be referenced to as numbers within square brackets, connecting to Tables 1 and 2. Appended Article No. 1 provides an additional, deeper analysis of stakeholders and the environmental situation in Mexico City.

*Environmental problems in Mexico City*

As most megacities, Mexico City faces enormous challenges that normally come together with overpopulation. These include air pollution, solid waste generation, energy consumption and emissions to air and soil. However, some problems are more intense here, because of historical, demographical and geographical causes. Appended Article No. 1 and Mejía-Dugand *et al.* (2011) provide an additional contribution to this topic.

Mexico City has historically had air pollution problems. Besides overpopulation as such, this can also be partly explained by the topographic conditions of the valley and its altitude. Being located 2240 m.a.s.l. the mix of oxygen in the combustion chambers of engines is not optimal, which creates poor combustion results. In addition, the altitude favors the reaction of pollutants to create smog and other
common urban pollutants. Finally, the fact of being located in a valley hinders to some extent the ability of winds to disperse pollutants, which aggravates the concentration levels in the city. On the other hand, there were around 3.7 million vehicles registered in the Federal District as of 2009 (SETRAVID, 2010). Although a vast majority of travels are made using public transport (SETRAVID, 2007), private vehicles are the main emitters of air pollutants [3]. Industry also contributes to this problem, but during the last years a large share of heavily-polluting industries have been moved away from the city, as has been the case in manifold cases around the world.

Another important challenge for Mexico City is its drinking water supply. This is not completely a surprise, since supplying 20 million inhabitants with drinking water does not seem to be an easy task. The city relies heavily on underground water extraction. This has led to over-extraction, at rates way beyond the replenishment rates (IDRC, 2004). This has been partly solved by bringing water from remote areas through the Cutzamala system2, which currently provides up to 30% of the city’s drinking water. This system pumps water from a 130 km distance, from sources that are located 1,100 m lower than the city. Although considered a great engineering solution, this has not only led to political problems (resource conflicts) but also enormous costs due to the infrastructure required and the energy consumed.

Moreover, over-extraction has not only resulted in supply problems; by extracting underground water, numerous spots in the city have shown a collapse of the soil layers (because of a combination of the extraction as such and the weight of buildings and roads, among other infrastructural components) and the subsequent sinking of some areas in the city. However, it is not only external infrastructure that suffers from this sinking. Underground infrastructure, in particular the water distribution system, suffers when pipes break, leading to leakages. It is estimated that up to 37% of drinking water is lost due to leakage in Mexico City (Economist Intelligence Unit, 2010).

All of the above has a tremendous effect regarding the quantity of the water supplied to the city. Regarding quality, one of the interviewees [11] mentioned that the administration assures that 95% of the water delivered is potable, however it becomes polluted once it reaches accumulation tanks located close to the inhabited areas. This might be the reason why it has been reported that a large share of people living in the capital do not trust the quality of the water provided (González Reynoso et al., 2010).

Finally, the third-most mentioned problem is solid waste. The Federal District produces around 12,500 tons of waste per day (Jefatura de Gobierno, 2010). As of 2011, all this waste was going to the Bordo Poniente landfill, which was also receiving waste from other municipalities belonging to the Metropolitan Area. In total, 30,000 tons per day were poured into this site [4]. The composition of this waste is 60% inorganic/non-biodegradable and the rest organic/biodegradable [11]. As of December 2010, 90% of the waste was being landfilled, and the remaining 10% sorted and recycled [4]. The landfill closed on December 19, 2011. This closure represented one of the major preoccupations for the waste management commission; i.e., finding a replacement [4]. Several surrounding municipalities refused to receive the waste coming from the Federal District, and other suitable places were difficult to find. Although it was mentioned that studies about the methane content and its recuperation feasibility are almost nonexistent [11], a Spanish-Mexican consortium was granted the recovery of the

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2 The Cutzamala is one of the main systems for the provision of bulk water to the Federal District. It takes water from the Cutzamala River, southwest of the city, and is composed of a series of reservoirs, tunnels and pipelines.
methane and the production of electricity in November 1, 2012 (Dirección General de Comunicación Social, 2012).

Other important challenges mentioned by different interviewees were:

- **Energy.** There are several challenges for the city regarding the quality of liquid fuels, electricity production, CO₂ emissions, and energy efficiency. Over 80% of its electricity is produced from oil, coal and natural gas (Economist Intelligence Unit, 2010). The availability of fossil fuels is large and the cost comparatively low, as the country is one of the world’s top oil producers.

- **Food security.** The challenge of feeding 20 million inhabitants is enormous. Although the preoccupation about quantity is latent, there is more focus on preserving the variety and diversity of traditional crops which are becoming extinct from the area due to urbanization and cultural change [11] (see also Samuelson, 2012).

- **Climate change.** Being a megacity, its impact on climate change is considerable. The administration recognizes this problem as one of the largest threats from a city and a global perspective (Secretaría del Medio Ambiente, Gobierno del Distrito Federal, 2008). In particular, the effect on changes in the intensity of rainfall is great, due to its geographical conditions and historical vulnerability to flooding.

- **Loss of biodiversity.** Apart from flora and fauna directly affected by infrastructure and human activities, the city has to protect its hinterland. In particular, a study by the London School of Economics estimates that 60% of housing in Mexico City is informal (Burdett and Sudjic, 2007). This situation poses a threat represented by the informal expansion of the city into protected areas or natural sinks, competition for scarce resources, inability to provide basic services (waste collection, sanitation, public transport) and inappropriate control of construction techniques.

- **Social responsibility and social equity.** These are inevitable topics when addressing urban sustainability. Even if strictly looked at from an environmental perspective, it is the right of all citizens to have good quality of air, water and soil, and to have equal access to green areas and public transport, and to a preserved natural heritage in the region. This is an enormous challenge for most Latin American cities, where high gentrification patterns and lax legislation and/or monitoring of industrial emissions to air, water and soil affect these conditions.

**Existing knowledge, stakeholders and triple-helix connections**

Environmental awareness has grown enormously in Mexico City, in part attributable to the bad reputation it gained during the second half of the twentieth century (see for example Toufexis, 1989) and to its regional and global visibility. A good example is the dramatic improvement in air quality during the last few years [3]. Intense monitoring activities take place in the city with the intention to control pollution levels and inform citizens in real time [3]. In the case of high levels of certain pollutants in the atmosphere, a contingency plan (called “environmental contingency”) is deployed, which among other things results in closing schools and even temporarily shutting down production lines for those industries labeled as highly pollutant.
Air pollution is not the only topic of interest in the city. There are numerous local research groups, governmental and non-governmental institutions involved in projects on mobility issues [7], emissions reduction [2,3,5,7,8,9], population [1], food security [11], local technology development and diffusion [2,6,11,12], waste treatment [4,9], energy efficiency and cleaner production [2], and biofuels [10,12], among others. Especially in the city, according to the Institute of Science and Technology of the Federal District (ICyTDF), there is a change of paradigm in the administration regarding the decision-making process and public policies development; that is, relying on scientific facts and knowledge instead of on personal opinions, trends or fashions [11]. This is unfortunately not the case in the industrial sector [11].

