GREEN ROOF TECHNOLOGY ADOPTION:
WHAT STAKEHOLDERS NEED TO KNOW ABOUT IT

By

MADRID ZUNIGA, Martha Eugenia del Rosario

THESIS

Submitted to
KDI School of Public Policy and Management
in partial fulfillment of the requirements
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MASTER OF DEVELOPMENT POLICY

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ABSTRACT

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The primary purpose of this research is to investigate how the constraints to implement Green Roof Technology have played out, according to the previous studies and two case studies and how they would engage, in the case of San Salvador, El Salvador. The main idea afterwards is to figure out possible ways to overcome all the constraints in order to achieve a successful technology implementation. To do so, more than twenty five papers were revised.

In the first part and in order to fully understand the topic, a study of basic concepts of GRT is done, including existing types, differences and benefits of implementing GRT such as energy conservation, increased lifespan, noise reduction, Urban Heat Island reduction, mitigation of air pollution, job creation and amenities enhancing. In addition previous studies are reviewed to find the constraints in the adoption of the GRT.

After exposing the basic concepts of GRT, the necessities of obtaining the benefits of implementing green technologies is stated and are described as an important part of the sustainable development being empowered worldwide in local and central governments agenda. It is also important to highlight all the effort to implement GRT is oriented to tackle global warming and mitigate its effects.

In addition the theory that supports the research is the Model of Innovation-Decision established by Everett Rogers (2003) which along many decades has been used to study the process of adopting new innovations. Complementarily, the hypothesis of this investigation is based on five previous relevant researches chosen with the following criteria: 1) similarity

between the research topic and the selected paper, 2) research method used to collect the data by the original author of the previous study, either face-to-face interviews or surveys were preferred, 3) the consulted population in the previous study is to include stakeholders such developers, city officials, architects, landscape architects and users. The chose ones are House (2009), Tam et al (2011), Hodges (2011), Taheri (2007) and Siegler (2006) exposing the constraints they found for the implementation of GRT which are the ones I agree with.

As supporting evidence for the aforementioned hypothesis two case studies are conducted to examine, in practice, the process of implementing GRT. The first case to cite is Toronto, Canada where the found constraints are: (1) lack of knowledge, (2) lack of incentives, (3) cost-based constraints (4) technical concerns and (5) lack of standards/regulations and specialized products.

The second case study conducted is the city of Seoul, South Korea, which reinforced the findings constraints found in Canada. Important is to highlight the merit of Prof. ByoungE Yang from the Graduate School of Environmental Studies of Seoul National University who was the precursor of the GRT movement in the city of Seoul and who he provided most of the information through an interview.

The most important outcome after observing the constraints in the implementation of GRT, are the ways to overcome them; in the case of Canada are research, demonstration projects, creating turn-key companies, compiling technical and cost-benefit analysis information, promotion, incentives and policy implementation and standards development. Similar ways are found in the case of the city of Seoul: research, seminars, centralizing information and creating institutions, policies and incentives, landscape or turn-key companies, technology development and standards formulation.

Most of the solutions to fade away the constraints are a result of knowledge built up and budget allocation from the central government.

ACKNOWLEDGEMENTS

This research would not have been possible without the helping hand of talented professionals that at the same time are very heart-warmed persons, who were always willing to lighten me up whenever there was darkness. They taught me the real sense of a Walt Whitman quote "keep your face always toward the sunshine and shadows will fall behind you" and encouraged me to follow it.

Firstly, I would like to express my gratitude to KDI School of Public Policy and Management that gave me the opportunity to study my master abroad, to nourish my knowledge throughout the program and to do this research.

I am also very grateful to few professors who opened their doors whenever I knocked on them and made livable the quotation "more important than the curriculum is the question of the methods of teaching and the spirit in which the teaching is given" (Bertrand Russell). They are:

- My thesis supervisor Prof. Yong S. Lee who played out the most important role along my research. He taught me based on his example, showed himself open to my ideas, advocated his time to guide me and believed in my capacity.
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- The initiator of the Green Roof Technology movement in South Korea Prof. ByoungE Yang from the Graduate School of Environmental Studies of Seoul National University, who gave me his time, inspired me and provided me with

valuable information to complete my case study on the city of Seoul, South Korea.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The process of urbanization in cities accounts for a large share of the world's economy, and wealth is often generated around such development. In many countries and cities, a rapid urban development means an economic growth and implies sustainable development as well. While in others, the increased urbanization process creates many environmental problems such as pollution, traffic and degradation, to mention some of them. The World Bank suggests "Building cities that are green, inclusive and sustainable should be the foundation of any local and national climate change agenda" (Hoornweg et al 2010, V). In other words, green growth in combination with urbanization should be addressed at the local and national level in the governmental plans, in order to tackle climate change.

Naturally, high rise buildings are growing exponentially within the cities due to enlargement of land shortage and increased demand for space. As a result, the usage of Green Roof Technology (GRT) as a green building practice is also increasing. This green infrastructure is already widely used in some developed countries such as Germany and Japan or being fostered in some others like United States and Singapore. Despite the location, the main stakeholders remain constant in the field of GRT: urban planners, environmentalists, designers, government officials, and real estate developers are the ones

Some people may think about GRT as a new wave, but it has been historically present with different shape since the Hanging Gardens of Babylon built by King Nebuchadnezzar (Osmundson 1999); but their current importance began taking shape in the late 20th century when benefits such as reduction of storm water runoff, cooling demands, urban heat island and noise as well as amenities enhancing, were discovered among the benefits that flow from the green roof movement.

Observing the historical and current usage of GRT I can surmise that this is not a new field in many regions of the world, but it seems to happen the opposite in the city of San Salvador, the capital of El Salvador. Even though there are some commercial and housing projects using such technology in San Salvador, there are still very few landlords who are willing to invest on it in a broad scale. In this context, the implementation of GRT is currently facing difficulties and constraints and is far from being widely adopted in San Salvador.

Taking into account the dependence of GRT on stakeholders' perceptions, the purpose of this paper is to examine what it might take for the city of San Salvador and its stakeholders to take GRT into a serious consideration.

To address this issue effectively, it is to understand what generally shapes stakeholders perceptions toward green roof technology, more specifically what would shape or constraint Salvadorans perception toward GRT. Its adoption in El Salvador's has not been as successful as other Asian, Canadian and U.S. cities. I am considering why would Salvadoran stakeholders are ambivalent toward the use of green roof technology? What are stakeholder's concerns?

According to previous studies and after compiling the most significant papers, the constraints have been identified as (Tam et al 2011, House 2009): lack of familiarity, lack of incentives, cost-based constraints, technical concerns, lack of standards/regulations and specialized products in the market. In my research I will examine how these constraints have played out in two case studies and how they might play out in San Salvador, El Salvador.

I want to take a look at the strategy to implement GRT in the city of Seoul in South Korea and Toronto in Canada, and the way these cities' governing officials have been able to reduce the impact of stakeholders' perceptions in the adoption of the technology.

II. CONCEPTS OF GREEN ROOF TECHNOLOGY

2.1 Green Roof Technology (GRT) basis

When public in general understand the concept of green roof, they mostly relate it to the shape of gardens on a flat rooftop of buildings, regardless the accessibility or activities allowed there (see figure 1).

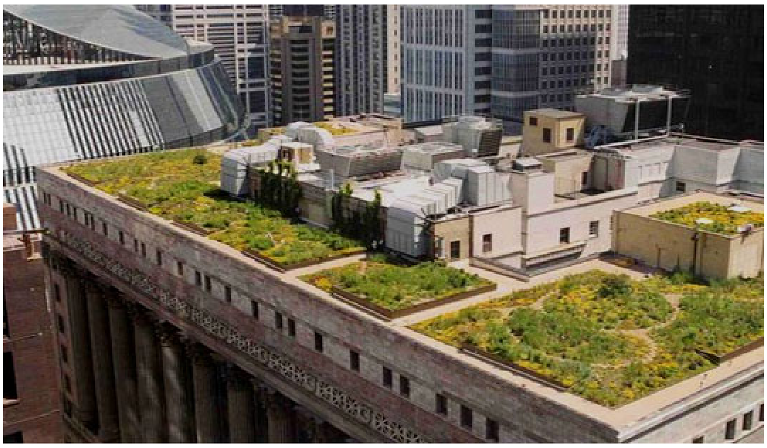


Figure 1. Green roofs on top of Chicago's City Hall, U.S. (Courtesy of www.chicagogreenroofs.org

To provide a general concept of GRT I will say that it is an open, green and pleasant space allocated over a built structure mostly flat rooftops, parking lots or underground structures, created by humans (Tomalty 2007).

They can be classified according to the soil depth in two general categories: extensive or intensive green roofs. There are other solutions falling in between these two categories such as: semi-intensive and semi-extensive (livingroofs.org 2004). According to the U.S. Department of Energy "an extensive green roof contains shallow soil and low-growing, horizontally spreading plants" (2004, 1). On the other hand intensive ones have profound soil allowing a wide diversity of plants such as shrubs and trees to grow. For the purposes of this paper the first two general categories will be enough.

Regardless the classification and their own characteristics, all the existing variants of green roofs are composed by the following elements: "vegetation, planting medium, drainage and filtering layer, root repellency layer and high quality waterproofing" (Tomalty 2007, 17).

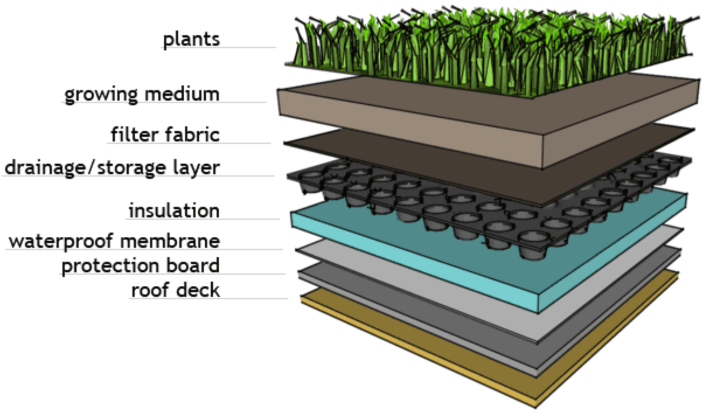


Figure 2. The Green Roof Elements (courtesy of www.greengarage.ca)

In table 1 there is a comparison between intensive and extensive green roofs in terms of weight, capital cost, maintenance, soil depth, type of plant, irrigation, vegetation layer, technical expertise required, structural support, uncertainty risk and long term benefits.

