Understanding perceptions and adoption of green stormwater infrastructure

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Abstract

Building on existing theories of diffusion of innovation and technology acceptance, the object of this study is to investigate how municipal officials' perceptions of key attributes of green infrastructure influence their attitudes toward adoption. In addition, this dissertation provides useful insights into the relationship between the diversity of green infrastructure tools that local jurisdictions across the US support with policies or programs, and the factors influencing adoption.

A key feature of this study is a nationwide survey conducted among US city stormwater managers, planners and other public officials, whose responses were combined with secondary data and analyzed using multiple regression techniques. Findings indicate that municipal officials' perceptions of relative advantage, compatibility, trialability, and perceived resources are significant predictor of favorable disposition toward adoption, while perceived risk has a negative influence on attitudes. In addition, the level of environmental awareness and support has the greatest impact on the number of green infrastructure strategies jurisdictions have adopted. Based on the analysis in this study, proponents of green stormwater infrastructure will be better prepared to promote diffusion of these strategies at the local level.

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1. Introduction

Stormwater runoff poses a serious threat to water quality in urban settings, where the first downpour of a storm can wash a large amount of sediments, plant nutrients, bacteria, chemicals, and other pollutants accumulated from impervious surfaces directly into receiving waterways (Moglen and Kim 2007). Impervious surfaces profoundly impact natural drainage patterns and diminish the ability to infiltrate rain and snowmelt, thus reducing the aquifer recharge and dramatically increasing the amount of stormwater runoff (Shuster, Morrison, and Webb 2008). It is estimated that the amount of stormwater runoff from areas covered by impervious surfaces can be as much as 16 times as high as that from undisturbed natural lands (Gill et al. 2007, Schueler 1995). As urban development continues and impervious surfaces cover expands, watersheds' ability to maintain a natural water balance is gradually lost and natural drainage patterns altered with subsequent increase in volume of water runoff, resulting in severe stream bank erosion and habitat alteration (Thurston et al. 2003, Moglen and Kim 2007).

Climate change, in addition to the challenge caused by growing population and expanding urban development, has the potential to impose further stress on water quality and aging infrastructure in the US. Ashley et al. (2005) suggest that the impact of climate change on existing stormwater infrastructure is likely to be significant in the future. More frequent extreme rainfall events will have a particularly negative impact on urban areas, where significant portions of the sewer network combine sanitary and storm sewers. Severe rainfalls, affecting the inflow to wastewater and stormwater infrastructure, can overwhelm conveyance and treatment systems and cause flooding and combined sewer overflows (CSOs) (Thurston et al. 2003, USEPA 2004).

Faced with the challenges of protecting water resources, drinking water and public health with a rapid pace of population growth and urban sprawl, a growing number of US municipalities are turning to green infrastructure to manage stormwater runoff, particularly if the strategies result in multiple other benefits. In recent thinking, portfolios of "green" infrastructure and technologies have been identified as 'best practices' at the local level when combined with traditional "grey" infrastructure to achieve greater urban sustainability and resilience. Existing stormwater and wastewater infrastructure alone is unable to manage stormwater in a manner adequate to protect and improve water quality (USEPA 2004). Conventional stormwater management, relying heavily on engineering-based methods such as large retention ponds and large conveyance systems, can minimize large fluctuations in stream flows and mitigate flooding risk in urban areas, but they do not address the ecological requirements of maintaining adequate base flows and natural fluctuations in storm flows that are necessary for healthy aquatic ecosystems (Thurston et al. 2003, Roy et al. 2008). Green infrastructure, in contrast, aims at maintaining and restoring the hydrologic functions of storage, infiltration, and ground water recharge, as well as maintaining the volume and frequency of discharges using strategies such as integrated and distributed micro-scale stormwater retention areas, reduction of impervious surfaces, and lengthening of flow paths and runoff time (USEPA 2010). Green infrastructure approaches, combined with modifications to traditional infrastructures such as expansion of storm-sewers or storm-water storage tunnels, is now being recognized for its value as a means for adapting to the emerging and irreversible impacts of climate change (Foster, Lowe, and Winkelman 2011).

As defined by the US Environmental Protection Agency (USEPA), green infrastructure is an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services (USEPA 2014a). When used as components of a stormwater management system, green infrastructure practices such as green roofs, rain gardens, and vegetated swales can recharge groundwater, provide wildlife habitat, cool urbanized areas, improve air quality, beautify neighborhoods and reduce stress on combined sewer systems. In traditional stormwater management, water is typically moved off from a site as quickly as possible to a centralized facility. Green infrastructure, instead, treats rainfall as a resource as opposed to a waste product. Essentially, these strategies attempt to model nature and reinstate predevelopment hydrologic characteristics through infiltrating, storing, filtering, evaporating, and detaining runoff, thus leading to a better quality of water recharge for underground aquifer reserves (Hager 2003).

Green infrastructure is bringing stormwater management, traditionally conducted in a centralized system of underground sewers and water treatment plants, to the municipalities' streets, parks, public facilities, and private properties. Social factors and economic realities continue to place pressure on non-adopters, pushing forward a gradual shift towards a more sustainable urban drainage design in the US. Due to many barriers and impediments within the complex nature of stormwater management, however, the transition from traditional runoff control practices to system integrating green infrastructure design will require action on many fronts, including in social, economic, and political-legislative spheres. Yet, little if any scholarly work has investigated the adoption of green stormwater infrastructure strategies in municipalities across the US and the attitudes of local planners, engineers, and other local government staff members involved in making decisions about stormwater management. My dissertation addresses this gap in the scholarly and green infrastructure literature by analyzing data from a nationwide survey of municipal staff members. Results of this study both provide an empirical base for understanding and promoting adoption of green stormwater infrastructure practices and add to the spare literature on the diffusion of environmental management practices at the local level.

1.1. Significance of the study

To the best of my knowledge, this dissertation based on data from a nationwide survey is the first quantitative analysis of the determinants influencing the breadth of green infrastructure adoption by local governments, and of the factors influencing municipal officials' attitudes toward adoption. As such, it adds to the innovation diffusion literature by applying this theory to the domain of local governments and local governments' engineers, planners, managers and other staff members (from now on collectively called "officials"). It also contributes to the growing body of literature on green infrastructure by illuminating the characteristics that make a municipality more likely to adopt a diverse array of green infrastructure strategies to manage stormwater runoff.

The transition from traditional runoff control practices to systems integrating green infrastructure design will require action on many fronts. Change must occur in social, economic, and political-legislative spheres. State and federal agencies, such as the USEPA, are vigorously promoting the adoption of green infrastructure to manage stormwater runoff in a more sustainable way. However, these practices and strategies are still new to many local governments and, to promote them more effectively, we should know to what extent local governments in the US are actively engaged in green stormwater infrastructure implementation, what are the determinants influencing adoption, and what are the attitudes toward adoption of actors involved in making decisions about stormwater management. Little if any scholarly work has investigated the diffusion of green infrastructure planning at the local level and perceptions of planners, engineers, managers and other municipal staff members. While stormwater managers and other technical staff members would lack the authority to unilaterally adopt and implement green infrastructure, they do have the ability to educate citizens and political leaders about the value of green infrastructure in mitigating problems relating to urban stormwater runoff and could became stormwater champions and change catalysts. By exploring municipal officials' perceptions of green infrastructure, this study reveals those factors that could become inputs into a theoretical framework to understand attitudes toward adoption of these practices.

Based on the findings of this study, proponents of green infrastructure practices will be better prepared to address issues related to strategy formulation and policy development. Ultimately, this study should serve to accelerate the adoption of green infrastructure by assisting change agents in promoting implementation of these sustainable stormwater management practices at the local level. Thus, the results of this study will help organizations such as the USEPA to refine their education, recruitment and implementation strategies so that more municipalities can adopt green infrastructure policies in the future, and pave the way for future research on opportunities for municipalities to adopt these stormwater management tools.

Finally, the need to understand the diffusion of green infrastructure and the factors that influence their adoption can be grounded in research that shows them to be effective in addressing some of the current environmental issues facing communities nationwide. The significance of research aimed at understanding the diffusion and adoption of sustainable stormwater management systems is tied to the wide range of critical concerns driving the sustainable stormwater management movement, including the effects of global climate change and environmental deterioration. The problem of the study is to investigate how municipal officials perceive key attributes of green infrastructure and the factors influencing adoption. Ultimately, the answers to these questions will help us understand the process and factors driving environmental innovation adoption by local governments.

1.2. Research questions

My research aims at giving insight into sub-national adoption of green infrastructure in the US. Numerous authors have written extensively about the benefits, and the various ecosystem services that green infrastructure supports. In the past decade, climate change and water issues have emerged as key drivers to green infrastructure thinking. Strategic green infrastructure planning has been promoted as an innovative approach to managing wet weather within urban areas, and as a way of mitigating and controlling climatic change. The concept of green infrastructure and its value in managing urban landscapes are increasingly being recognized by planners and practitioners, but the transition to sustainable stormwater management systems integrating green infrastructure tools presents both challenges and opportunities. Stormwater management innovations are not unique in that they must overcome significant barriers to achieve widespread diffusion and full acceptance. However, they may hold the key to addressing many of the present ecological and social concerns facing US municipalities. The purpose of this study is to determine which factors influence the attitudes of municipal officials toward adoption of green stormwater infrastructure, and which determinants drive adoption by local government entities.