This is seconded by the general consensus over the fact that the triple-helix is to some extent dysfunctional in the city. Two connections were described as problematic by different actors. First, the industry-academia relationship is weak and, in many cases, non-existent [9,11]. This relation works in this way: universities train professionals to go and work for the industrial sector, which in turn offers job opportunities (cf. basic microeconomic model). There is not a functioning feedback-relation between these actors, and knowledge developed at the universities is not efficiently used by industries, which normally have their own, isolated R&D activities. During recent years, however, the city’s government has made important efforts to reinforce this relation, especially by providing training and support for patenting and other tools for intellectual protection, and by connecting companies to eventual developers that need testing grounds in industry [11]. Second, an important component of the government-industry relation is weak; i.e., the proper communication and dissemination of policies, especially those that represent incentives, are not properly communicated and the benefits are not understood by the industrial sector [8,9,12]. Figure 6 describes triple-helix relations and highlights the links missing in the case of Mexico City.

![Figure 6: Triple-helix relations in Mexico City (left image) vs. a fully functional triple-helix (right image) (based on Etzkowitz and Klofsten, 2005).](image)

**Incentives and obstacles**

By analyzing the information gathered during the interviews and the field visits, it is possible to identify both incentives and obstacles to the solution of the environmental problems mentioned above, especially for the implementation of technologies that could help in such an enterprise. As mentioned above, there are at present three challenges that are particularly important for the different stakeholders interviewed. These will be discussed first, while other sectors or challenges will be discussed at the end of the section.
Air pollution

As previously mentioned, mobile sources (i.e. vehicles) are considered to be the largest contributors to this problem. This problem has been primarily addressed in four ways: air quality monitoring, quality of fuels, circulation restriction and replacement of technology (i.e. old vehicles for new vehicles). The most difficult part to control here has been the circulation restriction. This is due to the condition of the city as an industrial/economic hub, which means that not only local vehicles circulate through its streets, but also enormous amounts of “foreign” vehicles enter the metropolitan area every day. It has not been easy to achieve agreements with surrounding states to determine gaps and requirements [3]. In addition, those citizens with enough economic resources have opted for buying additional vehicles in order to avoid the license-plate based restriction.

Regarding public vs. private transportation, the problem is not shortage of services or lack of use of the public infrastructure and services. The problem is concentration, the amount of individual transportation, the number of cars in the streets and the distances travelled in each trip [7]. Mexico City has an extensive subterranean network of railways, and on the surface the demand is covered with buses, trolleys and vans. It has implemented a modern transport system based on buses running on dedicated busways (Metrobús), which has expanded successfully since its inauguration in 2005. Efforts are being focused now on continuing the expansion of these types of more organized systems and on the promotion of non-motorized transport (i.e. bicycle lanes and pedestrian facilities) [7]. The main difficulties remain in the complicated orography of the valley (which poses obstacles to the provision of efficient transport), but in particular the historical development of public transport provision. The latter represents hindrances for the implementation of organized systems (e.g. Metrobús) due to the negotiations needed with numerous, atomized, private suppliers and the change in user practices required [11]. Metrobús has managed to overcome some of these obstacles, not without social discontent and opposition, which is a sensitive political issue.

A second important pollutant emitter is fixed sources (i.e. industry). As mentioned before, most heavy-polluting industries have been moved out of the city. However, those still operating continue to contribute to this issue. Large companies have signed agreements regarding emissions reduction and have managed to reduce them by 7% in 2010, compared to 2009 [5]. An important effort made by these companies is to demand tougher requirements from their (small and medium-sized) suppliers [5,8]. Atmospheric monitoring has also helped in reducing emissions. When particular pollutants’ levels have been reached, industries in those areas are required to halt their operations until safe levels are reached again.

The government has created incentives to promote cleaner production practices, including emissions reporting throughout the year that can result in continuous operation even during environmental contingencies [3]. With these types of initiatives, the city has managed to increase the number of days within the allowed pollution limits to 198 in 2010, compared to 43 from previous years [3]. However, incentives and training regarding cleaner production and emissions reporting are not properly communicated, as mentioned above and as e.g. Baas (2005) found in his study. An additional obstacle is related to other sectors’ knowledge and participation. A clear example is the involvement of media in these types of issues and the harmful effects of misinformation on the companies’ public relations and reputation [12]. Last but definitely not least, informality and corruption (not necessarily linked to each other), and short-term sight pose tremendous barriers to the implementation of technologies and policies [9,12].
Drinking water supply

Initiatives for improving water quality were not mentioned by the interviewees. As mentioned above, the water administration assures that the water provided is safe for drinking. Thirty-six purifying plants were in operation as of 2008 (SEMARNAT, 2010). However, the general population distrusts its quality and prefers bottled water (González Reynoso et al., 2010). This can be based on traditional practices or in some cases in actual measurements that have shown poor quality due to filtration of feces, leakages from landfill sites or bad quality of accumulation tanks [11]. Regarding quantity, González Reynoso et al. (2010) reported that 14.4% of the capital’s inhabitants do not have regular provision of drinking water (or even no provision at all). In many cases, this is due to the informal expansion of the city and the difficulty of providing basic services to these new expansion areas. Although the city’s administration has initiated several programs to educate its citizens and to provide water-saving technology [11], González Reynoso et al. (2010) reported that the city has less water available in comparison to the year 2000. The challenges therefore lie in the improvement of accumulation sites (regarding quality) and the distribution network (regarding quantity). In particular, the leakage mentioned above poses serious challenges, due to the collapse of underground layers and the highly active seismic region in which Mexico is located. Thirty-seven percent of leakages in the distribution system are both a challenge and an opportunity, keeping in mind that thirty percent of the water comes from distant regions.

Solid waste

Landfilling is still a commonly accepted practice throughout Latin America. Technologies like incineration are normally not accepted due to cultural or economic reasons [4,11]. As mentioned above, the closure of the Bordo Poniente landfill has awakened the interest of different societal actors in finding solutions. In particular, the Waste Management Commission has started separation, recycling and composting activities, which will hopefully reduce the amount of waste reaching the landfill [4]. These activities are supported by different societal actors, including the media [12]. Other initiatives include the prohibition of providing free plastic bags in shops [11], and suggestions like charging extra to those who exceed certain limits of waste every month have also been proposed [4]. Opportunities in the waste processing sector look very promising, especially because it is advancing fast and because there is a lack of local technology to make the most out of e.g. recyclables [12].

However, besides cultural obstacles, there are economic obstacles. What is meant by economic obstacles is not only the lack of financial resources, but also the types of activities linked to waste management in the city. This is a big challenge. There are informal activities taking place at the landfill sites, where manifold individuals (locally known as “pepenadores”), and even whole cooperatives sort waste in order to sell the recyclable fraction. But this comes already from a previous stage. Several pepenadores take advantage of collection trucks to visit different areas in the city. This poses a dilemma for the Waste Management Commission, since, on the one hand, formalizing their activities represents costs, but on the other hand, eliminating their activities would directly affect collection and final disposal, since they divert a considerable amount of waste that otherwise would reach the landfill.
Other initiatives

Several different initiatives that could be linked to environmental problems in the city were named by the interviewees. For example, for the promotion of energy and water efficiency in buildings, the government has started a “green mortgage” program, by which there are special conditions for those who implement environmental technologies in their houses (e.g. solar heaters and meters) [11]. In addition, public companies, e.g. the water administration, besides certifying commercial brands that are considered to improve efficiency, are selling these components on their own which has made them more affordable for the general public. This is also the case for fluorescent bulbs, for which there is an extensive campaign offering good deals for acquiring this type of technology. The city’s climate change action plan also represents opportunities for the implementation of different projects. In particular, regarding CO₂ emissions reduction and energy efficiency, attention has been put into the ICT sector, which is estimated to be responsible for 2% of the city’s emissions [12].

Another sector that is particularly interesting in Mexico City is solar technology. As of 2011, there were plans to digitally map roof surfaces in order to quantify power generation possibilities [11]. In addition, with the pedagogic introduction of electric taxis in the city, the need for charging and storage technology has become a niche worth exploiting, especially when considering it on larger scale in the future [12].