Table 1. The Differences between Extensive and Intensive Green Roofs

Characteristics	Extensive Green Roof	Intensive Green Roof
Weight	Lower	Greater
Capital cost	Lower	Higher
Maintenance	Minimal	Higher
Soil depth	50mm to 150mm	200mm to 2000mm
Type of plant	Sedum and grass	Trees and shrubs
Irrigation	Limited	Regular
Vegetation layer	Thinner	Thicker
Technical expertise or practical experience requirement	Minimal	Higher
Structural support	Lower	Greater
Uncertainty risk	Lower	Higher
Long term benefits	Lower	Higher

Source: Tam et al 2011, 16

In spite of the differences between intensive and extensive green roofs, for the purposes of this paper I will refer them in general as green roofs.

2.2 Green Roofs: Buildings Benefits

Green roofs can be attributed many different benefits which can be categorized according to the population receiving them, as follows: building benefits and community benefits (Jennings 2008). I will first describe the building benefits in the following section, which are mainly: energy conservation, increased lifespan and noise reduction.

1) Energy conservation

Regardless the location, green roofs provide a thermal insulation to the structure where it is placed on, ending up in cost savings and energy savings. Depending on the season and location, green roofs are likely to save the energy used to cool down or to impede the heat losses from a building. For instance, during summer it reduces the exposure of the rooftop to the sun and the absorption of heat to the inner part of the building which causes a decrease the overall demand of air conditioning. On the contrary, during the winter it prevents the heat loses from the structure and reduces the need of heating system.

According to the type of building and green roof, energy savings may vary. A study in Toronto indicated that two green roofs of a gymnasium, with reduced amounts of flora, decreased the maximum temperature of the roof membrane during summer by more than 35°F (16°C) and the heat flow produced in the summertime through the roof by 70% to 90% compared with a conventional roof (Liu et al 2005 quoted in Sonne 2006). The reductions relied on the season in those cases.

The reduction of cooling load, from green roofs, varies from 1% to 25% (Wong et al 2003; Christian and Petrie 1996 quoted in Sonne in 2006), and that is the main factor that helps the energy savings. For example I can mention Chicago's City Hall green roof project that saved the city government an estimated of $3,600/year (U.S. Environmental Protection Agency 2008). As observed in the mentioned studies, there is no fixed reduction of heat or cooling loads, it depends on factors such as climatic conditions, green roof area, vegetation amount and location; moreover the benefit remain tangibles.

2) Increased Lifespan

When GRT is projected and properly built on top of a building, the lifespan of that rooftop is increased due to the protection it gives to the roof membrane. A common rooftop are likely to be affected by high temperatures or UV rays, entailing some damage for the roof membrane such as cracking (Dunnett & Kingsbury 2004 quoted in Jennings 2008) and leaking.

According to some European researchers a traditional roof membrane's lifespan is half that of a green roofs (Peck and Kuhn, 2000 quoted in Jennings 2008). For instance if a roof membrane has to be replaced every twenty five years, a green roof will require it within forty to fifty years (Bianchini and Hewage 2012). Others claim up to seventy-year life span of green roofs (Cohen 2009 quoted in Hodges 2011) while in Berlin they have lasted over 90 years without needing major repairs (Porche and Kohler 2003 quoted in Hodges 2011).

Agreeing with the previous studies and unrelatedly to the amount of added years, there will always be a considerable extra period for the lifespan if installing a green roof over a roof top.

3) Noise reduction

The existence of both plants and soil in combination with other elements are called Green Roofs Technology which in the top of a building forms a barrier for the sound generated in the periphery. Usually, hard surfaces reflect and generate the noise we hear, in the case of green roofs the depth of this system is what prevents the noise to be caused.

Dunnett and Kingsbury in 2004 found that in the German airport of the city of Frankfurt the usage of green roof contributed to the reduction of sound pollution by 5dB (quoted in Hodges 2011). In addition a study by Kalzip (livingroofs.org 2004) found that the vegetated roofs reduce sound by 8dB when compared to traditional roofing system. The disadvantage of this finding is that it insulated walls and ceilings also accounts for noise reduction, therefore more research has to be completed to give green roofs the specific quota (Hodges 2011).

2.3 Green Roofs: Community Benefits

After revising previous studies and according to my criteria, the main community benefits are: urban heat island reduction, mitigation of air pollution, job creation, storm water management and amenities enhancing. The community benefits are different from the building benefits because the impact is greater and more people receive the positive effects, while the others are perceived only by the owner or occupants.

4) Urban Heat Island(UHI) reduction

The current phenomenon affecting temperature between urban and rural areas, in which urban areas are warmer than rural areas, is called Urban Heat Island Phenomena. In urban areas there is an abundance of asphalt for roads, concrete for sidewalks and highways, and brick for houses and buildings, accounting even 5^{o}C difference in relation to the temperature of rural areas (livingroofs.org, 2004), where forest, water bodies and crops are predominating in the landscape accounting for the lower temperatures (Landsberg 1982; Oke 1982 quoted in Pompei II and Hawkins 2011); the difference in the composition of the materials between the two areas whether efficiently absorbing or inefficiently releasing the heat is the best description of UHI.

Another factor encouraging the UHI was cited by Chapman in 2005 “the canyon structure created by tall buildings enhances warming by creating multiple solar reflections and therefore multiple opportunities for absorption”. And Voogt in 2004 wrote “The increased surface friction associated with taller buildings reduces wind speeds and therefore limits heat transport from the city" (quoted in Pompei II and Hawkins 2011, 53).

In turn, some negative effects of the rise of urban temperatures occur, including effects on human health, air quality, and energy consumption (U.S. Environmental Protection Agency 2003 cited in Pompei II and Hawkins 2011) which could be mitigated if the existing vegetation within the city was increased through the usage of green roofs as aerial green zones or parks.

A study demonstrated that GRT could lower the temperature by 0.11–0.84 ºC and be a solution to UHI for the city of Tokyo in Japan, if planting with greenery at least 50% of the rooftops available in the city. This would trim around 100 million yen per day in the city's electricity bill (Look Japan 2000 quoted in Pompeii II and Hawkins 2011, 53). Concerning Tokyo's air quality, intensive GRT have been used to combat humidity and air pollution within the urban area (Green Roofs Benefits and Cost Implications, 2004).

5) Mitigation of Air Pollution

Mitigation of air pollution is a key environmental problem that needs to be addressed "Polluted air is directly attributed to declines in human health" (Mayer 1999 quoted in Rowe 2011, 2101). Improvements would lead to reduce mortality rates, increase productivity, and reduce governmental expenses in healthcare due to respiratory illness.

Vegetation has been widely demonstrated to sequester pollutants from air, control and filter out impurities. However spreading green areas within the urban areas is somehow difficult due to the large amount of existing impervious surfaces and the lack of available space. In this regard, GRT represents a solution to pollution given the fact that it doesn't need space in the ground level to be implemented.

According to an investigation the contribution of trees in the U.S. (Nowak 2006 quoted in Rowe 2011) result on 711,000 metric tons of pollutants removed per year.

Contaminants can be filtered out by plants and deposited in the soil to be either washed out through storm water runoff or absorbed by plants. It was quantified that the amount of air pollutants that 109 Ha of green roofs could remove is 7.87 metric tons (Currie and Bass 2005 quoted in Yang et al 2008). In addition, others have estimated that green roofs can remove 20% of dust particles per kilogram of particulates per year per square meter of grass roof (Peck and Callaghan 1999).

This small sample of studies brings some evidence of the results that can be achieved when implementing green roofs within urban areas. Sometimes it depends on the vegetation type in combination of the depth of the growing medium, but as long as the effect of the impervious surfaces in urban areas is diminished the air quality will improve and the human health as well, creating a direct relationship air quality-human health.

6) Job creation

This benefit refers to the stimulation of local economy, when the entire economy is empowered GRT simultaneously grows. Green roofs enhance the local job market for nurseries, landscape contractors, irrigation specialists, designers, and other green workers (Getter and Rowe 2006 quoted in Hodges 2011).

7) Storm water management (SWM)

GRT decreases the storm water flow rate, it has the capacity to retain storm water and release it after the soil becomes saturated. Although the green roof system doesn't prevent the runoff from going to the storm water system but reduces the negative impact of it by delaying the flow. The cited delay can range from 95minutes(Liu 2003 quoted in Getter and Rowe 2006) to 240 minutes(Moran 2004 quoted in Getter and Rowe 2006) and the outgoing runoff (Liu 2003) can be 5.6 times less than the incoming one (Getter and Rowe 2006). For example flow rates can be reduced on green roofs from 57% to 87%, according to North Carolina researchers (Moran et al 2005 quoted in Getter and Rowe 2006).

This storm water delay alleviates the flow downstream in the storm water system preventing flooding or erosion, which is a direct benefit for the community.

8) Amenities Enhancing

According to the design given to the roof top, during the planning stage of the building, roof gardens may contain several provided amenities: tracks, seats, shades, flooring, gardens, ponds, landscaping, for group or individual activities.

Visitors can come to roof gardens and find peace, a place for recreation, have fun with their kids within the city or even within the same building they inhabit (Yuen and Wong 2005), that is why roof gardens are considered settings for social and physical activities. In addition, it is important to ensure the success of green roofs through a well-planned and participative design phase otherwise the place will not fulfill neighbors' needs and as a result it will remain unutilized.

In this section, from numerals one to eight I have been listing the possible benefits of the implementation of green roof technology, both for the community and building users. According to the reviewed key benefits it seems like a prominent and highly beneficial technology to implement. On the other hand, given the lack of implementation in many cities all around the world, I can infer that there must be counter arguments which are likely to dominate the stakeholders' perception towards GRT more than the benefits it carries out. In the following sections I'm going to introduce these details.

III. PROBLEM STATEMENT

As I previously stated in the introductory section, economic growth should carry out sustainable cities development. In this context, green practices are a must to achieve sustainable development and therefore help to mitigate the effects global climate change.

In this regard, as a common issue with the rest of the cities worldwide, San Salvador in El Salvador, should implement green building technologies to tackle global warming and to receive all the benefits it implies. Specifically, GRT is one of those practices which have been widely adopted in other regions but not in San Salvador.

There are not many projects implementing green roof technology in San Salvador, as a result I can assume that there must be something impeding this adoption. The decision whether to implement or not this technology should come from stakeholders, consequently I can presume they are the ones who have the constraints to implement this technology.

I want to find out through this research about the constraints regarding stakeholders' perceptions in the area of green roof technology adoption in other regions and how this constraints play out in the city of San Salvador, El Salvador.

First of all, to fully understand the main purpose of this paper it is necessary to give some definitions contained in this claim. I will first recall on to the definition of green roofs, which are also called cooling roofs or garden roofs: "a green roof is a vegetative layer grown on a rooftop" (United States 2008) created by humans (Tomalty 2007).

Second, I have to clarify who are the stakeholders in the field of green roof technology. According to Donaldson and Preston "stakeholders are persons or groups with legitimate interests in procedural and/or substantive aspects of corporate activity" (1995, 67). In regard of the topic I'm addressing, the corporate activity can be interpreted as GRT and those persons or groups who would be the most affected individuals by the management of a site or project (Stein 1997): developers, government officials and professional experts working in the field (House 2009).