The specific research questions are as follows:

1) Is there a relationship between the following perceived attributes of innovations - relative advantage, compatibility, complexity, trialability, observability, perceived risk, and perceived resources as outlined by Rogers (2003), Moore and Benbasat (1991), Dupagne and Driscoll (2005) – and officials' positive attitudes toward adoption of green infrastructure?

2) What factors influence municipal officials' attitudes toward adopting green stormwater infrastructure?

3) What factors have a positive influence on adoption of green infrastructure planning at the local government level? Is adoption determined by internal characteristics (e.g., socio-economic status, political orientation)? Is adoption driven by external factors (e.g., federal stormwater regulations)?

By understanding the factors influencing attitudes toward green infrastructure adoption and those driving adoption by local governments, we will have better knowledge about how to approach the adoption process of green infrastructure and, more generally, environmental innovations. The findings of the study will benefit any potential localities considering adding green infrastructure tools to their menu of stormwater management strategies.

1.3. Research approach

A key feature of this dissertation is a nationwide survey of US municipal planners, engineers and other staff members, in which the respondents identifies the specific green infrastructure tools that their jurisdictions had adopted and shared their personal opinions and experiences with respect to green infrastructure planning. Secondary data were gathered on a number of economic, demographic, and environmental characteristics of the municipalities represented in the survey responses.

The methodology for this research project includes a review of the concepts underpinning green infrastructure planning and a brief introduction to the stormwater management regulatory environment in the US that helps put adoption of green infrastructure in context. This introductory overview is followed by a literature review section introducing relevant theories and findings from the diffusion of innovation and technology acceptance literature. This chapter focuses on prior findings regarding the factors influencing the adoption and implementation of innovations and attitudes toward innovation, and concludes with a brief explanation of how the relevant literature has helped to shape the research goals of this study.

A series of multiple regression analyses address the research questions and uncover the factors that influence officials' attitudes toward adoption, and estimate the impact of demographic, political-institutional, economic, and environmental variables on the extent of local government green infrastructure planning in the subject municipalities. Specifically, to address the first research question, I used a heteroskedastic ordinal logit model to investigate the applicability of Rogers' (expanded) theory of innovation diffusion as it relates to measuring the perceived attributes of green infrastructure. Then, to address the second research question, I developed a theoretical model grounded on technology acceptance, diffusion of innovation and organizational theories to identify factors that influence attitudes of local jurisdiction officials toward adoption of green infrastructure, and used structural equation modelling techniques to test the model. Finally, to address the third research question, I used a negative binomial regression model to test the influence of demographic, economic, environmental, and political predictors on the scale of adoption of green infrastructure as measured by the number of strategies supported by a policy, plan or program.

1.3.1. Survey instrument

The manuscripts within this dissertation use data from a nationwide survey of US municipal officials in which the respondents identified specific green infrastructure tools that their jurisdictions had adopted, and shared their personal opinions and experiences with green infrastructure. The survey comprised mostly Likert-scale rated items eliciting respondents' perceptions of green infrastructure attributes and attitudes towards adoption, in addition to close-ended questions regarding basic demographics and factual data about their community.

To better isolate a diffusible innovation and identify a population of survey recipients, I used the definition given by the USEPA, which describes green infrastructure as "*an adaptable term used to describe an array of products, technologies, and practices that use natural systems - or engineered systems that mimic natural processes - to enhance overall environmental quality and provide utility services. As a general principle, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff"* (USEPA 2014a).

The sample for this study included 840 employees (planners, engineers, and other staff members) of incorporated places (cities, towns and other municipalities) with population of 5,000 or higher in the US Census Bureau's 2010 population estimates. Choosing larger jurisdictions for the sampling frame has the advantages of bounding a population of interest and allowing more ready identification and targeting of a person with specialized expertise to answer the survey questions. To ensure that municipalities of different sizes were adequately represented in the survey, I grouped local jurisdictions into four groups by population size according to the 2010 US Census Bureau: 1) population of 25,000 or less; 2) population more than 25,000 or less than 75,000; 3) population of 75,000 or more, and less than 150,000; 4) population of 150,000 or more. The total sample size of 840 was then divided among the four strata using proportional allocation, which divides the total sample size among the strata in proportion to the strata sizes.

To identify potential survey participants, I searched municipality websites and acquired the identity, position title and email address for the appropriate contacts. If there was no obvious employees in charge of stormwater programs, or if their contact information was not provided online, I called the municipality to obtain a specific contact. While this approach is time consuming and labor intensive, it assures that the survey recipients are qualified to answer the survey's questions.

All participants received an invitation to an online questionnaire accessed through a Virginia Tech web page (Figure A-1 in Appendix A) which redirected respondents to a Qualtrics survey software website hosting the questionnaire. The online survey method was chosen because it ensures access to individuals in distant locations, it allows reaching difficult to contact participants, it can be completed at participant's leisure, and because of the convenience of having automated collection of extensive data, making data entry and cleaning more efficient.

The survey administration involved three points of contact:

1. Advance notice postcard and invitation letter mailed to recipients informing them about the upcoming survey email invitation explaining the research's objectives. Each letter also included the link to the survey webpage and a unique survey access code that allowed the survey responses to be sorted by municipality (see Appendix B);
2. First e-mail notification with cover letter and link to the survey with a private access code;
3. Second e-mail reminder with cover letter and link to the survey sent two weeks after first email.

A copy of the survey instrument is included in Appendix C. 300 respondents1 completed the survey, for a response rate of 35.7 percent. California is the most represented state (22 respondents), while the Midwest region (IL, IN, MI, MN, OH, WI) is the most represented area (44 respondents). The mean population of municipalities in the sample frame is 30,761, while the mean population of responding locales is 34,311.

1.4. Dissertation structure

This dissertation presents a multiple-paper format allowing for insertion of prospective publications rather than subsequent chapters as seen in a traditional layout. Therefore, it consists of individual research components that tie to each other but are prepared as distinct units. Even

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[1] Completing and submitting the survey was considered respondents' implied consent to participate into this research. I assured that their names, title and years of experience would not be revealed if they prefer to stay anonymous. Answers are confidential and will only be released as summaries in which no individual's answers could be identified, and the link between the identities of the respondents and their data was destroyed after data analysis. Appendix C includes the letter of approval from the Virginia Tech Institutional Review Board.

though the sections differ in scope and overall approach, they are designed to collectively offer a deeper understanding of the factors influencing green infrastructure diffusion and adoption.

The rest of the dissertation is organized as follows:

Chapter Two gives an overview of the stormwater management regulatory environment in the United States, creating a context for understanding the relevance of green infrastructure. It discusses persistent stormwater management problems and the policies and technologies, such as green infrastructure, developed to address them. In addition, the chapter highlights relevant concepts and benefits associated with green infrastructure implementation.

Chapter Three offers a review of diffusion of innovations and technology acceptance theories, which are extensively applied to investigate complex topics, such as ecological innovation, involving multiple factors and environments. Findings from previous studies have informed the selection of variables and research hypotheses for the manuscripts in this dissertation (Chapters Four, Five and Six). This section only offers a primer of the theory background, leaving more in-depth review of the relevant findings of previous diffusion studies to each manuscript.

Chapter Four investigates the applicability of Rogers' theory of innovation diffusion as it relates to measuring the perceived attributes of green infrastructure and to predicting municipal officials' attitudes toward adoption of these stormwater management strategies. As such, it contributes to the diffusion of innovation literature and identifies significant predictors and relationships that could provide new inputs for the development of services, plans and incentives designed to support diffusion of green infrastructure strategies among US municipalities.

Chapter Five develops and tests a theoretical model grounded on technology acceptance, diffusion of innovation and organizational theories to identify factors that influence attitudes of local jurisdiction officials toward adoption of green infrastructure for stormwater management. The contributions of this manuscript are two-fold. First, it assesses the applicability of a model combining elements of technology acceptance, diffusion of innovation and organizational theory to predict municipal officials' attitudes toward green infrastructure. Second, it uncovers relevant innovation attributes for explaining attitudes toward green stormwater infrastructure adoption.

Chapter Six investigates the impact of demographic, political-institutional, economic, and environmental variables on the extent of local green infrastructure planning in the subject municipalities. As such, this manuscript enhances the innovation diffusion literature by applying this theory to the domain of local government, and contributes to the growing body of literature on green infrastructure by illuminating the characteristics that make a municipality more likely to adopt these strategies for stormwater management.

Chapter Seven summarizes the study and discusses its limitations, theoretical contribution and practical implications for local governments and non-governmental advocates of green stormwater infrastructure.

2. Research background

To understand the diffusion of a technology or policy innovation, it is essential to consider the social, political, and cultural context in which it takes place. This section provides a brief introduction to the US stormwater management regulatory environment and to green infrastructure concepts and benefits.

2.1. Stormwater management in the US and emergence of green infrastructure

The diffusion of green infrastructure in the US is taking shape within the larger context of stormwater management practices, which are shifting toward more sustainable and ecological approaches. Planners and others practitioners are increasingly drawing upon the concepts of green infrastructure and its value in promoting better urban landscapes, land conservation, and urban regeneration. Green infrastructure is rapidly being elevated to well-known planning practices and effective adaptation strategies that help control the combined effect of urban development, population growth and climate change on stormwater runoff.