Regarding other types of energy sources, besides methane extraction from the closed landfill, there is a large interest in exploiting the local wholesale market for methane production. Seven-hundred and fifty tons of vegetable waste are produced every day at this venue, and most was not properly used (i.e. it was landfilled) as of 2011. Regarding liquid biofuels from waste, collection logistics and quality of the oils and fats are a common hindrance to economically and technically feasible solutions. On the other hand, liquid biofuels produced from crops have a strong opposition, mainly due to distrust about their competition with food [12]. However, there are research interests in areas such as biofuels from algae and by-products from the oil industry [10].

In general, other obstacles to the implementation of environmental technologies that are mentioned are also applicable to different kinds of technologies coming from abroad. For instance, Mexico (as a country) is part of the North American Free Trade Agreement (NAFTA) with Canada and the United States of America. This creates not only legal obligations but also benefits (e.g. taxes and fees) that make competition difficult for other actors. In addition, geographical vicinity and historical events have resulted in Mexicans leaning more easily toward American solutions, and Mexico has many times been the U.S.A.’s testing ground for many of their technologies [11,12].

A particular obstacle related to the way the city is administered is the problem of coordination. The Federal District is administered by sixteen different, democratically-elected administrators, which can belong to different (even opposed) political parties. When including the whole Metropolitan Area, this problem becomes even worse. This makes transversal issues, critical for urban sustainability, complicated [3]. Other obstacles mentioned are corruption, although considered to be decreasing [9,12]; lack of financing, although different financing models are showing good results [5,6,9,12]; legal instability [7]; cumbersome legal requirements [8], although the World Bank (2012) reports improvements; and social instability [12].
4.2. Bus Rapid Transit: an example of a complex solution implemented under complex conditions

In the previous sections, it has been stated that megacities are composed of intricate and complex relations, networks and interactions. However, when technical solutions seem to effectively solve problems that the city faces, they also represent important learning opportunities. One of these cases is Bus Rapid Transit (BRT) systems. Appended Article No. 2 provides a deeper analysis of the development of BRT systems in some of the largest cities in Latin America and the conditions for their successful spread along the continent. This case, it is claimed here, shows interesting traits that could be useful for the analysis of the diffusion of environmental technologies.

Transportation is an issue that all cities, especially the larger ones, sooner or later discuss. This is because of all the implications that it has on urban life. From an environmental perspective, the sector accounts for a large share of the emission of pollutants to the air (ITF, 2010), a problem largely accentuated in Mexico City. From an economic perspective, transport impacts manifold economic activities, e.g. the price and quality of goods and the mobility of inhabitants to their jobs. In the case of Mexico City, average speeds have been found to be as low as 3 km/h in some areas during peak hours (The Clean Air Institute, 2007), which results in about 3.3 million work-hours/day lost due to traffic or long commuting journeys and translates into two billion Euro in losses (IMCO, 2011). From the social and political perspectives, transportation is a sensitive topic given that many citizens cannot afford private transportation means. In Mexico City, even public transportation is highly subsidized, e.g. 67% in the case of the metro ticket, according to the metro’s administration (Metro de la Ciudad de México, 2009). An additional concern regarding equality is brought to the table when talking about sustainable cities, since allowing every citizen access to the cities’ services creates a shared and more inclusive society.

Although Mexico City’s underground system is extensive and covers a wide range, it is not enough to cover the whole metropolitan area’s transport needs [7,11]. Surface transport has developed chaotically over the years because of political, social and geographical reasons [7,11]. By chaotically, it is meant that numerous private operators have been providing the public transportation service. This is mainly done through buses and minivans, although other services such as electric trolleys also operate in the city. Such decentralized operation has brought difficulties for the administration and the wrong operative, structural and economic incentives, which result in a low-quality, unsafe and unreliable service. Recently, however, initiatives to organize the city’s transport have been taking place. This has not come without social and political discontent, which have been solved through different political and economic mechanisms (Lámberry Vilchis et al., 2011).

In particular, as mentioned in the methodology section (Section 3), the case of Metrobús, Mexico City’s Bus Rapid Transit (BRT) system, is interesting for this study’s aim. This transport solution has been operating in the city since 2005 and continues to expand (the most recent line was opened in 2012). What is interesting about this solution is how the adoption and acceptance process happened, and how the concept has disseminated through different cities in the world, none the least to several megacities. To a large extent, low costs in comparison to other alternatives and its ability to align to existing infrastructure have been the most remarkable features regarding its successful adoption. For the purpose of describing the adoption and diffusion process, data about all the operational BRT systems from a global perspective were collected with the help of the Institute of Transport and
Chapter 4: Stakeholders’ perspective

Development Policy (ITDP) in Mexico (see Appended Article No. 2). This facilitated the understanding of the system’s origins and its diffusion path from the south of the American continent.

In order to better understand the concept of BRT, the definition provided by the ITDP is adopted in this study (ITDP, 2007:11): BRT is “a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service.” BRT is a surface service that seeks to provide a service comparable to that of metros, and is usually referred to as “surface metro”. Up to 2011, this concept had been adopted by 38 cities in Latin America (including the megacities of Buenos Aires (ARG), Sao Paulo (BRA), Rio de Janeiro (BRA) and Mexico City) and 108 cities worldwide (including the megacities of Los Angeles (USA), Istanbul (TUR), Beijing (CHN), Chongqing (CHN) and Delhi (IND)). Several more projects were reported for the upcoming years (e.g. around 500 km are planned to be built in Brazil, partly due to the upcoming World Football Cup 2014 and Summer Olympic Games 2016).

Although data about global projects was collected, special attention was focused on the Latin America region, due to its condition as incubator and developer of the idea. Most BRT projects during the period 1972-2000 were implemented in Latin American cities. Although the concept is usually accredited to US developers, and Lima (PER) was an early adapter of the idea of prioritized public transport, it is the city of Curitiba (BRA) that is most often mentioned as the forerunner of these systems. The concept was only adopted by Brazilian cities until Quito (ECU) adopted it in 1998. However, it did not gain important international attention until Bogotá (COL) adopted it and improved several of its most representative characteristics (e.g., overtaking improvements, route flexibility, frequency, and the collection system). Figure 7 depicts the spread of the concept in Latin America during the period 1972-2011.

![Figure 7: Important milestones for the development of the BRT concept in Latin America, 1972-2011 (Adapted from Appended Article No. 2).](image)

The collected information makes it possible to analyze how this process looks from an international perspective (Figure 8).
Chapter 4: Stakeholders’ perspective

The diffusion process of BRT systems provides a foundation for understanding how complex solutions can be adopted under complex contexts (i.e. megacities). As described by Rogers (2003), an early adopter is required for providing a context where the solution works and where feedback nurtures its improvement (in this case, Curitiba). The adoption of the concept by other cities takes a long time, since the concept must prove to be compatible with local structures and easy to understand by locals. In this phase, information about the new concept flows easily among heterogeneous groups (e.g. only Brazilian cities implemented the system from 1972 to 1998). After these incubator cities provide improvements and show the benefits of the new system, there is a turning point, an adapter that takes advantage of this accumulated knowledge and adds characteristics that are further understood and easily transmitted (e.g. Bogotá improved the system and showed that it was operational under the context of a large city). These turning points can be seen in figure 9.

Figure 8: The global spread of BRT, 1972-2011.

Figure 9: The left-hand figure shows the cumulative km of BRT built in Latin America, while the right-hand figure shows the number of Latin American cities implementing BRT per year (1972-2011) (Adapted from Appended Article No. 2).