The last scope of the research attempts to define technology adoption based on the concepts given in the Model of Innovation-Decision established by Rogers (2003) and explained in figure 3. Adoption, which is a positive action toward a technology, is the process of engaging in activities to finally put in practice the technology or innovation in use Rogers (2003). Later on in the theory section this model will be explained broadly.

After reviewing these concepts, it is equally important for the claim of this research to know about the meaning of perceptions of stakeholders, both positive and negative (translated into constraints), regarding green roof technology. According to Rogers (2003) the most common questions an individual will ask about a new idea (innovation, technology) include: (1) "what is the innovation?" (2) "How does it work?"(3) "Why does it work?" (4) What are the innovation's consequences?", and (5) "What will its advantages and disadvantages be in my situation?"

For the purpose of this study, the individuals asking these questions can be stakeholders, and the factors shaping their perceptions toward green roof technology, in essence, are contained in the questions posed by Rogers. The last question might arise among decision-makers and can be manifested into barriers or advantages for the adoption of green roof technology.

In the following sections I will find the constraints identified by previous authors, and how each of them plays in the adoption of the technology, specifically GRT.

IV. PREVIOUS STUDIES

There are a few authors whose interest was to find out about stakeholders perceptions in the area of GRT or green infrastructure, either positive or negative. I found over twenty five published researchs addressing this issue. Among them, and according to the pursposes of this research I found five papers that are relevant for this research, the findings will be briefly described as follows and summarized in table 2. In this table the information was classiffied per author and contain the name of the paper, the method used to collect the perceptions, the identified constraints and some details about them.

House (2009), in his research paper, interviewed eight stakeholders to gather their perceptions on GRT, (that included developers, city officials, and architects) they were classified according to their regional awareness.

The findings were that the two types of GRT available today (intensive and extensive) have more positive attitudes than negative perceptions according to decision maker's understanding, but counter arguments exists. Three disadvantages were cited: installation cost, preservation and liability; meanwhile others were cited as positive: aesthetics, storm water management, thermal isolation, absorption of heat. The disadvantages were at the end transformed into constraints as follows: technical concerns, lack of knowledge and cost-based constraints, shaping the perceptions of the stakeholders in North Texas (House 2009).

Equally important, for the purposes of this paper, is the research titled "Applications of Extensive Green-roof Systems in Contributing to Sustainable Development in Densely Populated Cities: a Hong Kong Study" (Tam et al 2011) where, up to 2011, there were 53 governmental operated buildings (ex. Public offices, hospitals or schools) which have implemented green roof technology. In that research the methodology was to survey 426 respondents among university academics, government departments, consultants, contractors and interview 20 of them. The respondents were grouped as suppliers, government departmental employees, specialists, and academia; under five different disciplines including architecture, surveying, engineering, education and others.

The cited paper claims that "Although the green roof systems are not widely adopted, the respondents still agree that the applications of extensive green roof systems are feasible for existing buildings" (Tam et al 2011, 19). The findings mention enhancing optical facilities and air quality and reducing island heat as benefits of GRT. In addition, it is important for the owners of the studied buildings to have incentives from the government as well as promotion which are both scarce and overall restrict the decision to implement the technology; in other words lack of incentives, support and knowledge are some of the barriers they cited.

Hodges (2011) in his paper "Green Roofs in the Garden City: Exploring the Opportunities for Green Roof Policies in Missoula, Montana" found that spreading knowledge about GRT is the first step to encourage the implementation of this green practice among citizens and landlords. Also stakeholders mentioned that "voluntary, nonmonetary incentives" would be more desirable than "financial ones".

Collecting stakeholders' perceptions was also a duty for Taheri et al (2007) in "The perception of Cooling Roofs among professionals in Iran" in which they are willing to find out experts opinion about the suitability of GRT for Iran. A selected sample population composed of 40 professionals included building professionals, landscape architects, architects, urban planners, civil engineers, horticulture engineers, municipal managers, professional academicians and environmental experts; were targeted to participate in a survey that searched to answer three main points: "1) level of attraction towards advantages of green roof; 2) capability of green roof for environmental cooling; and 3) eligibility of different type of roof structure for green roof in present building form" (Taheri et al 2007, 30).

According to the results of the survey 97.5% agreed with the implementation of green roofs in Iranian cities. Furthermore 85% of the respondents believed that GRT is applicable when retrofitting, as well. Positive environmental impacts were cited: pollution and urban heat island reduction, decrease of solar radiation and energy consumption; and aesthetics. In this case, and as a result of the findings, the author is requesting a green roof policy, pointing out the lack of regulations in this area.

Table 2. Stakeholders perceptions based on previous studies

Author/ Date	Paper Title	Method	Constraints	Detailed Perceptions (+) Or (-)
House 2009	North Texas Stakeholders: perceptions of extensive green roofs	Interview 8 stakeholders	Technical concerns Cost-based constraints Lack of knowledge Climatic related issues Environmental benefits	Installation cost (-) Additional structure (-) Preservation (-) Liability (-) Aesthetics enhancement (+) Storm water management (+) Thermal isolation (+) Absorption of heat (+)
Tam et al 2011	Applications of Extensive Green-roof Systems in Contributing to Sustainable Development in Densely Populated Cities: a Hong Kong Study	Survey 426 respondents among university academics, government departments, consultants, contractors and interview 20 of them	Cost-based constraints Lack of knowledge Environmental benefits Lack of incentives	Feasible for retrofitting (+) Increase green features (+) Air quality improvement (+) Urban Heat Island improvement (+) High cost maintenance (+) Energy efficiency (+) Insufficient promotion by government (-) Lack of incentives (-)
Hodges 2011	Green Roofs in the Garden City: Exploring the Opportunities for Green Roof Policies in Missoula, Montana	22 individuals were interviewed	Cost-based constraints Lack of knowledge Environmental benefits Climatic related issues Lack of regulation	Storm water control measure (+) Amenity space benefits (+) Prolonged lifespan of roofing membranes (+) Energy efficiency (+) Urban heat island reduction (+) habitat preservation (+) Lack of financial incentives (-) Lack of knowledge (-) Lack of regulation (-)
Taheri 2007	The perception of Cooling Roofs among professionals in Iran	35 males and 5 female built environment professionals	Technical concerns Energy efficiency Environmental benefits	Reduce energy urban problems (+) Applicable to current building (+) City farming for food production (+) Ecological design Value for biodiversity

				Creation of green space Reducing solar radiation Reducing environmental cooling Reduce heat island effect Reduce air pollution Suitability to different
Siegler 2006	Green Roofs for Austin: Toward a More Progressive Model of Technology Transfer	19 interviews	Technical concerns Cost-based constraints Lack of knowledge Environmental benefits Climatic related issues	Initial financial cost Increased maintenance according to the climate High cost maintenance Amenity value Lack of incentives Lack of regulation Lack of investigation

Cost-based concerns, initial cost and high maintenance cost, and amenity values generation were some of the facts pointed out by stakeholders in 19 interviews (Siegler 2006) in the research paper called "Green Roofs for Austin: Toward a More Progressive Model of Technology Transfer".

V. THEORY AND HYPOTHESIS

5.1 THEORY

Along 30 years or so the process of adopting new innovations has been studied and one of the most famous models is described in the book Diffusion of Innovation, created by Everett Rogers and initially published in 1962. Many different researches have used this model as framework in a wide variety of disciplines. For the purposes of this paper I consulted 5th edition of this book.

When adopting a new “idea, practice or object that is perceived as new by an individual” (Rogers 2003, 412) diffusion is necessary to shorten the time until it the innovation is extensively adopted. Diffusion “is the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers 2003, 396). The main four elements of Diffusion of Innovation process are contained in the following concepts: innovation, communication, channels and members of a social system.

Given the innovation, and if the will is to spread it, communication should take place. It is described in this theory as the process through the one the participants share information with one another using different means called communication channels. Diffusion is a particular type of communication, which concerns the new idea. The essence of this process is the exchange of information (Rogers 2003).

The time is another of the elements integrating the diffusion of innovation process: time to acquire the knowledge, to adopt the innovation and the amount of people adopting the innovation in a certain period of time. There is a process inside this time dimension called Innovation-Decision process through the one an individual can pass from “first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation and use of a new idea, and to confirm this decision” (Rogers 2003, 650).

The Innovation-Decision process (see figure 3) is a logical and ordered course composed by five stages which are defined as follows: (a) knowledge (b) persuasion (c) decision (d) implementation and (c) confirmation.

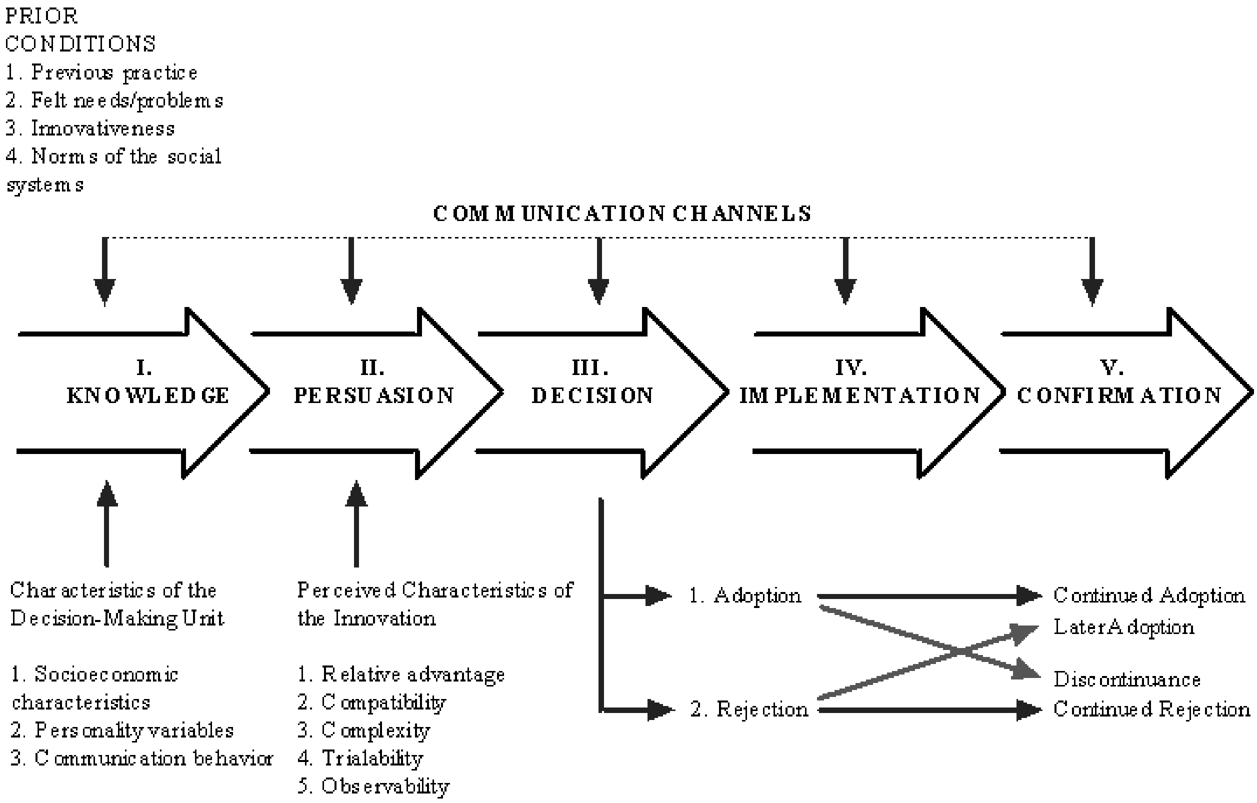


Figure 3 Model of Innovation-Decision. Source: Rogers 2003.