Stormwater runoff is a major environmental stressor in all landscapes and particularly in urban settings. During rain or snowfall events, water runoff from urban streets, parking lots and construction sites can carry oil, grease, sediment and other pollutants, either directly or indirectly through storm drains, into receiving water bodies. In addition to the problems caused by stormwater alone, many older cities have combined sewage and stormwater pipes which periodically, and in some cases frequently, overflow during intense precipitation events. Under rainfall conditions in which the flow in combined sewers exceeds the capacity of the pipe or treatment facility, a portion of the mix of wastewater and stormwater, including untreated runoff, sewage, and debris, is diverted directly to a nearby water body to prevent the flooding of homes and streets (Thurston et al. 2003).

CSOs have caused water bodies in the US to be overwhelmed with this mix of wastewater and stormwater since the end of the nineteenth century. Over time, it became evident that these sources of water pollution posed a serious threat to water quality. A wave of environmental policymaking activity in the US occurred in the 1970s and culminated with the adoption of the Clean Water Act (CWA) of 1972, formerly referred to as the Federal Water Pollution Control

Act (FWPCA), which regulates the basic discharges of pollutants into the waters of the United States and establishes quality standards for surface waters. The 1972 legislation created technology-based standards for point source discharges and declared as its objective the restoration and maintenance of the chemical, physical, and biological integrity of the nation's waters, establishing the goals of zero discharge of pollutants and attainment of water quality that is both "fishable" and "swimmable" (National Research Council 2008).

The CWA and the amendments that followed in 1977 and 1987 had a significant impact on how states, and by extension, the cities within those states, manage stormwater as it relates to surface water. Increased efforts were directed at diffuse, nonpoint sources of pollution[2] requiring industrial stormwater dischargers and municipal separate storm-sewer systems ("MS4") to obtain National Pollution Discharge Elimination System (NPDES) permits by specific deadlines and to develop stormwater management programs (SWMP), based on measurable goals and best management practices (BMPs). The Congress created a nonpoint source pollution demonstration grant program at USEPA to expand the research and development of nonpoint controls and management practices (National Research Council 2008).

Pursuant to the CWA, each state must develop Total Maximum Daily Loads (TMDLs)[3] for all the waters on the 303(d) list and characterized as fully supporting, impaired, or in some cases threatened for beneficial uses.[4] The USEPA published regulations in 1992 establishing TMDL procedures. It is at the discretion of states to set priorities for developing TMDLs, and timelines for the completion of TMDLs vary across the country. In approximately 20 states, the USEPA is under court orders and consent decrees to ensure TMDL completion with timelines range from five to fifteen years (USEPA 2014b).

The impetus for the NPDES Stormwater Program was a growing consensus that non-point source pollutants, particularly those contained in stormwater, are a continuing threat to the

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[2] Nonpoint source pollution refers to a source of pollution that issues from widely distributed or pervasive environmental elements. It generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification.

[3] A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. Pollutant sources are characterized as either point sources that receive a wasteload allocation (WLA), or nonpoint sources that receive a load allocation (LA) (USEPA 2014b).

[4] Beneficial uses supported by water bodies include aquatic life, fisheries, drinking water, recreation, industry, or agriculture.

nation's water quality.[5] Most of the USEPA's stormwater rules are implemented through permits under the NPDES (National Research Council 2008). In 1990, USEPA promulgated rules establishing Phase I of the NPDES stormwater program, which requires operators of "medium" and "large" MS4s to control polluted discharges. Phase I MS4s were automatically designated nationwide as medium MS4s if they were located in an incorporated place or county with a population between 100,000 and 249,999, or as large MS4s if located in an incorporated place or county with a population of 250,000 or greater. Each regulated MS4 is required to develop and implement a stormwater management program to reduce the contamination of stormwater runoff and prohibit illicit discharges.

The Stormwater Phase II Rule extends coverage of the NPDES stormwater program to certain "small" MS4s and was designed to accomplish pollution controls while conferring as much discretion as possible to covered municipalities. This program is an unfunded mandate, meaning that there is little funding support provided to municipalities to comply with the law, which could be a significant problem for small governments with limited staff and funding (Keeley 2007). Under this program, industrial, municipal, and other facilities must obtain permits every five years if they allow their discharges to go directly into any clean water sources. Although the specifics of the management plans are left to each municipality, Phase II requires MS4 to develop plans and adopt MBP's in six areas, called minimum control measures (MCMs): (1) public education and outreach; (2) public involvement; (3) illicit discharge detection and elimination; (4) construction site runoff control; (5) post-construction runoff control; and (6) municipal good housekeeping (USEPA 2000b). Municipalities must apply for a NPDES stormwater permit every five years. While National Pollutant Discharge Elimination System Phase II (Keeley 2007).

Increasingly, rather than relying only on conventional stormwater infrastructure, the USEPA and some states are emphasizing reduction in runoff volume in stormwater permits with the control of the natural water cycle and ecological systems through implementation of small-scale, environmentally sound technologies that involve natural or constructed biological systems for

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[5] Each point-based pollution source must have a NPDES permit that specifies which pollutants the source must control, sets numerical or narrative limits for those pollutants, establishes how often the source must monitor each pollutant, and in some cases limits the maximum allowable daily and/or average monthly emissions (National Research Council 2008).

stormwater treatment that effectively reduce imperviousness and facilitate infiltration (Niemczynowicz 1999). Several states are incorporating requirement to address flow and maintaining natural hydrologic conditions into regulations and MS4 permits. Over the years, the USEPA has expressed enthusiastic support for green infrastructure by publishing a series of documents to assist stakeholders interested in introducing green strategies in projects. Since 2007, USEPA's Office of Water has released four policy memos supporting the incorporation of green infrastructure into NPDES stormwater permits and CSO long-term control plans.

As USEPA states in its fact sheet "Incorporating Green Infrastructure Concepts into Total Maximum Daily Loads" (USEPA 2008), integrating green infrastructure into TMDLs can point the way toward implementation actions that can reduce stormwater runoff loads and erosive effects, and help meet pollutant loadings identified in the TMDL. The USEPA has developed a Municipal Handbook (USEPA, 2012), which contain a series of documents aimed at helping local officials implement green infrastructure in their communities. The documents cover specific terms to help municipalities introduce green infrastructure in the design of storm management facilities. One chapter identifies and discusses the most common funding options available to communities for funding green stormwater infrastructure, which include stormwater fees and loan programs (USEPA 2008).

In October 2011, USEPA's Office of Water (OW) and Office of Enforcement and Compliance Assurance (OECA) issued a joint memo encouraging USEPA Regions to assist their state and local partners in pursuing an integrated planning approach to Clean Water Act waste and stormwater obligations. The memo encourages USEPA Regions to assist their state and local partners in pursuing an integrated planning approach to Clean Water Act waste and stormwater obligations, and identifies green infrastructure as one example of a comprehensive solution that can improve water quality while supporting other quality of life attributes that enhance the vitality of communities.

The USEPA recently released a new national strategy for green infrastructure, along with a compilation of case studies that analyze the economic benefits and costs of green infrastructure and low impact development (LID[6]) programs (USEPA 2010). USEPA's new Green

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[6] The term LID is one of many used to describe the practices and techniques employed to provide advanced stormwater management; green infrastructure, conservation design, and sustainable stormwater management are other common terms these terms are often used interchangeably. However labeled, these practices seek to maintain

Infrastructure Strategic Agenda, published in October 2013, formalizes the agency's continued support for green infrastructure and outlines the actions planned to further the growth and success of using green infrastructure techniques to address water quality issues across the country (USEPA 2013).

When the upcoming USEPA's long-delayed rule to regulate stormwater runoff after construction is complete (national "post-construction" stormwater requirements), it will bolster USEPA's efforts to advance the use of green infrastructure techniques to control stormwater runoff. The agency is expected to issue its national stormwater proposed rule in early 2014. While the USEPA is evaluating new federal requirements for the use of green infrastructure, a number of states and municipalities across the country have been very proactive in encouraging and implementing green infrastructure.

2.2. Why green stormmwater infrastructure?

Green infrastructure has been the subject of lengthy discussion and action in the US and moved closer to the center of both public and intellectual discourse on stormwater management and sustainability (Benedict and McMahon 2006, Randolph 2011). Several communities, as part of their legal agreement with the USEPA or as best management practices, are investing in implementation of landscape-scale, environmentally sound technologies that involve natural or constructed biological systems for stormwater treatment. Sustainable stormwater management techniques, such as green infrastructure practices, are effective adaptation strategies that help control the combined effect of urban and population growth and climate change on stormwater runoff (Gill et al. 2007, Mell 2009, Oberts 2007, Wise et al. 2010).

As defined by the USEPA, green infrastructure is an array of products, technologies (including LID's), and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services. As a general principle, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff. When used as components of a stormwater management system, green infrastructure practices such as green roofs, rain gardens, and vegetated swales can

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and use vegetation and open space, optimize natural hydrologic processes to reduce stormwater volumes and discharge rates, and use multiple treatment mechanisms to remove a large range of pollutants (USEPA 2007a).

produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits (Clar 2001, USEPA 2010).

Green infrastructure in urban and peri-urban areas nourish ecosystem's health in multiple ways: through promoting biodiversity, maintaining the integrity of wildlife habitats and supporting ecological networks. Centralized management systems, such as large conveyance pipes and water treatment plants, can minimize large fluctuations in stream flows and mitigate flooding risk in urban environments. Conventional infrastructure alone, however, does not address the ecological requirements of maintaining adequate base flows and natural fluctuations in storm flows that are necessary for healthy aquatic ecosystems (Thurston et al. 2003).