Figure 10 shows this same process from a global perspective. The contribution of Indian and Chinese cities could be an explanation of the more rapid change in slopes compared to Figure 9.
Several reasons can explain this successful spreading of the concept. However, the most remarkable ones are highlighted below (more detail can be found in Appended Article No. 2):

- **Compatibility of the system with existing physical and social structures.** Physical compatibility led to dramatic savings in building costs (up to 1:10 compared to a subway) and shorter building times, which in turn results in less disruption of the city’s activities. Regarding social compatibility, no radically new technology was introduced (e.g. buses just changed design and comfort features). The major change for passengers occurred in the pre-boarding collection system, which was covered with education, information and support.

- **Improved image, performance, reliability and safety.** The new system created a marketing brand (nonexistent before) and implemented a centralized control system, provided state-of-the-art vehicles and eliminated the competition for passengers in the streets by restricting buses and operators allowed to drive inside the busways, defining timetables and paying operators per kilometer logged, not per passenger transported.

- **Known technology and lower maintenance costs.** Although the system’s vehicles feature new technologies, internal combustion engines and other commonly known technologies allow the system’s administration to rely on local providers for repair and maintenance, which results in lower costs and shorter lead times.

In summary, BRT systems have provided an urban transport solution to cities belonging to all the previously mentioned categories (i.e. emerging, transitional and mature). Its acceptance can be explained by the concept’s low impact on existing infrastructure and local practices, which results in low costs, higher compatibility with other connected subsystems, an easier understanding of its functioning and a faster introduction into the cities’ everyday life. Strong demonstration projects, where the systems can prove its benefits, are needed in order to boost the dissemination of the concept. For this, it is not only technical and economic characteristics that facilitate the process. Strong leadership skills and political influence were also shown to have a great impact on the successful implementation of BRT systems.
Chapter 5: The Swedish environmental technology sector

5. The Swedish environmental technology sector: composition, exports and governmental initiatives

In this section the supply side, i.e. Sweden’s environmental technology sector, will be analyzed. First, a discussion around the sector as such and why it is seen by many governments as a potential contributor to both economic growth and environmental protection will be presented. Next, the particular case of Sweden and its environmental technology sector will be presented, including important characteristics that will be useful for subsequent sections. Topics of discussion will be how the sector is monitored and what its composition is. Finally, a discussion about the agencies that were given the task to analyze the sector’s export activities and potential, and define strategies to increase exports is presented together with some discussions about the actual information they collected and the plans and strategies that stemmed from it. Appended Article No. 3 presents additional analyses and data that contribute to the understanding of this sector in Sweden.

5.1. Environmental technology exports: contribution and growth

Environmental protection and redress is nowadays in the international agenda, given the identification of the effects of human activities on natural systems and of possible future consequences. Manifold agreements, both binding and non-binding, have been signed by different governments promising to reduce the effects caused to a great extent by the current economic model. This has brought with it a complicated dilemma of economic growth – a growth mostly based on environmental degradation (extraction, consumption and pollution) – vs. environmental protection. However, technology is seen by many as a positive contribution to this dilemma. Although others claim that technology is the cause in the first place, it is generally seen as a compatible tool with both lines of thought, and as a help for the transition into a “green economy” (e.g. Jackson, 2009).

Having this in mind, a relatively new term has permeated many spheres of modern society: “environmental technology”. There are numerous ongoing debates about what this term really means (Nutek, 2008), which poses difficulties for the monitoring of the sector and for the understanding of the actual impact that it could have on the environmental challenge previously mentioned. In any case, in order to be consistent with the geographical location of the analyzed sector, and in order to facilitate the access to and the analysis of the data, the definition adopted by the extinct Swedish Environmental Technology Council is used (Swentec, 2008:8): “goods, systems, processes and services that offer clear environmental advantages in relation to existing or alternative solutions, seen from an life-cycle perspective.” This definition is also used by Statistics Sweden (SCB) and is in line with the definition given by the European Union Action Plan for Environmental Technology (ETAP), adopted by the European Commission in 2004.

Summarizing, environmental technology can contribute on the one hand to environmental protection and remediation through the amelioration of environmental conditions by reducing emissions, reducing the use of non-renewable resources, decreasing material and energy use, etc. On the other hand, it can aid economic growth by creating jobs, promoting research and development and stimulating the industrial sector. This represents large export opportunities, in particular for countries...
that have comparative advantages in this respect due to e.g. higher efficiency and accumulated knowledge.

In this thesis, common economic and financial terms like Gross Domestic Product (GDP) and turnover will be used with the intention of illustrating the current state of the local and international market and the actors involved, and in order to facilitate the access to data available through the different governmental agencies involved in this sector in Sweden.

In the particular case of Sweden, it can be found that tough legislation and early commitments have created incentives for the development of the environmental technology area. Rising prices for energy and raw materials have resulted in higher efficiency and technological development, to a point that Sweden is considered as one of few countries that have managed to decouple its economic growth from CO₂ emissions (ITPS, 2008). Even if this situation has created incentives for the growth of the internal demand for products, processes and services, most of the internal efforts have been laid into R&D activities. There is therefore a need to put more attention on creating a well-functioning internal market, where companies can gain experience, develop growth strategies and deploy demonstration cases for their solutions (ITPS, 2008). From an economic perspective, increased internal demand can also mean that the market might get easily saturated, especially considering the case of Sweden, i.e. a country with small cities, few inhabitants, and large uninhabited areas.

This situation justifies the interest that the government has put into promoting the sector’s expansion into international markets, especially considering that several years of expertise and heavy R&D investments have laid the ground for Sweden to become internationally recognized for its work towards environmental sustainability (see e.g. Yale’s EPI\(^1\) for a comparison of 132 countries). Internationalization is not a new concept for the country, keeping in mind that it has historically relied on exports for the sake of its economy: fifty percent of its annual GDP has been represented by exports during the last ten years (The World Bank, 2013). The natural responsible party for promoting international trade activities in Sweden is the Swedish Trade Council (Exportrådet), a governmental agency with offices in 60 countries around the world and with the mission of offering professional services for Swedish companies that want to develop their exports. Although, as it will be discussed later, this agency is involved with export promotion activities within the particular sector of environmental technology, it does not have specialized branches or services for this sector; rather, it provides a general export approach and administers different resources and instruments devoted to export activities by the Swedish government. Kanda \textit{et al.} (2012) provide a deeper analysis of the role, the different responsibilities, and the instruments that export promotion agencies use and provide a comparison of different agencies in selected countries.

For the environmental technology sector, the share that exports have over the total sector’s turnover is presented differently by different agencies. Statistics Sweden, for example, reported that around 17\% of the turnover was due to export activities in 2011 (SCB, 2012). Swentec, however, took a different approach and decided not to include areas like energy and heat producers, eco-tourism, organic farming, scrap and waste commerce and community services. In this case, that figure was reported to be roughly 37\% in 2009 (Swentec, 2009b). Nevertheless, it can be seen that there is potential to grow and to make environmental technology a stronger contributor to the Swedish economy. If environmental challenges, tougher global requirements and user demands are considered as business possibilities, then there is no reason to think that Sweden’s environmental technology does not have a

\(^{1}\) Environmental Performance Index. Available at http://epi.yale.edu
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potential opportunity to become a global player in this area. To address this point, presented first will be a description of the particular characteristics of this sector in Sweden.