First stage is knowledge that “occurs when an individual (or other decision-making unit) learns of the innovation’s existence and gains some understanding of how it functions” (Rogers 2003, 650). Second stage, persuasion, refers to the attitude, either positive or negative, of and individual toward the innovation. When engaging in activities that will end up in adoption or rejection is the third stage of the process called Decision.

Followed by implementation, which is simply the usage of the innovation. Confirmation is just the fifth and last stage of the process which is ensuring the decision taken, in order to avoid reversion by any situation of conflict (Rogers 2003).

Until now, the innovation-decision process has been described for individuals but they can also happen in organizations in a much more complex way, since it implies a group of individual working together in order to achieve common goal.

There are three types of organizational innovation-decisions processes:

- Optional innovation decisions: the choice of adoption or rejection made by an individual regardless the decisions taken by other colleagues.
- Collective innovation decisions: the choice of adoption or rejection with the consent of the rest of the colleagues.
- Authority innovation decisions: the choice of adoption or rejection made by few, but experts or powerful, members of a system.

In the organizational scale the innovation process is integrated by two sub process. In the initiation sub process there are two stages and in the implementation there three stages (see figure 4).

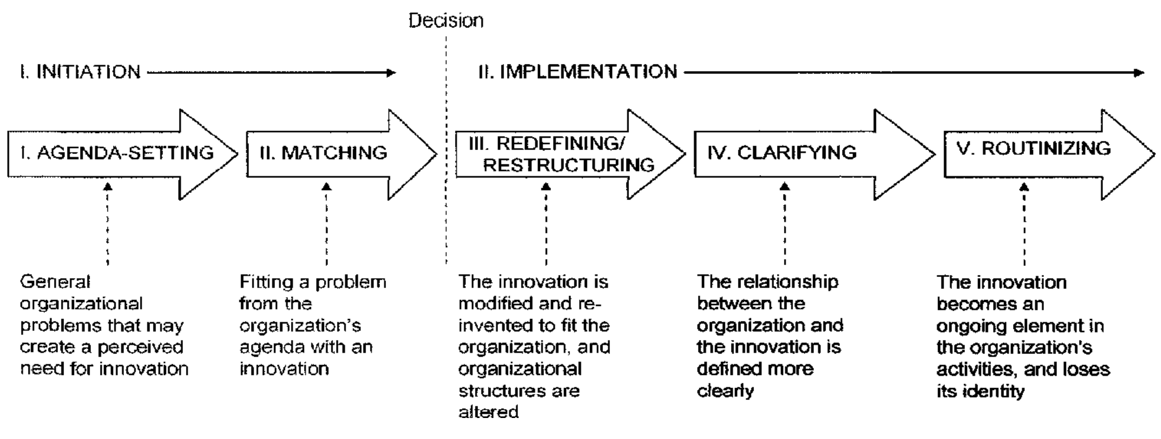


Figure 4. Model of Innovation-Decision in organizations. Source: Rogers 2003

In the area of green roof and according to the purpose of this paper, stakeholders will be considered as individuals, not collectively, because regarding each other's businesses they are not pursuing the same objective. There might be the case that they are organized as units in some extend, but when it comes to make profit from green roof they do it separately. Therefore, they will be considered individually.

5.2 HYPOTHESIS

Usually perceptions lead to actions, and reflect how processes are viewed; hence when trying to implement new technology it is important to find out about the perceptions of people. When seeking for perceptions, if we would target the entire population, it might be difficult to collect everyone's opinion; complementarily it would be representative if I collect the main stakeholders' perception in the field.

If looking forward to the implementation of GRT, stakeholders' perceptions towards a new wave can be either positive or negative. If positive they are called advantages, if negative they may be translated into constraints to implementation. This paper is willing to identify those main constraints, shaping stakeholders perceptions when implementing green roofs technology in any city. In this case Green Roof Technology Implementation works as dependent variable and constraints play as independent variables.

According to previous studies (Tam et al 2011; House 2009) there are five constraints shaping stakeholders perceptions: (1) lack of knowledge, (2) lack of incentives, (3) cost-based constraints (4) technical concerns and (5) lack of standards/regulations and specialized products.

1) Lack of knowledge

It is basically defined as an inadequate distribution of information that is currently available, if available.

It could also be the case that information is unavailable or inexistent; in those cases I will call it lack of knowledge or lack of information. Other ways to call it are lack of awareness or familiarity with GRT.

The knowledge can be provided from different sources, especially from the stakeholders: technology suppliers, technology builders, experts in the field, design professionals, contractors or governmental institutions. In the last case since government is the most interested group in boosting this technology due to public and community benefits, they should do as much as possible to fill the gap resulting from unawareness.

There are some cases that green roofs technology knowledge is acquired by pilot projects in governmental buildings or private buildings; through research in universities or by reviewing previous studies. There are many channels but the most important thing is that the knowledge should reach to stakeholders' hands.

Several groups are working to fill this information gap in many different places. Green Roofs for Healthy Cities, a Toronto-based organization, took the initiative to organize green roof conferences annually in order to support and encourage an adequate green roof industry. In addition, "the City of Chicago hosted 'Greening Rooftops for Sustainable Communities' the First North American Green Roofs Infrastructure Conference, Awards, and Trade Show in May 2003" (U.S. Department of Energy 2004, 14) to demonstrate the opportunities of green roof technology application and learn about green roof designs.

This problem has to be overcome before this technology is widely adopted otherwise it may result in long term reluctance that will hinder the implementation of this technology.

2) Lack of incentives

Green roof technology has a high initial cost and requires additional expenses given the composition of the system which includes specific materials, additional layers, special installation process and skilled labor. Very often this is taken as the main reason to refuse the application of this technology assuming budget constraints without considering long-term savings due the benefits that it also produce.

In general when government, either local or central government, is willing to take on projects that benefit the community they should use all the available tools and resources to achieve their goals. In this regard after the local or central government acknowledge that green roof technology will be beneficial for the public, private owners, and environment, among others, should promote its implementation intensively through policy change.

Consequently they should design various policies which are specified according to the focus, as follows: technology standards, performance standards, direct financial incentives, and indirect financial incentives (Carter and Fowler 2007)

According to the categories cited above, first technology standards and design specifications can be required in the building code directly demanding growing media, type of vegetation, water retaining capacity, roof surface reflectance, type of building and amount of required green roof area.

Second, performance standard is when GRT implementation is implicitly included in a policy in order to achieve certain performance standard, for instance LEED standards or storm water management policies; equally important is direct financial incentives, usually labeled as the most important type, consisting of subsidies, reimbursements, lump sum payments or grants (Carter and Fowler 2007), depending on the governmental or organizational funding. Finally indirect incentives can be explained with the following example: "a credit towards a municipality's storm water utility fee is popular for encouraging green roof installation. Storm water utilities are typically based on the amount of impervious surface which is found on a given site. Measures to the mitigation of impervious surfaces, such as green roofs, are given credit towards a portion of the storm water utility fee" (Carter and Fowler 2007, 156).

To cite a successful example of the aforementioned policies, I can state that in Germany there are “direct incentives and financial investment” (livingroofs.org 2004, 30), which have helped the industry to grow between “10-15% annually over the past decade” (livingroofs.org 2004, 30).

3) Cost-based constraints

There are some myths regarding the maintenance of green roofs. Some specialists believe that they require high maintenance throughout their life span but some case studies have demonstrated that in fact, once green roofs are settled down they require only annual maintenance or eventual maintenance due to any extraordinary natural event such as hurricane or tornado (U.S. Department of Energy 2004). However, others believe that given the special components of the green roof compared to a traditional one it requires specialized labor as well as increased demanding maintenance.

Other causes for the increased investment for GRT are the design costs due to the special design for the roof base and the structural loading; when retrofitting an existing building the structural capacity has to be revised, sometimes resulting on unviability for the project (Hui and Chan 2008; Urbis Limited 2007 quoted in Tam et al 2011). At the end, this cases may increase the initial budget but the benefits will always compensate them.

4) Technical concerns

Uncertainty is linked to hazards and technical concerns during the construction phase of green roofs, especially in the waterproofing layer and root barriers. Another concern is usually the vegetation able to rise on green roofs, it will probably require to the landlords a considerable amount of effort and time due to the lack of technical information in this regard.

The major technical concern is water leaking according to the U.S. Department of Energy (2004) which has been mentioned as one barrier to the implementation and seems to invalidate all the benefits for some individuals. Bruce Bitler, the Dallas-based assistant VP, engineering line product underwriting for Zurich North America said "If you're building a green structure with a vegetative roof, there's a lot of concern around the possibility that you'll end up with water intrusion and maintenance issues" (Greenwald 2012, 17). In this sense, it is demonstrated that technical issues can overshadow important standards, policies or knowledge that could produce viable change, such is the case of GRT.

5) Lack of standards/ regulations and specialized products

There is a clear need to develop standards and regulations for green roofs to ensure that a certain quality and performance objectives will be achieved through the implementation of this technology; with the advent of such standards those using green roofs can prevent system failures, disable sub-standard systems to be installed at a cheaper cost damage the reputation of green roofs. The absence of standards makes it difficult for clients and planners to check if their demands are being fulfilled by the designer or contractor. For example, the Canadian-based Green Roofs for Healthy Cities has developed a training seminar that was first presented in June 2004 whose objective is to fill the lack of information in relation to the Green Roofs Standards.

“The larger green roof manufacturers in the UK meet the German FLL Standards, but no one from outside the industry is monitoring these (or is able to) or the green roofs installed by any other manufacturer” (livingroofs.org 2004, 31). This issue led us to the guarantee of the systems provided by the manufacturer, in most cases are lacking of clearness about what is guaranteed and what is not.