Green infrastructure strategies for stormwater involves applying principles of landscape ecology to the urban built environment to model nature and reinstate predevelopment hydrologic characteristics through infiltrating, storing, filtering, evaporating, and detaining runoff, thus leading to a better quality of water recharge for underground aquifer reserve (Hager 2003, Niemczynowicz 1999, Ahern 2007). Other approaches comprise low-tech and cost-effective strategies including the preservation and protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands and highly permeable soils (USEPA 2000a, 2007b)

Among other benefits, this sustainable approach to stormwater management promote conservation and creation of landscape elements that support ecosystem services and have a positive impact on human well-being. Ecosystem services are benefits and goods provided by ecosystem functions, which are supported by underlying ecosystem processes and ecological structures (Costanza et al. 1997, de Groot, Wilson, and Boumans 2002, Farber et al. 2006). For example, drainage and natural irrigation is the benefit that human derive from the function of hydrological regulation, which depends on land cover for controlling runoff and discharge into water bodies (de Groot, Wilson, and Boumans 2002).

Several cities in the US are embarking on extensive infrastructure projects aimed at updating aging sewer infrastructure. However, the prospect of installing larger sewer conveyance pipes to address changes in precipitation patterns is an expensive and daunting undertaking, especially for those cities with older and failing infrastructure (Stoner 2006). Mixed strategies involving both traditional and green infrastructure represent innovative and promising approaches to meet CSO control policies. Construction of deep tunnels and reservoirs to detain stormwater runoff during extreme events could be complemented by implementation of decentralized, integrated and distributed micro-scale stormwater management practices. While traditional systems are designed to hold excesses of stormwater runoff until the treatment facility is able to treat and release it, thus addressing extreme events, strategically located green infrastructure elements restore soil hydrologic functions of storage, infiltration, and ground water recharge. This alleviates the rapid conveyance of polluted runoff towards sewers during smaller, frequent rainfall events. (USEPA 2007c, Hager 2003, Stoner 2006).

Green infrastructure strategies can reduce the quantity of runoff that reaches the combined sewer system by increasing the effective pervious area for storm water to soak into the ground. Carter and Fowler (2008), for example, have shown that strategically installed green roofs have the potential to reduce combined sewer volumes by more than 18 percent. Other strategies include intercepting storm-water before it reaches sewers and putting it into the ground instead. Installing rain gardens, permeable pavements, or bio-swales along roadways can improve filtration, replenish of groundwater supplies, and diminish overland stormwater flows (Stoner 2006). Green infrastructure practices are also found to be effective in reducing both stormwater peak flows and runoff volumes, both of which increase flooding and sedimentation risks. Volume control and water quality improvement are perhaps the most significant capabilities of green infrastructure practices (Jaffe et al. 2010).

Despite the recognized environmental, social and economic benefits of green infrastructure. However, local entities in the US face a number of institutional and procedural obstacles that limit the adoption of this approach to stormwater management. A 2011 report by the Clean Water America Alliance, based on a survey of more than 200 utilities, cities, government agencies, nonprofit organizations, and the private sector firms about barriers and opportunities for implementing green infrastructure, states that the lack of funding to support projects poses a barrier to diffusion of these practices. Other commonly cited obstacles are lack of understanding of the benefits green infrastructure, paucity of data demonstrating performance, and insufficient technical knowledge and experience (Lee and Yigitcanlar 2010, Abhold et al. 2011).

Local legal frameworks that guide development also may represent a significant barrier to green infrastructure implementation. Several communities, in fact, have development rules, such as subdivision codes, building codes, zoning regulations, parking and street standards and other local ordinances, that may prohibit implementation of green infrastructure (USEPA 2000a, 2010, Lee and Yigitcanlar 2010). At the same time, local codes often offer developers little or no incentive to conserve natural features. Adoption of green infrastructure practices may be hindered by land use ordinances and codes, or by roadway design guidelines and parking requirements of transportation departments (Stockwell 2009). Therefore, interdepartmental coordination among local authorities is critical for advancing broad adoption of green infrastructure. Great coordination and cooperation is needed, in fact, to review codes and processes so as to identify and remove conflicts between different policies and regulations (Stockwell 2009, Beisch et al. 2005, Benedict and McMahon 2006). Directors and managers should work in conjunction to promote partnerships between departments to promote GI approaches to the maximum extent feasible (Benedict and McMahon 2006).

In addition to collaboration across levels of government and interdepartmental coordination within local government, extensive collaboration between stormwater managers, urban planners, engineers, landscape architects, and city staff is key to advancing green infrastructure planning (Beisch et al. 2005, Earles et al. 2008)

2.3. Summary

Green infrastructure is increasingly recognized as a valuable approach to urban and regional landscape planning, and has been the subject of lengthy discussion and action in the US, moving closer to the center of both public and intellectual discourse on stormwater management and sustainability. Rather than relying only on conventional stormwater infrastructure, the USEPA and other public agencies recommends implementation of green infrastructure strategies as a means to achieve reduction in runoff volume in stormwater permits through control of the natural water cycle and ecological systems. Portfolios of green infrastructure policies and technologies have been identified, in combination with traditional grey infrastructure, as best practices to manage stormwater runoff at the local level while attaining greater urban sustainability and resilience. A prominent aspect of the political-legislative landscape of green infrastructure adoption is stormwater requirements enforcement. The USEPA has initiated a national rulemaking to establish performance standards to reduce stormwater discharges that will likely require implementation of green infrastructure tied to MS4 permits. In the meantime, a growing number of states and municipalities across the country have been very proactive in encouraging and implementing green infrastructure at all scales.

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3. Literature review

Several models and theories have been employed to investigate the factors that affect the adoption of innovations by individuals and organizations. These include diffusion of innovations theory (DOI), and the technology acceptance model (TAM). The following sections discuss these frameworks and studies based on these theories, identifying some key themes. The chapter concludes with an explanation of how the relevant literature has helped to shape the research goals of this dissertation.

3.1. Diffusion of innovation theory

Diffusion theories derive from the explanation of adoption of new technologies by farmers given by Everett Rogers in the 1950's. Since the first studies, research on diffusion of innovation theories has broadened its scope and associated empirical research (Daley and Garand 2005, Mooney and Lee 1999). Over time, the diffusion of innovation framework has been applied to a variety of disciplines such as anthropology (*e.g.*, the diffusion of cultural traditions among primitive tribes); medicine (*e.g.*, the contagion of a disease); education (*e.g.*, some 150 studies made at Columbia University under the direction of Paul Mort); rural sociology (*e.g.*, the diffusion of hybrid seed corn among farmers); medical sociology (*e.g.*, drug adoptions by physicians); industry (*e.g.*, the diffusion of a new product among consumers); and political science (*e.g.*, the diffusion of city manager governments in the US states) (Gray 1973, 1994, Daley and Garand 2005, Mooney and Lee 1999). Because the theory of diffusion of innovation has been applied and tested to a vast array of disciplines, this framework offers great generalizability of overall findings over time, and has emerged as one of the most multidisciplinary research topics in social sciences research today (Prescott 1995, Rogers 2003).

Diffusion is the process by which an innovation is communicated through channels over time among the members of a social system (Rogers 2003). This is the standard definition of diffusion in the field (Tornatzky, Fleischer, and Chakrabarti 1990). Although it has been applied to organizations, diffusion is a model of change that focuses on individual decision-making, (Ashley 2009). The four main elements in the diffusion of innovations are: (1) the innovation; (2) communication channels; (3) the social system or context; and (4) time.

3.1.1. Green infrastructure as an innovation

To understand the challenges associated with the diffusion of green infrastructure, it is first necessary to frame it as a type of innovation. An innovation is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption [regardless of actual newness] . . . as measured by the lapse of time since its first use or discovery" (Rogers, 2003, 12). Rogers points out that the term "new" can have many connotations. An innovation can be objectively new as measured in time from its discovery or first use. However, an innovation may be in existence for a long time before individuals gain knowledge of it, therefore, newness is a characteristic related to the perceptions of each individual. Zeldin, Camino and Mook (2005) also say an innovation may represent a scheme that challenges the status quo and requires significant change. In policy change, innovation should include the following three criteria: 1) originality and newness to the environment that it is being introduced to; 2) practical application and action; 3) significance and impact (Walker, 2006).

Green infrastructure system appears to meet these criteria as it is considered an innovative (and thus relatively risky) approach to stormwater control by most US cities that have traditionally relied on conventional stormwater infrastructure (Olorunkiya, Fassman, and Wilkinson 2012). Even though the engineering and ecological concepts underpinning green infrastructure systems are not entirely new (Mell 2008, Wright 2011, Benedict and McMahon 2006), green stormwater infrastructure is part of a paradigm shift in water management toward a more sustainable development and environmentally sensitive design (Spatari, Yu, and Montalto 2011, Roy et al. 2008).