5.2. The environmental technology sector in Sweden

As mentioned before, the first difficulty encountered when wanting to monitor the environmental technology sector is actually defining what it is composed of. This is due to the fact that virtually all technology (unless it directly harms the environment) can be considered as environmental if it contributes to the reduction of the impact caused by human activities. As an example, any software that optimizes the use of raw material and energy – and thus production costs – could be considered environmental technology, since it contributes to a certain extent to environmental protection. Furthermore, an engine that consumes less gasoline than a previous model could be seen as environmental technology, since it provides better performance compared to previous technologies, and so on and so forth. Both Swentec and SCB have provided important work in order to avoid as much as possible this problem and to make the sector’s monitoring meaningful (ITPS, 2008).

In 1993, SCB and other governmental agencies created a system of environmental accounts in order to link economic activities to the environment (Eurostat, 2001). In line with this, SCB created a database in 2000 with the intention to monitor the sector and its behavior over time. This led to the division of the sector into thirteen areas (as shown in Figure 11), which are connected to the national accounts system through the Swedish Classification of Economic Activities (Svensk Näringsgrensindelning - SNI). SCB provides yearly information related to the sector, such as the number of establishments, turnover, exports and number of employees.

Under this classification, the sector has been reported to be mainly composed of small and medium-sized companies (i.e. more than 90% have less than 50 employees) (ITPS, 2008). However, the largest part of the turnover is represented by companies with more than 50 employees (idem). Analyzing the sector internally, it can be found that, historically, renewable energy has represented the highest turnover, followed far after by waste management and recycled materials. A graph showing this behavior during the period 2003-2010 is shown in Figure 12.
When analyzing exports (Figure 13), this picture changes a little, with renewable energy still in the top position and recycled materials following. However, waste management is replaced by heat/energy saving and wastewater management.

Finally, similar to an analysis made previously, it is interesting to analyze exports as a share of the total turnover, for each environmental area (cf. exports vs. GDP). Figure 14 presents this comparison during the period 2003-2010. Although this rate has not been stable during this period, one can see that some areas (e.g. air pollution control, heat/energy saving and wastewater management) present a higher participation of exports in their overall activities, even comparable to the exports/GDP ratio of
Sweden’s economy as a whole. Areas like renewable energy and waste management perform poorly in this indicator, which probably reflects the fact that many providers are publicly owned and service cities or towns inside Sweden.

Regarding employment, the environmental technology sector employed 69,000 people in 2009 (SCB, 2012). The areas with more employees are waste management with 22%, renewable energy with 21%, and wastewater management with 10% (idem). As mentioned before, this might be a reflection of the ownership of these areas and the types of services they provide.

5.3. Mapping the sector and designing promotion plans

Recognizing the environmental technology sector’s potential to contribute to economic growth, several governmental agencies and institutes were given the task to perform evaluation studies with the intention of laying the ground for strategies and plans for the promotion of the sector, both internally and externally. Institutes like the Swedish Institute for Growth Policy Studies (Institutet för Tillväxtpolitiska Studier – ITPS), the Swedish Agency for Economic & Regional Growth (Närings- och teknikutvecklingsverket – NUTEK) and the Swedish Environmental Technology Council (Sveriges miljöteknikråd – SWENTEC) – all merged today with other governmental agencies, and the Royal Swedish Academy of Engineering Sciences (Kungliga Ingenjörsvetenskapsakademien – IVA) and Statistics Sweden (Statistiska Centralbyrån – SCB) have been involved in providing these evaluations.

In particular, Swentec was entrusted with the analysis of the sector and the preparation of a basis for continued governmental support and for increasing exports. The final report that Swentec presented to the government included eighty-two suggestions for measures to be taken for the promotion of
environmental technology exports (Swentec, 2010). These suggestions were much in line with the conclusions from ITPS (2008). In summary, recommendations were given around the following topics:

- Identification of the strong areas for Swedish environmental technology. This identification includes the renewable energy and waste management areas (cf. Figure 12); clusters of different areas like sustainable building and urban planning, environmental protection technologies (e.g. wastewater treatment) and system solutions (i.e. multi-disciplinary solutions); and sustainable transport.

- The need to strengthen and stimulate the development and adoption of environmental technologies through market mechanisms (e.g. taxes, regulations), awareness building (i.e. information provision and public procurement) and direct financial support based on particular technological solutions and company size.

- The need to develop a strong, well-functioning home market. Here, the role of governmental agencies and municipalities is highlighted. Involvement from the earlier stages of technology development (i.e. training and R&D), to testing, and all the way to commercialization (i.e. acting as demonstration, proof-of-concept grounds) is a must for these governmental bodies.

- The need to improve the access to capital to small companies, which as mentioned above, represent the majority of the companies in the sector.

- The need to coordinate the different efforts being made for the promotion of environmental technologies. By having manifold agencies and institutes providing information and requiring different actions, companies might get confused and abandon export initiatives.

- The need to monitor the international arena, help companies to find partners abroad and to influence international procurement. Particularly interesting would be to make use of those trained by e.g. SIDA in other countries to act as ambassadors and facilitate market entrance.

- A focus must be placed on system solutions if large scale commercialization is the goal. The commercialization of individual components is not recommended from an international perspective.

- The need to stimulate large companies that are already strong international players to act as locomotives, dragging smaller companies into the markets were they are settled.

Different plans and programs have been initiated with these conclusions and suggestions in mind. Governmental budget allocation to support R&D in the sector, business incubators, financial support to municipal initiatives for sustainable urban development (i.e. demonstration projects), international delegations (from and to Sweden) and many others can be identified. From another perspective, and in line with the interests of this study, several initiatives have been directed explicitly at exporting activities; these are:

- Symbiocity: This is probably the most representative program launched in order to promote environmental technology exports. This program is administered by Exportrådet (Swedish Trade Council) and has the intention of being a platform for the promotion of Swedish
expertise within the area of sustainable urban development. It presents a holistic view on how cities can be made more sustainable by showing examples of waste management, wastewater treatment, renewable energy, sustainable transportation and energy-saving solutions that have been implemented somewhere in Sweden. This concept is in line with some of the suggestions mentioned above, regarding the need to sell system solutions instead of individual technologies. Symbiocity presents difficulties, as Swentec (2009a) recognizes, regarding the fact that some solutions might be based on Swedish expertise but Swedish companies might not be able to deliver the required technology.

- **Demomiljö**: This program is a combination of international aid and proof-of-concept building. It is financed by the Swedish International Development Agency (SIDA) and administered by the Swedish Agency for Economic and Regional Growth (Tillväxtverket). Its objectives are both to provide better living conditions for people in partner countries and to provide demonstration grounds for Swedish companies within the environmental technology sector.

- **Centec**: The Swedish Embassy Center for Environmental Technology (Centec) started with financing from SIDA and has the objectives to improve living conditions in China and to spread knowledge about environmental technology solutions, both holistic and individual, which will facilitate the entrance of Swedish providers to the Chinese market.

- **SAGA**: The Swedish-American Green Alliance (SAGA) is a continuation of a previous agreement on renewable energies between Sweden and the United States of America (i.e. “One Big Thing”). The agreement has a wide scope, including cooperation in different areas, such as sustainable urban development (for which Symbiocity is suggested as a contributing tool), sustainable transportation and sustainable forestry.

- **In 2011**, the government launched a strategy for the development and export of environmental technology 2011-2014 (The Swedish Government, 2011), which highlighted potential and priority markets, defined action and follow-up plans and allocated a budget, based on the different studies mentioned above.