Since there is not standardized definition about it when discussing “green roof” it can be interpreted as “reflective roofs, roof made of recycled material, vegetated roofs or any other typology associated to sustainability. To solve this issue a group under the American Society for Testing and Materials (ASTM) in the U.S. will develop a standard practice guide to establish a technique "for assessing green roofs and include technical requirements as well as considerations for sustainable development" (U.S. Department of Energy 2004, 14). On the other hand the *ForschungsgesellschaftLandschaftsentwicklungLandschaftsbaue* (FLL), the Landscape Research, Development & Construction Society in Germany, has developed industry standard tests for green roof technology components" (Nelms et al 2007)

5.3 RELATIONSHIP BETWEEN THEORY AND HYPOTHESIS

In the Innovation-Decision process, Rogers (2003) explained that the first stage of the innovation-decision process is achieved when individuals learn about the existence of technology and enhance their understanding about the innovation. On the contrary, I found that whenever the "Knowledge" stage is not achieved, it means there is a lack of familiarity with the technology which will constraint the implementation, in this case of GRT. As a consequence prior conditions should be generated, mainly focusing on the recognition of a problem or need which for my purpose is to tackle global climate change through environmental technologies.

Moving forward to persuasion, assuming there is knowledge. This is where individuals or stakeholders want to reduce the uncertainty toward the innovation (GRT). They need to be familiar with the benefits regardless to the role they play. In this stage rejection or adoption can happen. Rejection of the technology might also be due to lack of knowledge about advantages and disadvantages, lack of incentives, existence of technical and cost based concerns or any other uncertainty governing the stakeholders. On the other hand, if decision stage generates positive results adoption of technology is achieved. The persuasion stage is key issue in the innovation decision process.

Continued adoption implies implementation. This adoption of the technology can be reversed during the implementation phase due to lack of incentives or lack of standards/regulations or both. This can also happen during the confirmation stage.

Summarizing I consider there is strong relationship between the five-stages of the innovation-decision process and the constraints found in the hypothesis development (see figure 5)

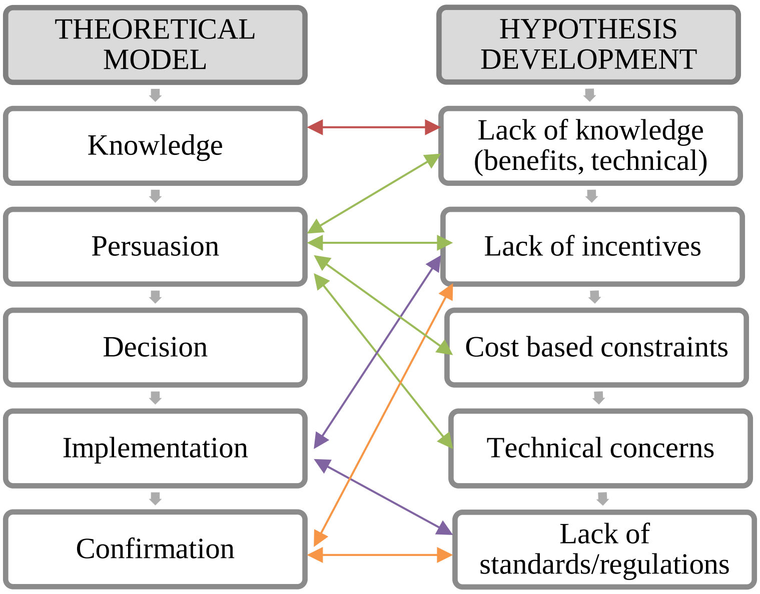


Figure 5. Relationship between Innovation-Decision process by Rogers and Hypothesis Development

VI. METHODOLOGY

This research uses data from selected previous studies as supporting evidence for the hypothesis development. To make the mentioned selection of papers, three main criteria were used: 1) similarity between the topic of this paper and the selected paper, 2) research method used to collect the data by the author of the previous study, either face-to-face interviews or surveys were preferred, 3) consulted population in the previous study has to include stakeholders such developers, city officials, architects, landscape architects and users.

After carrying this process out , five papers were picked House (2009), Tam et al (2011), Hodges (2011), Taheri (2007) and Siegler (2006) which attempts to discover stakeholders' constraints regarding the adoption of green roof technology.

Once the data is extracted from the papers, it is going to be summarized in a way (see table 2) that it will define the major constraints for the adoption of GRT, which constitutes the hypothesis of this paper.

The hypothesis is also supported in the theory of “Diffusion of Innovations” by Rogers (2003) which describe five stages as main process of innovation-decision: (1) knowledge, (2) Persuasion, (3) Decision, (4) Implementation and (5) Confirmation.

In order to find supporting evidence for the hypothesis I will conduct two successful case studies on green roof technology adoption which are going to be reviewed in terms of the identified constraints, willing to identify the instruments or possible ways to successfully overcome them and finally how those lessons can help to foster the successful implementation of such technology in San Salvador, El Salvador.

In the case of Korea and due the lack of information in English I will interview the main expert and initiator of the movement of GRT, in order to find the proper information regarding the implementation of this technology in Seoul, South Korea.

VII. CASE STUDIES

In this section I will review two case studies in order to provide evidence for the formulated hypothesis, which argues that the constraints to green roof technology implementation are:

1) Lack of familiarity or knowledge about the technology
2) Lack of incentives for the ones implementing it such as fiscal or financial incentives
3) Cost-based constraints such as high initial cost, structural demands or high maintenance
4) Technical concerns associated with confidence such as waterproof system, root barriers and climate adaptability
5) Lack of standards/regulations and specialized products

By looking at these case studies I might find out if during the implementation of GRT in other countries, the stated constraints were the only ones which played out and if there is any other to add. Complementarily I want to take a look into the details of each constraint implications.

I will first develop the case of Canada taking a look at the city of Toronto, but also the case of the city of Winnipeg. The next case to be developed is the case of the city of Seoul in South Korea. After concluding the two case studies, the main idea is to figure out possible ways to overcome all the constraints in order to achieve a successful technology implementation in the city of San Salvador in El Salvador.

7.1 City of Toronto, Canada

7.1.1 Background of Green Roof Technology in Canada

Many technologies and innovative products face barriers when trying to enter a market due to users' and stakeholders' uncertainties related with costs, benefits and technique even if they have been probed in other regions; this situation prevents it to be widely adopted. For Canadians, the barriers were materialized on November 24th 1998 through a one-day workshop in Toronto, Canada attended by over sixty participants between industry and government stakeholders (Peck and Callaghan 1999) where they identified the constraints to the usage of GRT. The mentioned barriers were identified as: lack of knowledge and awareness, lack of incentives to implement, cost-based barriers and technical issues and risks associated with uncertainty. A brief explanation of each will be described in the following paragraphs.

7.1.2 Constraints to the implementation of Green Roof Technology in Canada

1) Lack of Knowledge and awareness

According to my own perception and based on previous studies, I can say that in general GRT is widely known in Germany and other European countries but not in the same proportion in North America. Regardless the location, even if GRT is already implemented in some cities or countries, users don't usually notice them and assume them as common landscape spaces.

The reinforcement of stakeholders' knowledge is a must in the subject of GRT, especially concerning (a) policy makers, (b) how-to professionals, (c) researchers and (d) general public (Peck and Callaghan 1999). Support and promotion of the new technology is directly linked to the reaction of the stakeholders (public, building owners, building industry). The explanation of the role of each of the mentioned group as follows:

1. The group of policy makers involves politicians and government staff at all levels, with a particular interest for municipalities' staffs. Regardless the level of commitment to technology implementation, all of them should be informed about the social, environmental and economic benefits of GRT in order to help promoting the implementation of this sustainable technology.
2. Expert professionals involved in the execution of GRT like "bricklayers, roofers, framers, landscapers and mechanical contractors" (Peck and Callaghan 1999, 42). The green roof system is integrated by different elements which together will create the final outcome. These different layers can even vary in warranty or contract type, in this sense it can be risky for the owner to deal with it. This problem has been solved in Europe or Canada, by creating turn-key companies that implement the complete project and fulfill all the technical requirements giving a unique warranty for the contract.
3. Researchers should have all the available data and be familiar with it in order to do their research in the fields that haven't been yet explored such as "detailed energy savings information from different types of applications; growing media and plants; detailed information on storm water benefits and the benefits in aggregate; modeling economic benefits from different applications; large scale benefits, such as reducing greenhouse gases by reducing the Urban Heat Island Effect and reducing storm water runoff"(Peck and Callaghan 1999, 42).
4. General Public needs to be aware of the public and economic benefits of green roofs in order to demand from government the necessary incentives for the residential, commercial and industrial sector. "Benefits that need to be communicated to this group include: improved storm water management, improved air quality (i.e., particulates), reduction of greenhouse gases, more

amenity/recreational space, better local food production, jobs/employment opportunities, aesthetic benefits". (Peck and Callaghan 1999, 42)

2) Lack of incentives

Many of the successful cases of green roof technology implementation in Europe derive from a very strong legislation and financial incentives demanding from the new developments to implement green roofs or to create market for these technologies.

Through the workshop held in 1998 in Toronto, the reasons of the lack of government support were identified as well as the major types of potential government incentives. The reasons as follows (Peck and Callaghan 1999):

1. Lack of easily accessible social, environmental and economic information regarding benefits.
2. The benefits are long-term while start-up costs are required which drive the investor away.
3. When a green roof project is already executed many of the economic benefits are not shared by the initial developers or investors. In this sense successful cases are very scarce

On the other hand the major types of potential government incentives, as follows: "research and demonstration projects, grants and subsidies for implementation, green roof procurement policies for publicly owned buildings, legislation, by-laws and building codes requiring installations" (Peck and Callaghan 1999, 45).

3) Cost-based constraints

As explained before there is a generalized lack of knowledge about GRT, and part of that is the lack of detailed information about long-term economic benefits and associated costs. In relation to long-term economic benefits, it can occur that unexpectedly the costs increase and become higher than the planned cost; consequently the long term benefits decrease. Associated cost of GRT can be initial capital costs, maintenance costs, additional infrastructure (hand rail if the place is public) and lifecycle costs. Those facts are commonly believed to be costly and that is the reason why it will sometimes discourage investors from implementing GRT.

Other associated disincentives which can be also interpreted as risks are (Peck and Callaghan 1999):

1. In case of economic crisis, maintenance costs are the first to be cut, which can put in risk the system.
2. Long-term maintenance costs are uncertain because are expected to be low but they might increase due to unexpected situations.
3. In the area of insurance and liability since there is generalized lack of knowledge and can affect the effectiveness and quality of the delivered services.
4. Turn-key developers are unlikely to be benefited from the operational cost savings due to some additional consultancy and structural design.
5. Decision-makers are not willing to make long-term investments just for the public benefit due to financial constraints.
6. Procurement used to base their decision in quality, longevity and innovation but nowadays those aspects are sacrificed and cost is prevailing.