The characteristics of the specific innovation as perceived by potential adopters influence the decision to adopt or reject an innovation. In general, if an innovation is perceived to exceed the benefits and costs of existing alternatives, the possibility to consider an innovation adoption will increase. Many researchers posit that innovation attributes are significant factors influencing innovation adoption, suggesting different types and number of innovation characteristics (Damanpour and Schneider 2008, Frambach 2002, Tornatzky, Fleischer, and Chakrabarti 1990, Walker 2006). Tornatzky and Klein (1982) authored a meta-analysis of studies investigating the association between innovation characteristics and adoption and found that compatibility, relative advantage, complexity, cost, communicability, divisibility, profitability, social approval, trialability, and observability are identified as ten most frequently addressed characteristics of innovation. Damanpour (2008), based on the review of 75 studies, posits that compatibility, relative advantage, and complexity are the most consistent significant factors to innovation adoption. However, the most prominent distinction of innovation characteristics is based on Rogers (2003) model. According to Rogers' model, the characteristics of innovation that are the most responsible for influencing adoption are:

1. Relative advantage, *i.e.* the perception that the innovation is better than the idea, product or process already in use by the potential adopter. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption is likely to be.

2. Compatibility, *i.e.* the degree to which an innovation is perceived as being consistent with the needs of the potential adopters. Adopters are looking for products they can incorporate into their systems without much effort and without having to change values.

3. Complexity*, i.e.* the degree to which potential adopters perceive the innovation as difficult to understand and use. If an innovation is easy to understand and use, the likelihood of adoption increases.

4. Triability, *i.e.* the degree to which an innovation can be experimented on a trial basis before wholly committing to adoption. Trialing an innovation provides information that reduces uncertainty about the relative advantage of the practice, and is important because it provides an opportunity for adopters to learn the skills needed to apply the innovation. In addition, the small-scale nature of a trial allows adopters to avoid the risk of large financial costs if the practice turns out to be not sustainable or fails due to inexperience.

5. Observability, *i.e.,* the visibility of results of the innovation in practice. If observers can readily see the results of an innovation, the likelihood of adoption increases (Rogers 2003). Higher observability means that fewer trials may be necessary to sufficiently reduce uncertainty associated with adoption.

These innovation attributes determine the rate of adoption. In summary, innovations that are perceived by individuals as having greater relative advantage, compatibility, trialability, observability, and less complexity will be adopted more rapidly than other innovations (Rogers 2003). Relative advantage, compatibility, and complexity have been reported in the adoption studies as the most influential predictors of adoption across multiple disciplines, while trialability and observability are found to be statistically less significant (Meuter et al. 2005, Rogers 2003,Yi et al. 2006).

3.1.2. Communication channels

In Rogers' diffusion model, the second element of diffusion of innovation is communication channels, the process by which individuals create and share information with one another. Drawing heavily on communications theory, diffusion of innovations highlights mass media channels and interpersonal networks as valuable types of communication channels. While mass media channels are more effective as a means of innovations knowledge circulation, interpersonal channels are more suitable for forming and changing attitudes toward a new idea (Rogers 2003). In the context of green infrastructure, *communication* may be distributed in different ways. Interpersonal communications between experts and the public, opinion leaders and stakeholders are as essential as mass communications in bringing about green infrastructure adoption. Information concerning the benefits of the usage of green infrastructure could be achieved through training courses, webinars, as well as distributed informational materials. Diffusion of innovation cannot be achieved unless others transfer knowledge and diffuse information about innovations to others (Liyanage, Elhag, and Ballal 2012). Knowledge and competence are key elements that influence adoption of green infrastructure.

3.1.3. Social system

The social system is the boundary within which the innovation is diffused -for example, organizations, neighborhoods, and states (Ashley 2009). The *norms* of a social system are the established patterns of behavior for the members of the system where the innovation is introduced. In the context of green infrastructure, structural barriers such as zoning codes, building ordinances and other regulations can constrain or drive green infrastructure innovations (Nowacek 2003). Environmental factors can apply pressures for organizations to adopt innovations or upgrade technology. The use of regulations creates an administrative innovation where the decision is made by those with authority, and takes away the optional innovation decision of the individual (Rogers 2003).

Another import aspect of the social system element of diffusion of innovation that can be used to help in the adoption is the use of opinion leadership to influence other individuals' attitudes towards adoption. Opinion leaders and change agents are often referred to as technology champions (Rogers 2003, Howell, Shea, and Higgins 2005, Thompson, Estabrooks, and Degner 2006). Champions deliver knowledge transfer at an interpersonal level that plays an important part in adoption (Koebel 2008). Green infrastructure champions could support diffusion of green infrastructure adoption by increasing recognition of this approach to stormwater management and by sharing experiences.

3.1.4. Time

Time is central to the diffusion process. Rogers (2003) defined the *rate of adoption* as "the relative speed with which an innovation is adopted by members of a social system" (Rogers 2003, 271). For instance, the number of individuals who adopted the innovation in a period of time represents one measure of the rate of adoption of the innovation. The perceived attributes of an innovation are significant predictors of the rate of adoption. Rogers reported that 49 to 87 percent of the variance in the rate of adoption of innovations is explained by the five innovation attributes previously described: relative advantage, compatibility, complexity, trialability and observability. In addition to these attributes, communication channels (mass media or interpersonal channels), social system (norms or network interconnectedness), and change agents may increase the predictability of the rate of adoption of innovations.

Rogers suggested that adopters of innovations fall into five general categories: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards (Rogers, 1995). Empirical investigation demonstrated that, for a variety of innovations, the frequency their adoption over time is normally distributed (Gray 1973, Rogers 1995). The cumulative distribution of adoption of innovations follows the "S"-shape of the cumulative normal curves-shaped curve, with few adopters in the beginning, many in the middle, and few at the end (Rogers 2003).

3.1.5. Adoption of innovation

Diffusion theory focuses on innovation adoption as a process. Rogers (2003) defines adoption as "a decision to make full use of an innovation as the best course of action available." The adoption process begins with an entity first becoming aware of the innovation, and ends with the final adoption.

Several scholars have advanced different frameworks to describe the innovation and adoption processes. However, one of the most recognized is the five-stage innovation-decision process model by Rogers (2003). Rogers (2003) described the innovation-decision process as "an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation" (Rogers 2003, 172). It holds that each individual passes through a five-stage process when deciding whether to adopt an innovation (Rogers 2003). The five stages include knowledge, persuasion, decision, implementation and confirmation. In the first stage, the individual or organization becomes aware of the existence of the innovation and gains some understanding of how it functions (Rogers 2003). By acquiring the knowledge base of the innovation, an entity is able to reduce uncertainty (which equates to risk) prior to the adoption decision. The importance of the information stage in the intent to adopt an innovation should not be overlooked. At the most basic level, individuals cannot choose to adopt an innovation if they do not know if its existence. Beyond the initial knowledge of an innovation, individuals or corporate actor learns may choose to pursue additional knowledge, which becomes the foundation for forming attitudes towards the innovation. Rogers refers to knowledge beyond awareness of an innovation as "how to" and "principles" knowledge (Rogers 2003). Individuals first seek to know how an innovation is used and may eventually wish to understand the underlying principles that allow the innovation to function.

In Rogers' (2003) second stage, potential adopters form attitudes, either favorable or unfavorable, about the innovation based on the knowledge they have gained. Individuals are persuaded (either positively or negatively) based on their experience and influences from their social system, and their knowledge of the innovation (Ashley 2009). Defining the attributes of innovations that shape a favorable attitude toward adoption and influence the decision to adopt has been the focus of much scholarly research. The most prominent distinction of innovation characteristics is based on Rogers' model and the five innovation attributes previously discussed.

The third stage of the adoption process is about making the decision to adopt or reject the innovation, while the fourth stage is implementation: the individual or organization puts the adopted innovation to use. The final stage is confirmation, where the individual or organization seeks to confirm the decision made, and may reverse the choice if exposed to conflicted messages about the innovation (Ashley 2009).

Diffusion of innovation studies proved that individuals and organizations follow a similar stage model in the innovation decision and implementation process (Rogers 2003, Zaltman 1973). Individuals and organizations also share essential characteristics that influence innovation adoption. For example, individuals with larger incomes tend to be more innovative than their counterparts with fewer resources. Similarly, larger organizations are usually more innovative because of the greater availability of economic resources and technically skilled staff (Martínez-Ros and Labeaga 2002). In addition, larger organizations may generally feel more need to adopt innovations in order to support or improve their activities and productivity (Frambach and Schillewaert 2002).

An important variable frequently investigated in organizational innovation research is the presence of an innovation champion. According to Rogers (2003, 414) an innovation champion "is a charismatic individual who throws his or her weight behind an innovation, thus overcoming indifference or resistance that the new idea may provoke in an organization". The importance of innovation champions should not be overlooked because of their critical role in both the innovation adoption and implementation of process. Other organizational characteristics that influence the innovation adoption process include economic, political, and social features that relate to the motivation to innovate and the strength of obstacles (Damanpour 1991).

According to Rogers (2003, 404) "an organization is a stable system of individuals who work together to achieve common goals through a hierarchy of ranks and a division of labor… they handle large-scale routine tasks through a pattern of regularized human relationship." Although somewhat less stable because of election cycles, the definition of organization applies to the general environment of local governments. Because green stormwater infrastructure adoption process takes place within an organizational setting, it is necessary to reflect on potential organizational influences. However, the focus of two manuscripts in this dissertation is municipal officials as individuals. Local jurisdiction staff members play a unique role in the adoption of new stromwater management practices. According to Zaltman et al. (1973, 13), “those factors influencing individual perceptions of innovation directly or indirectly influence the organization’s perception.” While they do not have the decisional power to unilaterally adopt an innovation, they serve as the resident technical expert in support of the decision making body. In this capacity, they can contribute greatly to the agenda setting stage in the innovation process. According to Walker (1977), “those who manage to shape the legislative agenda… are able to magnify their influence many times over by determining the focus of attention and energy.”