Keeping in mind the composition of the sector, the characteristics and features discussed by the different actors analyzing it, and the suggestions, plans and strategies that resulted from their work, a basis is set for a further analysis. Using the theories discussed and the empirical results from field studies, Chapters 6 and 7 discuss the conditions for megacities to become platforms for the diffusion of environmental technology given the different sustainability concerns presented above.
5.4. Participation of the Swedish environmental technology sector in export activities

On one hand, the discussion presented above about the sector’s composition and the most representative governmental initiatives to promote exports provides a foundation for the understanding of the strategies designed to pursue the goal of increased exports. On the other hand, it is interesting to analyze how the actual recipients of these initiatives react to them, and what effect do they perceive in their activities in international markets. More detail about this analysis can be found in Appended Article No. 4.

As mentioned in Chapter 3, information about around 730 companies was collected and classified by field and area. Information about their products, their location and contact information contributed to building a database. In this case, the different categories slightly differed from the ones defined by SCB with the intention of getting deeper detail about the companies' activities, based on their products instead of their SNI. Table 4 shows the different fields included in the database and the number of companies within each field:

Table 4: Number of companies included in the database, categorized according to their offerings.

<table>
<thead>
<tr>
<th>Field</th>
<th>No. of companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>238</td>
</tr>
<tr>
<td>Consultancy</td>
<td>113</td>
</tr>
<tr>
<td>Water management</td>
<td>95</td>
</tr>
<tr>
<td>Other</td>
<td>90</td>
</tr>
<tr>
<td>Waste management</td>
<td>83</td>
</tr>
<tr>
<td>Air pollution/quality</td>
<td>48</td>
</tr>
<tr>
<td>Sustainable building</td>
<td>39</td>
</tr>
<tr>
<td>Soil</td>
<td>14</td>
</tr>
<tr>
<td>Noise control</td>
<td>8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>728</strong></td>
</tr>
</tbody>
</table>

A web-based survey was sent to all these companies asking about their participation in export activities and about their awareness and participation in and perception of governmental initiatives to promote exports in the sector. After a month, the response rate was around 25% (172 companies).

Regarding their participation in export activities (i.e. if they are currently exporting or thinking of doing it in the future), there was a vast majority (79%) that reported active participation in these kinds of activities. The figure was 17% for those not exporting or thinking of doing so, with the main reasons as follows:

- Recently established companies.
- Local market niche.
- Exports are not considered in their core business/business idea.
- Limited capacity/resources.
Chapter 5: The Swedish environmental technology sector

These results are to a large extent in line with what was discussed in the previous section, i.e. companies have not created a local market strong enough to demonstrate their product/service’s application; bigger companies are the ones exporting and smaller ones just act as suppliers (indirect exports) or there is a lack of access to financing and other type of internal resources needed to increase competitiveness.

Those companies that reported active participation (or intention to participate) in international markets were asked about their awareness of governmental initiatives that could be in line with their needs. Almost two-thirds reported not being aware of governmental initiatives (this can include not knowing about any initiative whatsoever or not finding initiatives that could suit their needs). Out of those reporting being aware of governmental initiatives, a third reported not having participated in any of them. The reasons given for this were mainly:

- Difficult to access (e.g. expensive, unclear benefits, cumbersome process).
- Lack of resources (e.g. time, staff).
- Application denial.

Apart from lack of resources, which was also mentioned as a reason for not participating in export activities, difficulty of access was something that numerous companies mentioned. This was also something discussed by governmental agencies analyzing the sector. They highlighted that there is a need for coordination among the different agencies and governmental institutions that are involved in export promotion, because unclear requirements and conditions might confuse and discourage companies from participating in them. This issue poses an important challenge for the governments, whether or not it was considered from the beginning. Figure 15 summarizes these results:

![Figure 15: Awareness of fitting export governmental initiatives and company participation (Adapted from Appended Article No. 4).](image)

The final stage of the survey aimed to see if those companies participating in governmental initiatives could related these initiatives to any successful business abroad. This was clearly a subjective evaluation, but it provided insights on the perceived effectiveness of export promotion programs. Only those companies participating in financial aid-related programs reported successful businesses connected to their participation. The majority of companies participating in information, education and
training, trade and mobility (i.e. business delegations) and international aid programs reported no
successful deals, sales or agreements that could be connected to them.

The results from this survey confirm to some extent the results reported by agencies like ITPS and
Swentec, e.g. how companies might perceive the different processes as cumbersome or confusing,
because of the lack of clarity and the numerous agencies and institutions involved. The results also
show at least a partial sign that a majority of the surveyed companies in the sector are not participating
in export promotion initiatives, or do not perceive the existing ones as effective regarding their export
activities.
6. Analysis and discussions

So far, the different components of the analysis of megacities as platforms for the diffusion of environmental technology have been discussed. With the help of the various theories described in Section 2, the different conditions necessary for technological solutions to be understood, accepted, adopted and further spread have been described and analyzed. This section starts by providing a deeper discussion about the research questions defined in Section 1. Thereafter, a more aggregated discussion is presented with the intention to address the aim of the study.

RQ1: What are the main environmental problems faced by Mexico City, and to what extent can technology help to solve them?

As a megacity, Mexico City faces numerous environmental challenges. It can be seen that to a large extent, the identification of these problems and especially their prioritization depends on the specific stakeholders, since their interests are of course influenced by the role they play and the interaction they have with any given problem. However, the special geographic and demographic characteristics of the Valley of Mexico accentuate three problems: water supply (both quantity and quality), waste management and air pollution.

It is clear that technology has already had an influence on how these problems have been handled. In the case of air pollution, monitoring and real-time information provision have played significant roles in the reduction of atmospheric pollution. In addition, better quality of the fuels and newer engines have contributed to emissions reduction. No particular end-of-pipe technologies were mentioned by stakeholders in the industrial sector. Regarding waste management, technological solutions are considered (e.g. gasification) but the focus is still more on finding physical space for landfilling activities or measures to decrease the actual amount landfilled (i.e. separation, composting and recycling). Extraction of methane from the closed landfill could be considered more of an energy-related solution than waste management. Finally, regarding water supply, technology has helped solving both the quantity and quality problems. However, leakage and pollution close to the end user still pose challenges that could be solved with the proper technology. A better reuse of the water treated at the wastewater treatment plants could help decrease the dependency on remote sources and the subsequent energy use and political problems.

RQ2: How do different stakeholders in Mexico City perceive, understand and use technology to solve environmental problems?

Technology is a widely adopted tool in Mexico City. Different stakeholders understand technology as a necessary tool to address the challenges the city faces. The differences reside in how it is related to other components and stakeholders in the city. Governmental actors have to consider social implications of replacing formal or informal systems that, to a certain extent, provide services to the
Chapter 6: Analysis and discussions

city. Companies, on the other hand, focus on regulation and economic resources. Finally, academia is focusing on developing their own technological solutions and more than that, protecting innovations and benefitting from them.

The city has seen significant improvements in several areas, and this has been to a great extent due to technological implementations, as mentioned in RQ1. Citizens and other stakeholders recognize this and become more receptive to technology. This is the case of e.g. transportation systems, air monitoring and environmental governance.

RQ3: How do technological solutions permeate a city and diffuse to other cities, and how is this diffusion and adoption process characterized?

Different networks and their actors formally or informally agree on common goals, in this case regarding environmental challenges. With these goals in mind, society expects certain effect on the problem from any agreed upon solution. Information is sent both inside and among networks, and resources are mobilized in order to address the problem and decide on a solution. Once the problem is fully understood and communicated, solutions are sought and suggested. The rejection or adoption of any solution is based on the projected positive impact and the compatibility of the solution with existing structures or subsystems with which will have to coexist. An important condition not only for the successful adoption, implementation and continuation of technological projects, but also for the future expansion of the scope and further diffusion into other parts of the cities or even into other cities, is the adequate identification and the timely involvement of stakeholders in the process.