4) Technical Issues and Risks Associated with Uncertainty

Technical barriers were identified during the workshop mentioned in the previous items, which reflected the high knowledge the participants have in the field (Peck and Callaghan 1999):

1. Lack of specialized products on the market and pilot projects might lead to failure or inefficiency. Transportation costs may affect the market's supply

forcing the industry to look for substitutes and to decrease the quality of the system.

2. Lack of technical specifications for adequate plants to the system which can lead to a poor look in some of the seasons or low performance of the system.
3. Dismissing the follow up stage by the designing consultants may result warranty concerns among clients or unsuccessful project and damage the image of the technology
4. Lack of standards and regulations, which should be included in the building code

7.1.3 Possible solutions to the constraints

In the particular case study of Canada the constraints to GRT adoption have been stated clearly by Peck and Callaghan (1999) in the research paper "Greenbacks From Green Roofs: Forging A New Industry In Canada", which have been explained in detail in the last items. After reviewing some literature, I based my analysis of the constraints on two research papers Peck (2002) and Banting (2005), related with the implementation of GRT in the cities of Toronto and Winnipeg in Canada and came up with what I call possible solutions to overcome green technology implementation constraints (see table 3). These are: research, demonstration projects, turn-key companies, compilation of technical and cost benefit analysis information in a central place, promotion, incentives, policy implementation and standards development. The detailed description of each item as follows:

1. Research

This is the main tool to fight against the lack of knowledge, awareness and information. In general research is related with public and private investment in the sense that since funding is required; in the city of Toronto and Winnipeg grants have been received to address these issues from governmental institutions and the research has been done mostly on cost benefit analysis, social and environmental benefits and lifespan cycle.

Through this tool Toronto's Urban Heat Island model was created; Toronto's storm water quantity and quality research has been done; feasibility study about green roof strategy development in the downtown area of the city of Winnipeg was executed; measurement of the environmental benefits of green roofs in Toronto, potential monetary savings for the municipality and ways to incentivize implementation of green roofs, are among the fields researched.

To succeed in fulfilling the information and knowledge gaps is important and crucial to have all the previous and newly generated researches compiled in a data base which can be accessible to everyone and administrated by an specific institutions, as the case of "Green Roofs for Healthy Cities" (GRHC) a public-private consortium for green roof infrastructure which is willing to establish an effervescent multi-million dollar market in North America.

2. Demonstration Projects

The implementation of demonstration projects work as an educational field, in the sense that accurate data can be collected regarding environmental benefits, cost benefit analysis, maintenance costs, adequate selection of plants. Also for professionals and clients without experience in the field, that are willing to implement the new technology in their projects is very useful to perceive the generated environment in the building beforehand.

This is a very easy way to promote the usage of green roof technology. All the collected data and executed research during the implementation of the demonstration project has to be available for the public in general including researchers, policy makers and how-to professionals.

3. Turn-key companies

The green roof system is integrated by many layers which can imply different suppliers, different kind of contracts among contractors and suppliers, even different warranties. Consequently there is a variety of professionals working in the field of green roof technology. If all these facts are gathered, the system instead of providing a solution for the client is creating more trouble.

To avoid this kind of complications, integrated systems are provided which should be installed by a turn-key company which should in charge of the whole process of the implementation of the green roof system including warranties and maintenance.

4. Compilation of technical and cost benefit analysis information in a central place

The information collected in the research stage is useless if it is not accessible for all the stakeholders. In order to centralize it, in the case of Toronto "Green Roofs for Healthy Cities" (GRHC) devoted itself to gather all the available information in a website www.greenroofs.org

5. Promotion

Mostly governmental institutions such as the city office, federations of municipalities and related institutions are leading the promotion of this technology most of the times through demonstration projects and advertisements.

6. Incentives

There are some investors who are willing to implement this technology but due the high initial cost that it has most of them are discouraged. In this regard incentives to the ones willing to implement this technology are a good solution to increase the adoption.

In the case of the City of Toronto a Green Roof Strategy was developed in 2006 to encourage GRT construction in the city, and included the installations process, incentives, approval process and publicity and education. As a result 7,000 m2 of green roof systems were delivered in 2006/2007. “The resulting Eco-roof incentive program, launched in 2009, has approved applications for 8100 m2 of green roofs on 14 projects” (J. Welsh, personal communication 2008 quoted in Currie 2010, 1)

7. Policy implementation and standards development

In order to standardize the performance of green roof systems, there must be guidelines to be followed by contractors or reviewed by the government to give approval to any project.

The existent guidelines are produced by *ForschungsgesellschaftLandschaftsentwicklungLandschaftsbau* (FLL) a landscape industry organization in Germany. An English version entitled "Guideline for the Planning, Execution and Upkeep of Green Roof Sites" was issued in 2002 (Ryerson Polytechnic University 2005, 39).

A summary of the constraints, solutions and tools are embodied in table 3.

7.2 City of Seoul, South Korea

7.2.1 Background Green Roof Technology in South Korea

High density developments are rapidly increasing within the cities; as a result it deteriorates the environment and reduces the amount of green open spaces available in the city which help to enhance the urban experience of the citizens. Those green spaces also produce social, economic and environmental benefits for the users.

Korea is not the exception to this rapid urbanization process. The Seoul Metropolitan Area’s rapid population growth positioned it in the 6th most densely populated area and 9th largest producer of Carbon Dioxide in the world, accounting in the high energy consumption and land-use and land-cover (LULC) changes (Han 2007).

According Choi (2008) in the urban area of the city of Seoul, there is lack of green spaces (parks) due the fact that more than 80% of green areas are concentrated in the green belt surrounding the city either mountain or forest. As a result, there is a need to eliminate the unequal distribution of green spaces and improve the accessibility of existing and new green areas. According to Tong (2011) only half or less of urban areas in Seoul are serviced by parks within a walking distance (or 1,000 meters according to the study, whereas half a mile or 800 meters are regarded average walking distance in many other studies).

In order to supply the demand of green spaces in urban areas, now GRT are supported by the city government.

Table 3. Constraints for GRT in Canada: problems, concerns, and possible solutions

Constraints	Problems & Concerns	Possible Solutions	Action Plan
Lack of knowledge	Policy makers are not familiar with the social, environmental and economic benefits derived from green roof technology	Research	Modeling the Urban Heat Island in Toronto (Peck 2002)
			Formulating a model that allow individual building owners and other municipalities to measure the benefits of GRT (Banting 2005)
			Monitor energy savings and conducting storm water quantity and quality research on pilot projects (Peck 2002)
			Measuring GRT performance on summer temperatures reduction (Peck 2002)
			Conducting feasibility studies about green roof strategy development for flat-topped buildings (Banting 2005)
		Demonstration projects	Generating reliable technical data on energy efficiency (Peck 2002)
			Generating reliable technical data on storm water retention (Peck 2002)
			Conducting research on city-wide potential spin off greenhouse gas, smog reduction and energy efficiency gains by reducing cooling energy needs in all buildings (Peck 2002)
	The knowledge and skills, embodied in experts, needed for the implementation are fragmented at various operating levels	Creating turn-key companies	Increasing the awareness of green roof technology benefits by giving professionals the opportunity to visit a working demonstration site with multiple applications (Peck 2002)
	Researchers don't have full access to the available information in the field of green roof technology	Compilation of technical green roof information in a central place	Creation of institutions such as the "Green Roofs for Healthy Cities" (GRHC) which is a public-private consortium willing to establish a market for GRT in North America (Peck 2002)
			Quantifying the potential benefits of technologies relating to storm water management, water and energy conservation, and air pollution through the Sustainable Technologies Consortium is a public partnership between the Toronto and Region Conservation Authority (TRCA), Seneca College, the University of Guelph and Ryerson University. The mandate of the consortium is two-fold, second one is to pursue scientifically defensible research in sustainable development (Banting 2005)
			Creating an online data base with detailed technical information (Peck 2002)

Constraints	Problems & Concerns	Possible Solutions	Action Plan
	The information about public and economic benefits derived from green roof technology is not accessible for public in general	Promotion	Promoting green roof development in the city as Toronto has been doing over the last several years through volunteers under the Rooftop Garden Resource Group (RGRG)
Lack of incentives	Absence of government support	Research	Conforming multisectorial team like the one the City of Toronto made in partnership with Earth and Environmental Technologies (OCE-ETech), the Federation of Canadian Municipalities, and Ryerson University researchers; and conducting research about potential monetary savings to the municipality through the use of GRT, and minimum thresholds of green roofs that could be used as a part of any incentives or programs (Banting 2005)
	Long-term benefits are highlighted but the need for high capital investment drive investors away	Incentives	Including green roofs as part of the environmental policies. The City of Waterloo developed an Environmental Strategic Plan, which was adopted by Council in 2002. Green roofs fit into the Environmental Strategic Plan in all important areas.
			Designing procedures to help policy makers to develop appropriate incentives for implementing green roof infrastructure in partnership with the private sector (Peck 2002)
	Absence of demonstration projects, grants and subsidies for technology implementation	Demonstration projects	GRHC, in partnership with researchers and government staff, are developing a $1 million, 3 years project: Toronto City Hall Podium Roof and the gymnasium steel deck roof at the East view Neighborhood Community Centre (Peck 2002)
			In 2003, the City of Waterloo received a grant of $25,000 for a "Green Roofs Feasibility Study." As a condition of the grant, a green roof demonstration site was to be constructed on a city-owned building.
Cost-based constraints	Lack of information about associated costs (capital cost, maintenance, life cycle) and long-term economic benefits	Research	Developing models to predict cost and benefits related to green roofs. In Toronto, Ryerson University team has been charged by OCE-ETech to develop a generic technological solution to do so. (Banting 2005)
		Develop pilot projects	Generating reliable technical data on green roof performance in extension of roof membrane life span (Peck 2002)
		Developing resource of technical information and cost benefit analysis	Developing a common resource of technical information and guidelines for further research in benefit analysis. In Toronto GRHC coordinated this kind of research (Peck 2002)
	Long-term maintenance cost are unknown	Research	Conducting green roofs feasibility study to identify a city-wide green roof implementation plan for municipally owned buildings, including identification of potential costs and associated maintenance (Banting 2005)
	Lack of public investment	Partnerships	Development of Public Private Partnerships for the execution of projects

Constraints	Problems & Concerns	Possible Solutions	Action Plan
Technical issues and risk associated with uncertainty	Lack of specialized products on the market	Encourage the market	Creating institutions such as "Green Roofs for Healthy Cities" (GRHC) a public-private consortium is willing to establish a market for green roof infrastructure in North America (Peck 2002)
	Lack of accessible prices for specialized products		
	Lack of knowledge about adequate vegetation to use	Develop pilot projects	Generating reliable technical data about plant survival in the specific climatic context (Peck 2002)
		Develop relevant rules, regulations and standards	Involvement of the municipalities rooted on the main Environmental Policies (Banting 2005)
			Supporting green roofs through Environment policies within the City's Official Plan (Banting 2005)
			Developing ASTM standards (Banting 2005)

Source: the constraints and possible solutions in this table are borrowed from Peck 2002 and Banting 2005

This initiative first started as a study group in 1998 by professionals of landscape architecture leaded by Prof. ByoungE Yang of Graduate School of Environmental Studies, Seoul National University accompanied by government officers, researchers, and private developers.