3.1.6. Determinants of innovation adoption

A large body of literature has emerged that seeks to understand and explain why governments adopt particular policies or programs (Berry and Berry 1990, Walker 1969, Mintrom and Vergari 1998, Haider-Markel 2001). Early work on the diffusion of policy innovations focused on developing innovation scores for states to establish their relative innovativeness (Walker 1969) and explaining variances in patterns of adoption such as the interaction between pairs of adopters and non-adopters (Gray 1974). Contemporary scholars have employed more elaborate models focusing on the various factors that predict or explain the probability or *likelihood* of adoption.

For a specific policy, the literature on the determinants of the policy diffusion process typically divides the process into internal factors and external factors (Gray 1994, Berry and Berry 1990,Berry and Berry 1999, Matisoff 2008). Internal determinants and external determinants models were first introduced in a 1969 article by Walker that looked at the adoption of innovative policies at the state level. Explanations based on the internal determinants model contend that state policymakers respond to internal characteristics s political, economic, and social characteristics of their state environments when crafting policy, while external factors capture the geographic interactions among states, external policy networks, and vertical influences from the federal government that influence policy innovation (Gray 1994, Fredriksson and Millimet 2002). While most of the early diffusion studies focuses on either approach, more recently, contemporary scholars have employed more elaborate models incorporating internal determinants and external effects (*e.g.* Berry and Berry 1990, Berry and Berry 1999, Chandler 2009, Daley 2007).

3.2. Attitude theories

The theoretical model for the study combines aspects of the technology acceptance model (TAM) with aspects of diffusion of innovation theory in complimentary manner. The innovation decision process involves the evaluation of an innovation by the individual and, based upon this evaluation, the formation of an attitude toward the innovation. The attitude literature provides a useful theoretical framework to understand and define the linkages between beliefs about adopting (and using) the innovation (*i.e.*, the innovation characteristics), attitudes, acceptance and the eventual adoption/rejection decision. Davis (1989b) advances one of the most influential models of acceptance, the TAM model, which specifies the causal relationships between innovation characteristics, user perceptions (compatibility, perceived usefulness and ease of implementation) and behavioral impacts. Overall, the TAM provides an informative representation of the mechanisms by which technology design choices influence user acceptance.

The TAM concept was developed by drawing on various elements of expectancy, self-efficacy, behavioral decision-making, and innovation diffusion theories. The model postulates that acceptance of a new technology or an innovative product is influenced by innovation-related characteristics of the product as perceived by individual consumers (the aforementioned “secondary attributes”), including *perceived usefulness* and *perceived ease of use*. The *attitude* formed based on these attributes influence consumers’ intentions to use the technology or product (Davis 1989b). Specifically, TAM posits that ease of use and the perceived usefulness of a new technology influence consumers' attitudes toward using the technology, which in turn directly influences intentions to use the technology (Davis 1989b). While Davis’ TAM model is conceptually different from the Rogers’ diffusion of innovation theory, they share some common features. For instance, *complexity* which is one of Rogers’ perceived characteristics of innovations is closely related to *perceived ease of use* in TAM (Davis, 1989), and *relative advantage* parallels *perceived usefulness* (Moore and Benbasat 1991).

Several studies have shown that the TAM has an acceptable predictive validity when measuring the usage of innovations such as new information and communication technologies (Venkatesh

2000, Chuan-Chuan Lin and Lu 2000, Moon and Kim 2001). The belief-attitudes-behavior assertion proposed by TAM and supported by the results of numerous research studies demonstrating users' perceptions and attitudes are important determinants of innovation implementation acceptance (Davis 1989b, Chau 1996).

With a significant body of literature lending support to TAM, the model has emerged as a powerful one with which practitioners can predict green infrastructure acceptance and usage behavior. When municipal officials foster publics' beliefs in ease of use and usefulness of green infrastructure, adoption and implementation are more likely to occur.

3.3. Conclusions

Diffusion of innovation is a widely adopted social theory that is very flexible and allows investigation of complex topics involving multiple factors and environments, such as environmental innovation policy and technologies. Existing research on innovation diffusion suggests many possible demographic, social, economic and environmental factors that could help explain the degree of green infrastructure planning adoption by US municipalities. The findings of those studies helped shape my dissertation's research questions and informed my work.

Rogers (2003) proposed that five attributes of innovations are highly effective in predicting rate of adoption and influencing perceptions of innovations. They include relative advantage, compatibility, complexity, observability, and trialability. The existing literature shows that the type of innovation influences which attributes are the best predictors of intent to adopt. Relative advantage, compatibility, and complexity typically rank as the strongest predictors. Observability and trialability can have statistically significant correlations, but usually play a lesser role in prediction equation modeling. Similar trends are seen across a wide range of innovation offerings, including sustainable innovations.

As with any innovation, there is no guarantee that green infrastructure will enjoy widespread diffusion and adoption. However, the available literature does provide insight for change agents and proponents of green infrastructure. Although the adoption process can be characterized as a collective innovation decision within an organization, scholars acknowledge the influence of individuals in forming organizational perceptions towards an innovation. An individual is persuaded (either positively or negatively) grounded on how they interpret what they have learned about the innovation according to their experience and influences from their social system. Because shaping a favorable or unfavorable disposition can affect adoption, it is important to understand the perceived characteristics of green infrastructure that shape local officials' attitudes toward adoption.

4. Measuring the perceived attributes of green stormwater infrastructure

Abstract

Using Likert scale data from a nationwide survey of 250 municipal officials, this paper investigates the applicability of Rogers' theory of innovation diffusion as it relates to measuring the perceived attributes of green infrastructure.

The diffusion of innovation model proved to be a useful framework to identify significant attitudes predictors. However, the results do not support theory in all areas, suggesting that green infrastructure differs from other innovations. The results of a heteroskedastic ordinal logit model indicate that the odds of a positive disposition toward adoption of green stormwater infrastructure are greater for younger professionals and higher perceived levels of resources, relative advantage, compatibility, and trialability, and reveal that complexity and observability are not significant predictors. In addition, officials who perceive a higher degree of risk associated with green stormwater infrastructure are less likely to have a positive perspective toward adoption.

Overall, this research contributes to the diffusion of innovations literature by investigating the suitability of Rogers' attributes to predict attitudes toward adoption of green infrastructure and by considering the contextual influences of perceived resources and risk. In addition, this paper identifies significant predictors and relationships that could provide new inputs for the development of services, plans and incentives designed to support diffusion of green infrastructure strategies among US municipalities.

4.1. Introduction

The combination of land development and anthropogenic pollutants presents a primary challenge for stormwater mitigation, with rainfall runoff in urban and suburban areas posing a serious threat to receiving waters' quality (National Research Council 2008). Under natural conditions, the amount of rain converted to direct runoff is less than 10 percent of the rainfall volume, with roughly 50 percent infiltrated and 40 percent returning into the air (USEPA 2003). The large infiltration volume depends on trees, vegetation, and open green space of undeveloped land that capture precipitation and snowmelt, allowing it to largely infiltrate where it falls. However, because of urban development and the increasing percentage of land covered with impervious surfaces, the land's ability to absorb rainwater has progressively diminished and natural drainage patterns altered (USEPA 2003, Foley et al. 2005). In recent years, the need for a more integrated and sustainable approach to stormwater management practice has become apparent (Niemczynowicz 1999, Hager 2003, Wise et al. 2010). Sustainable stormwater management techniques, such as green infrastructure practices, have emerged as effective adaptation strategies that can help control the combined effect of urban development and population growth on stromwater runoff (Mell 2009, Oberts 2007, Wise et al. 2010)

Green infrastructure refers to sustainable stormwater management practices that also provide other ecosystem services such as reduced greenhouse gas emissions or wildlife habitat. Examples of green infrastructure include grass and forest buffers and use of porous materials for paving, as well as protection of environmentally sensitive site features such as riparian buffers and wetlands, and implementation of small-scale practices like rain gardens and rain barrels (USEPA 2010). Green stormwater infrastructure design involves applying principles of landscape ecology to the urban built environment (Ahern 2007). Essentially, this sustainable approach to stromwater management attempts to model nature and reinstate predevelopment hydrologic characteristics through infiltrating, storing, filtering, evaporating, and detaining runoff, thus leading to a better quality of water recharge for underground aquifer reserve (Hager 2003, Niemczynowicz 1999).

Many US cities have adopted green stormwater solutions in an effort to meet water quality standards in regulatory programs and reduce runoff volume. Despite its evident benefits, however, green stormwater infrastructure implementation appears hindered by the existence of manifold barriers and adoption has not reached significant scale (Roy et al. 2008, Brown 2007, Abhold et al. 2011). Due to the relative novelty of green infrastructure, proponents struggle with counteracting negative attitude and resistance to change (Roy et al. 2008, Keeley et al. 2013, Sullivan et al. 2010).

Little research exists that focuses on understanding local government officials' perceptions and attitudes specifically related to green infrastructure. In an attempt to fill this gap, this study borrows principles from Rogers' (2003) diffusion of innovations theory to investigate green infrastructure attributes as perceived by engineers, planners, and other officials of local jurisdictions across the US.