Most systems that are proposed for the solution of urban problems involve complex connections and require alignment with numerous components. This makes proof-of-concept an important prerequisite for the consideration of a given solution. Diffusion happens easily when solutions are understood by the recipients and when a connection to the set goal is identified. In addition, distrust can be overcome when information is transmitted more clearly within the network, something which is happens more frequently in homogeneous networks. Cities that see solutions implemented under contexts that they can actually relate to their own more easily, accept solutions that are not developed locally.

RQ4: What strategies is the Swedish government using for the promotion of environmental technology exports, and what are these strategies based on?

As previously discussed, the government is using different strategies. The analysis of the sector, its composition and its main characteristics, resulted in the definition of plans for the development of environmental technologies, for the strengthening of the local market and for the access of companies for financing. Sectors with the largest potential for export were defined based on local strengths and global demand, and the role of municipalities in supporting small and medium-sized companies was described. Given the composition of the sector, offering holistic solutions instead of focusing on individual products was considered of great importance when thinking of entering international markets and getting the benefits of large-scale sales. In addition, demonstration projects were given
particular importance, and municipalities were described as important facilitators of opportunities for this purpose. Governmental support for the development of these kinds of projects was defined. Locally, an agency for the promotion of projects within the issue of sustainable urban development was created. Internationally, SIDA has implemented a project for the financing of demonstration projects with Swedish environmental technology. Other strategies include direct agreements with countries for the mutual development of sustainable solutions in different areas.

From the perspective of the case study, it was found that holistic solutions are a complex concept and that local stakeholders in the city have difficulties to identify the compatibility of such solutions considering their current situation and constraints. This rejection brings additional disadvantages because detached, individual components that could represent business opportunities are overshadowed by the initial rejection. Additional difficulties arise when demonstration projects in similar, easier to connect contexts, are not provided.

**RQ5: To what extent do environmental technology companies participate in export activities, and how do they perceive governmental export promotion strategies?**

A great share of the Swedish environmental technology companies mentioned in this study shows active participation in export activities. Although it was not analyzed how this involvement in international markets started, a general state of unawareness about governmental initiatives for the promotion of export that could suit the companies’ characteristics was expressed by the companies involved in the study. This unawareness can be divided into (a) companies that do not know about any governmental initiative whatsoever; and (b) companies that know about some initiatives, but do not find the right incentives to join them (i.e. they do not fulfill their needs). An additional group of companies knows about initiatives that could be useful given their characteristics, but decide not to participate because of additional reasons that make participation difficult. Finally, out of those companies that have participated in governmental initiatives for environmental technology export promotion, only those that received financial support declared a connection between this program and a successful business in international markets. Information provision, business delegations and international aid programs were not perceived as effective by most of the surveyed companies.
7. Conclusions: an insight on the complex dynamics of megacities – contextualization, flexibility, demonstration and other conditions

In this section, the discussion will focus on how different conditions affect the process of adoption and implementation of environmental technology in a megacity like Mexico City and how this could be influenced, keeping in mind the description of supply and demand provided in previous sections and the theories discussed in Section 2. As it was previously discussed, the identification of environmental challenges and the focus of societies in general into reaching more sustainable states have led to the formulation of agreements, regulations and commitments. Significant importance has been put into the concept of governance (i.e. the coordination of social initiatives that aim at achieving a different state, in this case a sustainable state).

Societies are driven by common goals (e.g. protection, commerce, shared infrastructure, social life); this is why cities and human agglomerations in general are formed. In particular, technical systems are created to fulfill some of those societal goals, e.g. pipelines for the provision of drinking water, domestic and industrial energy supply for comfort and for production, public transport for reaching places where social activities take place, etc. A common, general concept of “what is good” is formed and societal actors strive to build a state where “what is good” prevails, based on their values and beliefs. This can be done through legal mechanisms (e.g. laws, regulations), financial mechanisms (e.g. taxes, incentives), social mechanisms (e.g. educating, voting, volunteering), and technological mechanisms (e.g. communication and transport systems). Every once in a while, because of different reasons (e.g. political changes, social crises, environmental crises, scientific discoveries, among others), this conception changes and a new goal is set. Society then looks for new solutions, tools to achieve this new goal and reach the new state.

However, society as such has a momentum, a way of functioning strongly tied to systems that supported the previous state, and to which most became accustomed to. This refers not only to technical systems, but also to legal, financial and social (cultural) ones. This poses an enormous dilemma for society. On the one hand, a problem and a need to change are identified, so any solution suggested is expected to have a positive impact on the current state. On the other hand, this solution must have the smallest negative impact possible on existing structures, in order to avoid social chaos.

This is an important question to have in mind, especially when talking about cities. Cities are very complex human systems, composed of numerous connections and relations, networks and actors and complicated interactions. This makes them rigid and physically and socially vulnerable. Many of the solutions that are suggested for addressing the current environmental challenges require radical changes in structure (i.e. in scope and time) regarding how things work. Even when a problem is understood, there is opposition coming from many flanks, especially from connections that might not be obvious to the naked eye. In other words, everyone’s problems are no one’s problems. This is more accentuated in a city like Mexico City, with more than twenty million inhabitants. The conception of where society should aim vastly influences the way a problem is understood and addressed, as will be discussed next.

Once common goals regarding a state that society wants to reach are set and agreed upon, different actors start taking actions in order to steer and govern change. Politically, society raises awareness and
leaders make the problem public. Scientifically, the problem is identified, studied and monitored and conclusions and recommendations are given based on methodic analyses. Financially, solutions to the problem are suggested and, depending on public prioritization and resources availability, a budget is allocated. Culturally, both problems and solutions are scrutinized and normally, the short-term impacts on practices, values and beliefs are assessed.

Networks within and among groups are created in order to communicate, present and discuss findings, effects, actions and possible solutions. All the different actors influence and are influenced by every other actor in the network. Information travels within these networks and it is transformed by each group according to its particular role in society. Society creates an image, a perception of both problems and solutions that depends on the particular context and on everything that society has previously built (not only in a physical sense). The ability to coordinate defines to a great extent the promptness with which a particular problem will be addressed. For this, homogeneous groups have advantages because information travels easier, finds fewer hindrances and suffers fewer changes. This is why external actors sometimes disturb this process. Acceptance or opposition happen based on the compatibility or incompatibility of arising issues with existing social, political, cultural and physical (technological) systems.

Finally, keeping in mind how societal goals are set, and how networks are built in order to pursue those goals, it is necessary to understand the actual obstacles that hinder their achievement. Once a goal is set and the desired impact decided, the problem has to be studied and understood. Networks are built and information travels and is transformed, and prioritization and resources availability influence the suggestion of a solution. Acceptance or rejection occur depending on the perceived effectiveness of the solution in reaching the goal and on its impact on existing social and physical structures.

In Appended Article No. 2, this relation is discussed with the aid of a model composed of four quadrants, where solutions to sustainability problems can be classified according to their impact on the set goals on the one hand, and their alignment to existing structures on the other hand, as shown in Figure 16. Quadrant I represents solutions with a high positive impact (i.e. a strong effect towards the desired goal) and a strong alignment with existing structures (i.e. low disruption of established practices and preferences). Quadrant II represents positive impacts but low alignment (i.e. positive effects might happen in the long term, but in the short term existing structures are heavily disturbed and social opposition might actually undermine potential positive effects). Quadrant III includes solutions that heavily disrupt existing social structures and have a very low positive impact on the established goals. Finally, Quadrant IV groups solutions that might not represent disturbances but that do not contribute to common goals (i.e. they are quickly abandoned and forgotten).
This ability of solutions to align facilitates the understanding of how the actual solution works, which in turn facilitates diffusion, adoption and implementation by a particular social group. Innovative solutions spread faster when the recipient group sees the benefits of adopting them, and when it finds it easy to use them and incorporate them into their everyday life. This realization of the benefits is particularly difficult in an urban sphere, especially at a megacity scale, given the magnitude and the scope needed.