In the period of 1998-2003 a series of seminars and symposiums were organized by the aforementioned study group, but it was until the end of this period that the Korea Green Roof Association was established with Prof. Yang as the founder. On the other hand Seoul city government started a green roof policy in 2002 with many benefits for the users of this feature in their buildings.

During the period of 2002-2010 a total of 202,449 m^2 of green roofs were built on 446 buildings encouraged by the subsidy program promoted by the city of Seoul (Tong 2011).

7.2.2 The subsidy program in Seoul, South Korea

The main tool of the establishment of a new technology is a subsidy program for the ones willing to implement it, in order to encourage its usage even though it implies risks. In the case of the city of Seoul, the Seoul City Government implemented a subsidy program to empower the adoption of GRT. To be benefited from this programs different variables play out, such as location of the project, type of project, type of green roof, allocated area. A brief summary of the program is described in table 4.

7.2.3 GRT Policy Implementation in Seoul

The information regarding implementation of Green Roof Technology in the city of Seoul was taken from the founder of this movement Prof. ByoungE Yang during an interview last November 15th 2012.

I first started the talk with Prof. Yang by mentioning the constraints that Canada faced before and while implementing GRT there, immediately after, he mentioned the similarity between the case of Seoul and Canada regarding the constraints himself and his colleagues faced when trying to convince the stakeholders about it.

Table 4. Summary of Seoul City Government Subsidy program for Green Roofs

Features of the program	Description
Eligibility for green roof subsidy	According to the budget limit that the Seoul City Government has, application for Green Roof Subsidies Program has to be submitted, public and private buildings qualify if they have more than 99m2 of greenery on the rooftop.
Building type	Priorities are given to buildings with • More easily accessed by numerous and varied visitors • Roofs should play a environmental educational role for the general public • Mostly for welfare purposes • Such elements to positively impact environment, increase environmental awareness and enhance community amenities • Fundamental in the urban ecological networks to promote biodiversity in the area • Dedicated to healthcare institutions such as hospitals, kindergarten and children's daycare center • Another variety in which the rooftop has been greened and is planning to use it intensively
Subsidies	• Up to 50% of costs for those private owned buildings centralized in the inner area of the city, checking the design including the structure and construction. • Up to 70% of costs for those private owned buildings observable in the foreground • 100% of costs for those buildings owned by the city government • Eligibility covers other public buildings once the owner is willing to incur in 30% or more of the costs.
Subsidies to different type of green roofs (2011) (1 KRW = 0.00086 USD)	• Up to 90,000 KRW/m^2 for extensive green roofs • Up to 108,000 KRW/m^2 for semi/intensive green roof • Buildings in central areas of the city are given special treatment such as increasing the upper limit of area, a raise in the support per unit area up to 126,000 KRW/m2 for extensive green roof, and up to 150,000 KRW/m2 for semi/intensive type green roof.
Achievements	• Over 200,000 m^2 have been constructed by the program up to 2010 • Increment in the annual budget was made in 2007

	• In 2011, the planned number of projects was109 and the projected area was 51,527m2 • Green Seoul Council voted five best sustainability policies of Seoul in 2009, and this program ranked the 2nd • Best Administration Award' was awarded to the Seoul City Government, the 1st Korea Green Roof Award in 2009 for the success of the green roof subsidy program.
Improvements required	• 50% of construction cost is subsidized; the rest of the investment should be strictly audited so that the developer creates the proposed space and not one with lower quality due the lack of investment on its side.

Source: Tong 2011

He cited, as the first step, of the implementation, researching as well as advocating the information regarding benefits of green roof technology to "people and city government officials" which are main stakeholders in the process. This step was also identified in the case of Canada as Lack of knowledge.

After that, he said that provision of incentives from the government's side is very important since construction project costs are high. The absence of these conditions was called in the case of Canada as lack of incentives.

Another important fact is to encourage technology development. In this regard, private companies should develop green roof technologies like waterproof membrane, soil layer, planting material and all the kinds of materials needed for the proper functioning of the technology. The created technology should be cost effective since this is one of the main tools to succeed in the market.

The cost effectiveness issues are achieved when the market created is widened as the time goes by. In this process, private companies will be competing against each other resulting in gains for the consumers in terms of prices. This fact will reduce consumers' burden while implementing the technology, which is another constraint identified in the case of Canada: cost-based constraint.

There was one main identified constraint, belonging to the technical constraints, concerning all the developers willing to implement such technology, which is leaking problem. In this regard, during the evaluation of the project in the Seoul City Government check counter posing to a set of technical recommendations and among those they check if the project is considering green roof membrane.

7.2.4 Solutions to the constraints

a) Research and Seminars

In the early stage of the implementation of the technology, research was done were the gaps or lack of information existed. Thereafter the information was shared through seminars and symposiums. In this way they combated the lack of information and knowledge.

b) Centralizing information and creating institutions

The implemented knowledge sharing program (seminars and symposiums previously mentioned) was possible only because all the information available was gathered in the Korean Green Roof Association. This institution was created by the initiative of Prof. ByoungE Yang and the interest of researchers, private companies and experts in the area. After the creation of this association and long time working for the green roof technology enhancing, they became advisors for the Seoul city government, helping in the creation of policies, revising projects, suggesting improvements for current policies, advising.

c) Policies and incentives

A subsidy program was created promoting the utilization of this technology in existing buildings; on the other hand new buildings were required to do it by an ordinance promoted by the Seoul city government.

With the creation of the Korean Association of Green Roof more incentives were created for the companies working in the technology development. Each year, a company is awarded with the “best technology creation prize” which is a value added to the products companies are promoting in the market.

d) Landscape companies (turn-key companies)

There is no theory without practice. These companies play a very important role, since they are, at the end, the ones in charge of the execution of the projects. This are in other market called as turn-key companies.

e) Technology development

It is important to develop technology in the different layers that compose green roof: soil, waterproof membrane, vegetation, etc. This will encourage the market size and the options for the developers.

f) Standards formulation

Standards were created in order to warranty a minimum quality for the project. The existing regulations were reflected from German standards, but those are not required standards just at the level of recommendation.

VIII. DISCUSSION

This paper intended to discover the factors or constraints shaping stakeholders' perceptions toward GRT implementation. The usage of this technology has been widely studied around the world; as a result at least 25 papers were consulted, finding the most important studies and successful cases in countries like Canada, United Stated of America and Germany.

The main research question that I planned to answer was: what are the main constraints that shape stakeholders perceptions toward extensive green roof technology? Related questions, as follows: why are the stakeholders ambivalent about green roof technology implementation? What are stakeholders' concerns?

To answer these questions, I reviewed more than 25 published studies, most of them showing the benefits of green roof technology drawing from different kind of methodologies: survey, interviews, literature review, site analysis and measurements. On the other hand at least five papers I reviewed were investigating a similar topic.

The stated problem reflects the necessity of El Salvador to implement green practices and specifically GRT in order to tackle global warming. The implementation of it is nowadays emerging or spread already in other latitudes, but regardless the effort shown by other cities, in El Salvador the stakeholders' are still reluctant to implement it, even if there very few projects using it.

To mention some of the benefits, I divided them into two categories: a) for the buildings, integrating the usage of intensive or extensive green roofs and b) for the community where these buildings belong to. Some of the most cited benefits are: reduction in heating and cooling costs, increased life span, noise reduction, urban heat island reduction, mitigation of air pollution, job creation, storm water management and amenities enhancement.

Despite the significant benefits, one of the reasons of the reluctance to implement it may be the coexistence of some strong issues contrasting with the benefits that GRT carries out.

The theoretical background of my research is based on The Diffusion of Innovation of Everett Rogers first launched in 1962, here he describes the influence and importance of diffusion when an innovation is taking place, which is the moment that an individual perceives a certain project is new and exchange information about it. But the diffusion is integrated by four concepts: the innovation, communication, channels and members of a social system (Rogers 2003). If I was asked to choose the most important among them, I would say it is communication, since there cannot be spread of technology when there is no exchange of information among users or they don't reach mutual perceptions, and diffusion is part of this communication process.

Throughout the Innovation-Decision process an individual goes from acquiring the knowledge until the formation of the individual's opinion toward the technology. The Innovation-Decision process implies five stages (a) knowledge (b) persuasion (c) decision (d) implementation and (e) confirmation (Rogers 2003). These definitions are going to be retaken below.

On the other hand, according to the most important research papers I found there are five constraints shaping stakeholders perceptions: (a) lack of knowledge, (b) lack of incentives, (c) cost-based constraints (d) technical concerns and (e) lack of standards which were previously explained.

By looking at the theory and compare those both with the hypothesis and the case studies I can see the direct relationship between theoretical and practical cases in most of the stages (see figure 5 and 6). I can say that the theory considers the existence of certain condition (knowledge, regulation, incentives, etc.) and the hypothesis considers the absence of them, where the case studies confirm that there is the absence of mentioned conditions when starting the process of implementing the technology (see figure 6 and table 5).

The absence of the stages stated in the five stages of the Innovation-Decision Process proposed by Rogers (2003) lead to the constraints stated in the hypothesis, as it was initially the case in Canada; later on and after more than one decade working against those constraints they have implemented several measures that might help to overcome the identified constraints.

The same happened in Korea where the constraints existed before the Green Roof movement started to show results.