Within the diffusion of innovation process literature, Roger's model links the formation of a favorable or unfavorable disposition toward an innovation to five characteristics of the innovation itself: (a) relative advantage, (b) compatibility, (c) trialability, (d) observability, and (e) complexity. I extend this model to include two additional factors associated with the receptiveness toward adoption of innovation: (f) perceived risk and (g) perceived resources, as advanced by Driscoll and Dupagne (2005), Ostlund (1974) and Lin (1998). While relative advantage, complexity, trialability, observability and complexity principally pertain to specific innovation characteristics (Rogers 2003), risk perceptions and perceived resources capture uncertainty originating from factors other than the innovation itself, such as those related to level of decision uncertainty and the size of negative consequences associated with adoption (Gao, Leichter, and Wei 2012). Subjective evaluations of risk are influenced by multiple factors such as individual's personal values, risk taking propensity, social context, belief and stake in the outcome (Beecher et al. 2005). The contextual effect of practical experience with green infrastructure on attitudes toward adoption was also investigated.

As education specialists, state, and federal agencies begin to encourage green stormwater infrastructure, it is useful to know how these practices are perceived by public entity individuals to devise effective assisting strategies. By investigating which perceived attributes of green infrastructure practices contribute to respondents' receptiveness toward adoption, this research will suggest a framework to design incentives and plans suited to promoting this sustainable approach to stormwater management, and pave the way for future research on opportunities to overcome attitudinal barriers to the adoption of these plans and policies.

The specific research question that this paper attempts to answer is:

- Is there a relationship between the following perceived attributes of innovations - relative advantage, compatibility, complexity, trialability, observability, perceived risk, and perceived resources as outlined by Rogers (2003), Moore and Benbasat (1991), Dupagne and Driscoll (2005) – and officials' positive attitude toward adoption of green infrastructure?

Through use of ordinal regression analysis, this research seeks to find which variables from the policy diffusion framework are the best predictors for the different levels (1= negative, 2= neutral, 3= positive) of attitude toward adoption.

The rest of the paper is organized as follows:

First, I provide a brief review of the relevant literature, delineating factors that can predict attitudes toward green infrastructure by drawing from theories of diffusion of innovation. In this section, I also develop hypotheses on the main effects of perceived attributes on attitudes.

Second, I detail my research design by discussing data collection, variable operationalization, and data-analysis procedures. After a discussion relating to the choice of appropriate econometric model, appropriate diagnostic tests are undertaken and their results discussed in this section.

Third, I present and discuss analysis results and their implications.

Finally, I discuss implication for policymaking and note several limitations of this study that suggest a need for future research. All statistical analyses in this paper were performed using Stata 13.1 statistical software.

4.2. Literature review and hypothesis development

This study draws upon theories of diffusion of innovation and organizational innovation. Diffusion of innovation—the process by which innovations spread across organizations and individuals—comprises a widely adopted, flexible social theory that allows investigation of complex topics involving multiple factors and settings, such as environmental technology innovation. Because this theory has been applied and tested in a variety of disciplines, it offers ample generalizability of overall findings over time (Prescott 1995).

The characteristics of the specific innovation and the availability of suitable policy models comprise key factors in determining successful diffusion. For numerous innovations, there is a consistent time lag, often of many years, from the time they become available to the time they are widely adopted (Rogers 2003). A wide variety of staged models describing the innovation adoption process exists, with the numbers of stages described being as high as ten (Nutley et al. 2002; Wolfe, 1994). In an effort to integrate the array of relevant variables into a coherent framework, Wejnert (2002) suggests that the factors that influence an entity's decision to adopt a particular innovation can be grouped according to whether they relate to: (1) the innovation itself; (2) the innovator; or (3) the environmental context in which the innovation occurs. The characteristics of the specific innovation and the availability of suitable policy models constitute important factors in determining successful diffusion. This research focuses on the first element- the innovation- which is described by Rogers (2003) as “an idea, practice, or project that is perceived as new by an individual or other unit of adoption.”

4.2.1. Green stormwater infrastructure as innovation

An innovation is often old ideas put together differently and perceived as new by the stakeholders, and may represent a scheme that challenges the status quo, often requiring significant change (Zeldin, Camino, and Mook 2005, Rogers 2003, Faber 2002). Green infrastructure systems appear to meet these criteria as they are considered a risky and innovative approach to stormwater control by most US cities that have been relying on conventional stormwater infrastructure for a century or more (Olorunkiya, Fassman, and Wilkinson 2012). Even though the engineering and ecological concepts underpinning green infrastructure systems are not entirely new (Mell 2008, Wright 2011, Benedict and McMahon 2006), green stormwater infrastructure is part of a paradigm shift in water management toward a more sustainable development and environmentally sensitive design (Spatari, Yu, and Montalto 2011, Roy et al. 2008).

Empirical studies on the diffusion of innovations have produced a wide array of theories regarding the nature of the diffusion process and the factors that increase the rate of adoption (Nutley, Davies, and Walter 2002). In addition to the characteristics of the adopters, much of the research focusing on the identification of variables affecting the likelihood of adoption has identified perceived characteristics of an innovation as significant factors (Rogers 2003, Koebel 2008, Nutley, Davies, and Walter 2002, Walker 2006, Damanpour and Schneider 2008, Frambach and Schillewaert 2002). According to Rogers’ (2003) five-stage adoption model, individuals form either a favorable or unfavorable image of an innovation during the second phase of the process and based on five perceived attributes of the innovation itself (see Figure 4-1).

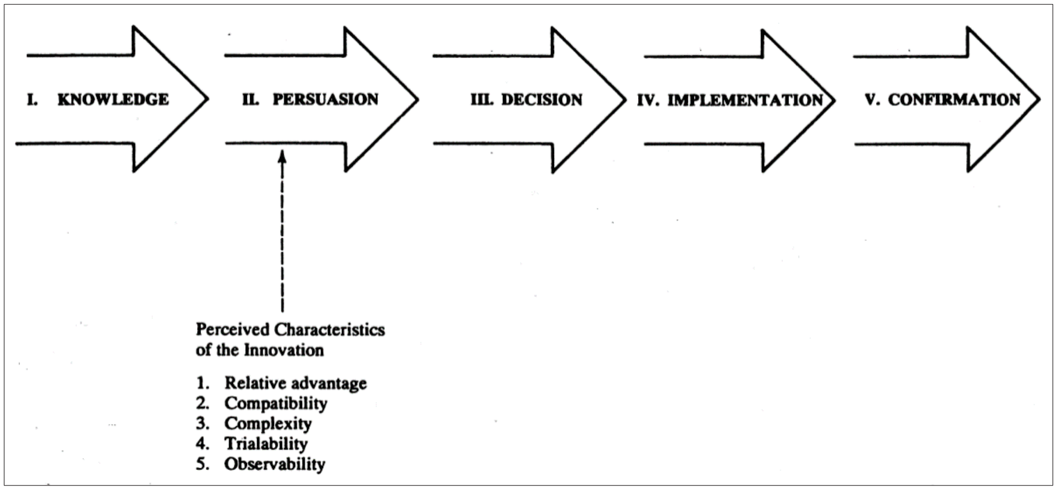

Figure 4-1. The five main steps and perceived innovation attributes in the innovation-decision process based of the work of Rogers (2003).

In the first stage, individuals gain knowledge of an innovation's existence and how it functions. Beyond the initial knowledge of an innovation, individuals may choose to seek out additional knowledge, which becomes the basis for forming an attitude towards the innovation (Rogers 2003). An individual is persuaded (either positively or negatively) grounded on how they interpret what they have learned about the innovation according to their experience and influences from their social system. Because shaping a favorable or unfavorable disposition can affect adoption, it is important to understand the perceived characteristics influencing the innovation-based attitudes.

In the context of green infrastructure, understanding the factors that influence attitudes toward adoption of local planners, engineers, and other public agency staff engaged in making decisions about stormwater codes and management is paramount to support successful diffusion of these strategies. Supporters of green infrastructure can become adoption champions and provide strong technical and/or political leadership to the adopting community pushing the adoption process forward (Kazmierczak and Carter 2010).

4.2.2. Countervailing effect of relative advantage, compatibility and complexity on attitudes

Generally, the rate of innovation adoption is found to be positively related to perceived relative advantage, compatibility, trialability, and observability, and negatively related to perceived complexity. Relative advantage, compatibility, and complexity have been reported in the adoption studies as the most influential predictors of adoption across multiple disciplines, while trialability and observability are found to be statistically less significant (Meuter et al. 2005, Rogers 2003,Yi et al. 2006).

Rogers (2003, 229) conceived *relative advantage* as "the degree to which an innovation is perceived as being better than the idea it supersedes", which is often expressed as economic profitability, social prestige, or other benefits. Thus, relative advantage is the perception that an innovation is improving upon the current situation (Weisburd and Lum 2005, Rogers 2003). This attribute of an innovation has been consistently found to be a reliable predictor of positive perception and adoption (Rogers 2003, Driscoll and Dupagne 2005, Meuter et al. 2005, Yi, Fiedler, and Park 2006).

In the context of stormwater management, systems integrating traditional and green infrastructure constitute an innovation that may offer additional environmental, aesthetic, and ecologic benefits when compared to traditional stormwater infrastructure (Keeley et al. 2013, Kloss 2008, Wise et al. 2010, Thurston et al. 2003). Centralized management systems, such as large conveyance pipes and water treatment plants, can minimize large fluctuations in stream flows and flooding risk to urban areas, but such traditional infrastructure alone does not address the ecological requirements of maintaining adequate base flows and natural fluctuations in storm flows that are necessary for healthy aquatic ecosystems (Thurston et al. 2003).