As mentioned in Section 2, trialability at this scale poses enormous challenges, not only because it is expensive and impractical to implement pilot projects just for the sake of trying a particular technology, but also because it is of great importance to consider normative and cognitive mechanisms (Hillman et al. 2011) and the shape they take in any targeted market. This can be seen in contrast with initiatives from the Swedish government like Symbiocity. In the case of Mexico City in particular, actors see the solutions tied to the concept as distant, inapplicable and even utopian under their context [4,6,11]. A holistic solution is presented as the main facade and no particular components are shown, but only a giant, clockwork coordinated concept that is not easily graspable and that creates a barrier for a further, deeper interest into smaller constituents. In this case, stakeholders in Mexico City miss both the forest and the trees.

When living under such a giant, complex city, systems are difficult to understand because the concept of connection is more abstract and distant, especially when proof-of-concept happens in a different cultural and political context. Particular solutions might be more effective when addressing transitional and even emerging megacities, in opposition to the action plans that the governmental agencies have suggested. This creates a dilemma for the government, because the developing world is where development is happening faster, and where most megacities are located. This means that systems, in particular technical ones, are deeply embedded and shielded against large disturbances. In this case, initiatives like Demomiljö seem more adequate, but might of course be more expensive since they are realized through aid and charity. However, the investment might pay off, at least in the developing world, as these initiatives provide tangible and contextualized solutions that address shared problems.

Megacities are attracting enormous global attention due to the identification of overpopulation as a serious challenge for humanity. All three groups (i.e. emerging, transitional and mature) are interesting from an environmental perspective, given their challenges. Mature megacities represent however a

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4 Please refer to Tables 1 and 2 in Section 3.
small share in the overall list of megacities. As their label says, these cities have solved many of their environmental problems, have good capacity to handle different types of challenges and in addition have reached low or negative growth rates, leaving them more time and resources to focus on these problems. Emerging and transitional megacities, on the other hand, are still struggling with more serious environmental problems and have more difficulties to allocate resources to handle them. Transitional cities exhibit lower growth rates and are to some extent more organized, have better existing infrastructure and are more able to address environmental challenges than emerging cities, which lack infrastructure and resources and face higher growth rates.

Mexico City could be classified as a transitional city given its slowing growth rate (the Federal District has actually reported a decline in its population) and the improvements in environmental performance and governance. It is clear that many problems still remain to be solved, which represents business opportunities for environmental technology providers. On the other hand, transitional cities are gaining more and more attention from an economic perspective, as it is believed they will become important generators of economic wealth in the near future. This has created an interesting race for international visibility which has resulted in interesting urban renovation projects. In particular, much attention has been on environmental concerns and international commitments. This represents enormous windows of opportunities for technology providers willing to understand problems and contextualize their offerings.

Flexibility and compatibility are often searched-for concepts when looking for technological solutions. The race for visibility, attracting skilled professionals, foreign investment and even tourism has accelerated technological change and adoption in unprecedented manners. In many cases, implementation has been facilitated by proof-of-concept projects among homogeneous groups of cities (see e.g. appended Article No. 2). It takes an “early adapter” (to use Rogers’ (2003) terms) to show the benefits and the actual functioning of a technological solution in a familiar, closely-related environment, in which conditions can be connected to local conditions in “later implementing” cities. This is where environmental technology providers should focus.

Such venues are willing to try new solutions and act as platforms for the spreading of concepts in the region. This poses tremendous challenges for both the governments (who want to promote exports) and for the companies that are willing to export. Such challenges can be covered with usual market information gathered through e.g. embassies or commercial attachés in the region. Each region has focal points, cities that have already gained a special visibility in different areas like urbanism, public transport, renewable energy, energy efficiency or environmental governance. From there on, other cities in the region will loosen their common barriers and will be more willing to analyze foreign solutions.

Conclusions from this study might be applicable to other emerging and transitional megacities. Smaller cities within these categories might present similar behaviors, but must be analyzed with more detail.
Contribution of this thesis

Throughout this thesis, Mexico City was analyzed through a case study in order to better understand conditions for the successful diffusion of environmental technology for the solution of environmental problems in urban settlements. By considering different stakeholders’ perspectives over the past, current and future problems that the city faces, the possible solutions to them and the role that technology could play in this regard, a discussion about the conditions for the successful adoption and diffusion of environmental technologies was presented. To do so, the current environmental situation in the city was described in detail, highlighting the most important and urgent problems, as well as the obstacles to possible solutions. With a particular example of a complex system implemented under complex conditions (i.e. BRT systems), and with the help of the Multi-Level Perspective approach and Governance and Diffusion of Innovation theories, a model was developed showing the importance of providing solutions that align to indigenous systems (i.e. economic, technical and social) and at the same time offer substantial gains towards societal goals.

In addition, the Swedish environmental technology sector was analyzed. Its past and current composition and its behavior in different performance indicators was shown and discussed. The more or less recent focus of governments in the sector for the increase of exports and the subsequent contribution to economic growth was described, together with the particular initiatives taken by the Swedish government and the results from the assessment of the sector by governmental commission. Based on the findings from the demand side (i.e. Mexico City), as well as from the actual providers (i.e. Swedish environmental technology companies), a set of discussions, conclusions and recommendations were presented for the successful diffusion of technologies in megacities (especially transitional and emerging ones).

Further research

Interesting questions arise from the different discussions in this study. There are numerous projects where the successful adoption of environmental technologies has led to significant improvements on the environmental performance of cities. Further analyses of these projects would give insight into the way problems are identified, the different stakeholders involved, the solutions suggested and the process of implementation and adoption. Furthermore, it would be interesting to see how diffusion happens inside the city itself, i.e. how networks grow and coordinate transversal issues such as wastewater collection and treatment, traffic management or pollution control.

Additionally, it is of great importance to devote attention to the special characteristics of the environmental technology sector in Sweden. The distribution of the sector’s turnover, employment, and size vary from other industrial sectors in the country. This gives signals that it might need a different treatment in some aspects. The areas contributing the most to total turnover are not necessarily the ones exporting the most (in percentage terms, at least) which could be a sign of the composition of these areas, the ownership of the companies involved and the markets where they sell. In addition, it is important to analyze the distribution of these contributions, i.e. how much is represented by a few large companies instead of many small ones. This could have an impact on the design of governmental initiatives and the promotion of the many small and medium-sized enterprises comprising the sector.
Chapter 7: Conclusions

Additional recommendations given by the different agencies entrusted with the task of analyzing the sector regarding the importance of coordinating activities are of particular importance. A large number of agencies and institutions handling the sector might confuse companies and discourage their will to export. Thus, a follow-up on governmental initiatives would also be another contribution to the study of environmental technology exports. Analyzing time series, for e.g. Symbiocity and figures about actual businesses closed through this tool and the specific areas that benefit the most from it, would be of great importance for understanding the effectiveness of marketing tools for the promotion of exports. A cross-comparison of other governmental initiatives can also give deeper insight into the actual results that the sector is achieving in international markets.
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