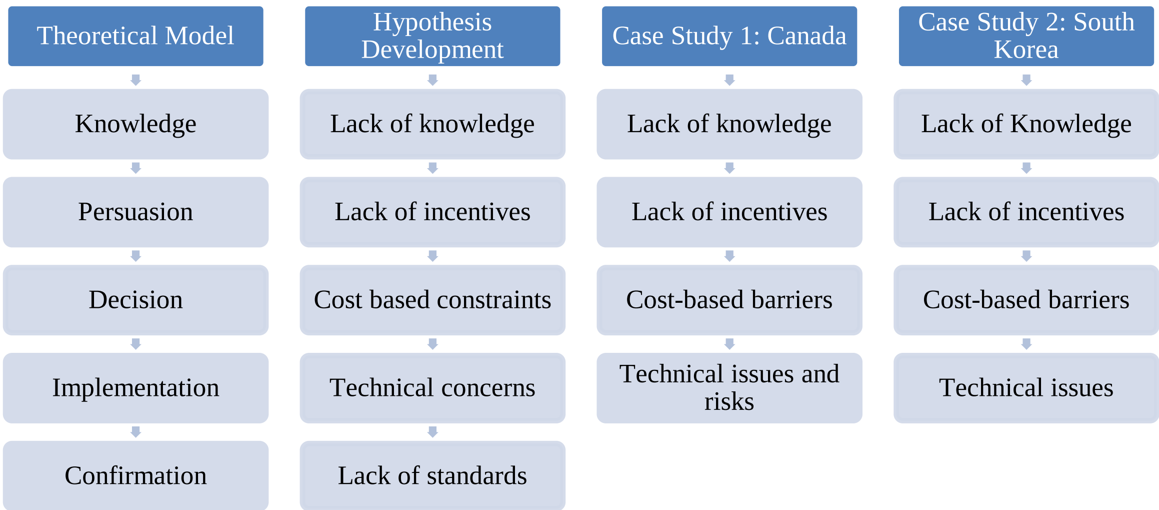


Figure 6. Summary of theory, hypothesis and case studies stages and constraints. Source: Rogers 2003 (Theoretical Model); House 2009, Tam et al 2011, Hodges 2011, Taheri 2007 and Siegler 2006 (Hypothesis Development); Peck and Callaghan 1999 (Case Study 1: Canada);Yang 2012 (Case Study 2: South Korea).

The possible ways to overcome the constraints in the case of Canada are: research, demonstration projects, turn-key companies, compilation of technical and cost benefit analysis information in a central place, promotion, incentives, policy implementation and standards development. The ones mentioned before basically correspond to the theoretical model stated by Rogers.

In the case of Korea there were certain actions taken by the main stakeholders which help to the successful implementation of green roof technology: research and seminars, centralizing information and creating institutions, policies and incentives, landscape companies, technology development and standards formulation.

A brief explanation of each of the outlined facts in figure 6 is given in table 5.

Table 5. Summary of theoretical model, hypothesis and case studies

Model Innovation-Decision Process	Hypothesis	Case Study 1: Canada	Case Study 2: South Korea
Knowledge	Lack of knowledge	Lack of knowledge	Lack of knowledge
Learn about existence of innovation and gain some understanding of how it function	inadequate distribution of currently available information	Reinforcement of stakeholders' knowledge about social, environmental and economic benefits	Creation of the Korean Green Roof Association gathering all the experts and researches
Persuasion	Lack of incentives	Lack of incentives	Lack of incentives
Refers to the attitude, either positive or negative, of and individual toward a certain innovation	Refusing the implementation of green roof technology due has a high initial cost and additional expenses	Strong legislation, demonstration projects and financial incentives are demanded from new developments	Creation of ordinance and subsidy program to encourage the developers to implement the technology
Decision	Cost-based constraints	Cost based barriers	Cost based barriers
engaging in activities that will end up in adoption or rejection	Common belief about high maintenance throughout the life span	costs appear to be much higher than the actual cost it carries and consequently the market doesn't succeed in the implementation of this technology	The encourage of the technology development will help to decrease the market price and make the technology cost-effective
Implementation	Technical Concerns	Technical issues and risks	Technical issues and risks
the usage of technology or innovation	Uncertainty is linked to hazards and technical concerns during construction phase	Lack of specialized products on the market , pilot projects and technical specifications for the components of the green roof technology	Leaking problem is the main concern among the ones willing to implement the technology
Confirmation	Lack of standards/ regulations and products		
ensuring the decision taken, in order to avoid reversion	need to develop standards and regulations to ensure quality and performance objectives during the implementation		

Source: Rogers 2003 (Model Innovation-Decision Process); House 2009, Tam et al 2011, Hodges 2011, Taheri 2007 and Siegler 2006 (Hypothesis); Peck and Callaghan 1999 (Case Study 1: Canada);Yang 2012 (Case Study 2: South Korea)

After revising the case studies, I found that besides the fact that the implementation of green roof technology is benefiting the community, which at the same time should be the main interest of local governments or/and central government, most of the times the technology implementation is encouraged by professionals, experts or/and researcher visioning all the benefits in the short and long term after the acceptation of the innovation by the main stakeholders.

But the goodwill of initiators of the movement, after some work, should be always accompanied by government decisions and above everything budget allocation for the provision of subsidies. It is recognized that cost of having traditional roofs vrs. green roofs, is different, and of course the second one is higher. The implementation of green roof can be expected by launching a policy, but with an incentive program as it was the case of South Korea.

Finally, regardless the fact that green technology was adopted in Canada and South Korea, at a certain point of time, thanks to the creation of incentives, supervision and improvements are continuously required. Beyond everyone’s desire, since the implementation strongly depends on incentives and budget allocation from the government, political issues are also affecting the process. If the present governor has other interests the incentives for the subsidy program may decrease, but if it is his target to convince the citizens then budget will be allocated undoubtedly so it depends on the politicians.

IX. CONCLUSIONS AND RECOMMENDATIONS

When I talk about the stakeholders I'm referring to different levels of involvement, and according to that level, is the influence or the impact they have in the field. The stakeholders are in general concerned about their investments vs. The long term benefits offered by the GRT.

The Stakeholders are the main actors in the field of Green Roof Technology (GRT), no decision can be made if they do not provide the supporting evidence, encourage the production or approval of the technology, respectively. Their interference goes from the first stage of the implementation of GRT which is knowledge provision, until the follow up and beyond, once the technology has been adopted.

After revising the innovation-decision process, I can first conclude that most of the achievements when implementing a new technology rely on the knowledge sharing stage. In this stage the benefits are promulgated in response to the disadvantages that some other detractors may expose as a result of illiteracy in the area. When the information resulting from researches, experiments, case studies is gathered in a central source and disclosed to private building owners, public officers, local governments, suppliers and other stakeholders, the likelihood of acquiring the technology is higher than when there is lack of knowledge about it. Different and effective channels should be used, such as symposiums, seminars, publications and institutions.

Regarding the likelihood to accept that the GRT is beneficial for each one of the stakeholders, which is what the theory calls persuasion, if I evaluate this stage in light of some of the constraints such as lack of knowledge, lack of incentives, cost- based constraints and technical concerns, I can say stakeholders will be persuaded only if they are totally convinced of the paybacks of the GRT through promotion, demonstration projects, pilot projects and incentive programs from the local governments and public-private partnerships.

The complete absence of constraints will increase the persuasion rate which at the same time will have a positive effect in the rate of adoption of GRT.

The aforementioned ways to overcome some of the constraints lies on knowledge, which I can infer from the case studies and previous studies, is the basic tool to dilute the doubts about the technology and for the stakeholders' to take the decision to adopt it. In the case of El Salvador, even if there are many existing researches, demonstrations, and companies around the world, the country's experts should build up their own knowledge and institutions in order to gather the information about local Green Roof Technology behavior and once it is collected and firmly established it can be shared and promulgated. If the information provided to the rest of stakeholders cast doubts, it will have serious repercussions on the implementation of GRT causing ambivalence and delay on the innovation-decision process.

Even when the GRT is implemented, there is always a chance for discontinuance of it; there is where the incentive programs and adequate policies appear to ensure the continuance and avoid reversion of the implementation.

A successful technology implementation in El Salvador will be accompanied a strong research program, a reinforcement of existing government institutions their officials, the creation of new and specialized institutions, a diversified knowledge program to spread the findings of the research, promotion of the technology in order to encourage the market and the suppliers, a rich incentive program.

As previously mentioned, a successful implementation of GRT need resources allocation, a provision of budget from the central government has been the key solution in both case studies, therefore the encouragement of environmental technologies it is highly recommended in order to tackle climate change and fade away the constraints dominating in El Salvador.

APPENDICES

APPENDICES

APPENDIX A

TRINITY GARDEN, SEOUL, SOUTH KOREA

Trinity Garden is green roof located in the 5th floor of Shinsegae Department Store in a the commercial district of Myeongdong in the city of Seoul in South Korea.

It was built in 2007, featuring a some of the finest artwork done by sculptors of modern times, such as Henry Moore and Joan Miro.

From the garden roof I could have nice views from Namsan Tower and some other famous buildings near the district.

Figure 7. Modern sculptures at Trinity Garden

Figure 8. Planting material at Trinity Garden

Figure 9. Protection for plant at Trinity Garden

Figure 10. Modern Sculptures at Trinity Garden

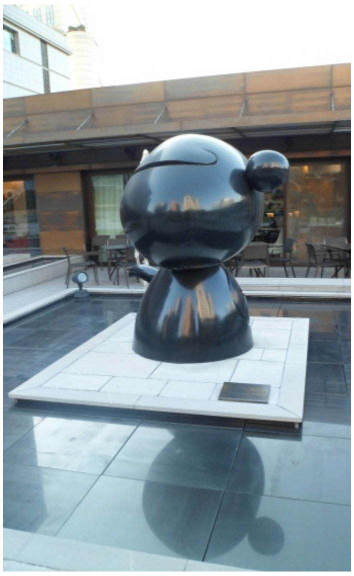


Figure 11. Views from Trinity Garden

APPENDIX 2

SKY PARK, SEOUL, SOUTH KOREA

The Sky Park is in the 11th floor of the Shinsegae Department Store, in the commercial district of Myeongdong in the city of Seoul in South Korea.

It is very well equipped and furnished as any other public space in Seoul, or even better. It has wooden floor, a beautiful fountain, benches, a curved pergola, and two terrace areas serving the indoor restaurants.

Regarding the vegetation it has different kind of shrubs but also tall trees.

Figure. 12 Visitors at the Sky Park

Figure 13. Fountain at the Sky Park

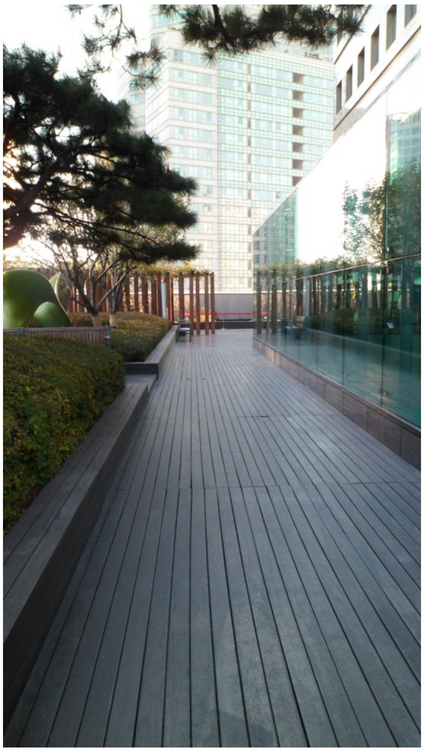
Figure 14. Shrubs and tress at the Sky Park areas

Figure 15. Pergola, benches and terrace

at

Figure 16. Sculptures Sky Park

Figure 17. Wooden paths at Sky Park



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