With traditional stormwater management approaches, water is typically moved off from a site as quickly as possible to a centralized facility. Green infrastructure, in contrast, attempts to model nature and reinstate predevelopment hydrologic characteristics through infiltrating, storing, filtering, evaporating, and detaining runoff, thus leading to a better quality of water recharge for underground aquifer reserve (Hager 2003, Niemczynowicz 1999). In addition, green infrastructure can reduce vulnerability to climate change, and offer effective adaptation and mitigation strategies to control the impact of urban growth on stormwater runoff (Gill et al. 2007, Mell 2009, Oberts 2007, Wise et al. 2010). Because of the environmental and aesthetic qualities and other benefits of green infrastructure systems, I expect relative advantage to be a reliable predictor of attitudes toward adoption.

For an innovation to be adopted, in addition to improving upon the current situation, the innovation must lend itself to the attitudes and beliefs of the population to which it is being introduced. This attribute is defined as *compatibility*, which Rogers (2003, 15) describes as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters." An idea that is more compatible with adopters' norms and values becomes less uncertain and is regarded as familiar (Rogers 2003). While green infrastructure techniques have been demonstrated to be very effective for new and urbanizing areas, some of the principles of green infrastructure approaches, specifically the source control approach and the use of micro-scale control techniques, can also be used to retrofit existing stormwater infrastructures in highly urbanized areas (Clar 2001).

This approach to stormwater management provides broad flexibility and applicability scope as it can be implemented in newly developed areas or used to retrofit existing stormwater facilities (Clar 2001, Gill et al. 2007). This type of decentralized structures also has more flexibility than traditional centralized systems, allowing for adjustments and experimentation over time (Roy et al. 2006, Roy et al. 2008). In addition, both homeowners and developers would benefit from beautification with managed landscapes and waterways. The beautification of natural surroundings through planning of green infrastructure elements, while promoting the quality of life, can additionally contribute to increase residential property values (Cho et al. 2009, Wise et al. 2010, Kong, Yin, and Nakagoshi 2007). Moreover, because of its flexible and multifunctional nature, green infrastructure may be implemented in a variety of urbanized and rural environments and design to meet specific socio-economic (*e.g.*, neighborhood revitalization) and environmental goals of individual communities.

Contrary to relative advantage and compatibility, *complexity* associated with an innovation is expected to delay the adoption process. Complexity, defined as "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers 2003), contrasts with ease of use, which describes the state of a particular system as being perceived to be relatively free from physical and mental effort (Davis 1989a). The easier to understand an innovation is, the more likely it will be perceived favorably, and adopted faster. Hester and Scott (2008), for example, found that absence of ease of use (proxy for complexity) had a negative impact on perceptions of Wiki technology and ultimately lead to decreased adoption and usage. If an innovation is too complex, individuals may form a negative perspective of it (Zaltman, R., and Holbek 1973).

Some of the specifics of stormwater green infrastructure facility construction to mimic natural hydrologic cycle and on site infiltration, especially under varying physical environments, can be challenging. Technical details of green stormwater infrastructure systems can be overwhelming, especially to those individuals or organizations with limited engineering expertise or experience, while uncertainty about design approaches and practices may diminish confidence and cause confusion in implementing green infrastructure (Abhold et al. 2011). However, unfamiliarity with green infrastructure technologies may be overcome through increased exposure to outreach efforts (Abhold et al. 2011, Hendricks and Calkins 2006).

These concepts from the diffusion of innovation literature as applied to the green infrastructure context suggest the following three hypotheses:

H1. The perceived relative advantage of stormwater systems integrating both traditional and green infrastructure has a significant positive influence on respondents' attitudes toward adoption.

H2. The perception of compatibility of green infrastructure has a significant positive influence on attitudes toward green infrastructure.

H3. The perception of green infrastructure being complex has a negative influence on respondents' attitudes toward adoption.

4.2.3. Direct effect of trialability and observability

Trialability is defined as "the degree to which an innovation may be experimented with on a limited basis" (Rogers 2003). A trial is a way for a potential user to experiment with an innovation before fully committing to adoption. This is particularly important for early adopters as they have little prior examples of use to decrease levels of uncertainty (Rogers 2003), whereas increased adopter experience will decrease the importance of trialability. According to Murphy (2005), the more easily the innovation can be tried, the more easily it will be adopted. If small projects can be tested before larger projects are undertaken, the adoption rate of an innovation increases, so the ease with which green infrastructure can be tested through pilot projects without making a commitment to full-scale adoption should have a positive impact on attitudes.

The decentralized nature of green stormwater infrastructure practices offers great flexibility, allowing for testing and adjustments over time (Roy et al. 2008, Roy et al. 2006). While some green infrastructure tools, such as green roofs, may not be easy to implement on a trial fashion because they require a substantial level of financial commitment (Calkins 2005), other strategies, such as rain gardens and bioswales, do not require huge effort and financial investment early on and can be installed in backyards, or city parks as pilot projects without full-scale and long-term commitment.

The likelihood of adoption of an innovation increases if results can be readily seen and communicated to others by the potential adopters (Driscoll and Dupagne 2005). Opportunities to observe a new technology first hand are important to potential adopters, allowing them to familiarize themselves with it prior to full scale adoption. They may see drawbacks and benefits to an innovation during this early exposure, thus decreasing uncertainty about it (Greenhalgh et al. 2004, Rogers 2003). The degree to which the outcomes of green infrastructure projects can be seen by others (*observability* of the innovation) could help promote the continuation of this approach in later development and adoption by other communities. For example, outreach and demonstration projects, such as the ASLA green roof in Washington DC, which allows professionals and general public to view green stormwater techniques first hand and acquire technical information are beginning to gain ground across the US (Weinstein 2010).

Based on the above considerations, I hypothesize that:

H4. The perception of trialability of green infrastructure will have a significant positive influence on attitudes toward adoption.

H5. The perception of observability of green infrastructure has a significant positive influence on attitudes toward adoption.

4.2.4. Effect of perceived risk and perceived resources

In addition to the five innovation characteristics advanced by Rogers' theory, this study investigates perceived risk and perceived resources as significant factors influencing attitudes toward adoption of green infrastructure. Perceived risk refers to the degree of outcome uncertainty associated with the innovation as perceived by the prospective adopters (Driscoll and Dupagne 2005). Risk perception is regarded as a factor that influences the attitudes and adoption of several innovations such as new high-tech products (Yiu, Grant, and Edgar 2007, Rogers 2003, Gao, Leichter, and Wei 2012, Sarin and Chanvarasuth 2003).

Rogers (2003) discusses uncertainty, a dimension of risk, as relative to the newness of an innovation where limited prior knowledge causes potential adopters to lack understanding about predictability, structure, and information regarding the adoption outcomes. Potential adopters of innovations face difficulty in determining whether the innovation will reliably function and will be financially viable after implementation. Risk poses a concern for all innovative practices including green infrastructure. Due to the novelty of this approach, multiple layers of risk influence receptiveness to adoption of green infrastructure (Roy et al. 2008). While many green infrastructure practices have been well studied and implemented under a variety of soil and climatic environments, many planners and engineers remain skeptical on the results from different regions with similar climate and soil conditions. Lack of adequate data related to the performance in various settings (*performance uncertainty*) has been constantly reported as a barrier to adoption in the green infrastructure literature (Abhold et al. 2011, USEPA 2007c, Roy et al. 2008, Brown 2005).

Resource security allows adopters to be more confident and able to deal with uncertainty and risk associated with innovations (Rogers 2003, Savage 1985). Potential adopters' perceived level of resources is found to be positively related to the rate of adoption or innovativeness (Driscoll and Dupagne 2005, Lin 1998). A better understanding of perceived resources construct within the innovation adoption framework may help practitioners to formulate strategies for improving attitudes toward innovation adoption. Perceived resources refer to the self-perceived availability of financial and technical capability to support the innovation (Lin 1998, Dupagne and Driscoll 2010, Driscoll and Dupagne 2005), with the emphasis of the construct on the availability of resources to potential adopter when considering adoption of an innovation.

Within the green stormwater infrastructure realm, some decision makers think that more cost analyses are needed to provide convincing evidence of the viability of this approach (Roy et al. 2008). Professionals belonging to smaller and less affluent jurisdictions may think their community does not have the capability nor the financial resources to implement green infrastructure. Perceived high cost of short and long term maintenance, in addition to lack or poor coordination of available funding, are often identified as factor negatively affecting attitudes and adoption of green infrastructure in the related literature (Wise et al. 2010, Abhold et al. 2011, Thurston 2011, Stockwell 2009). I expect the degree of respondents' perceived resources to be positively correlated to their attitudes toward adoption.

H6. Risk perception associated with adoption of green infrastructure has a significant negative influence on attitudes toward adoption.

H7. Perceived resources are positively correlated to attitudes toward adoption of green infrastructure.

4.3. Methodology and data presentation

4.3.1. Survey and sample

The data collection instrument is a survey designed to measure the key constructs of interest. To ensure the content validity of the constructs, I developed the questionnaire based on existing scales and instruments of diffusion of innovation theory, most of which are broadly adopted in related studies. In particular, I used Likert scale questions to collect data regarding respondents' perceptions of relative advantage, compatibility, trialability, observability, complexity, risk, and resources associated with adoption of green infrastructure using items adapted from the work of Rogers (2003), Driscoll and Dupagne (2001), Moore and Benbasat (1991), Ostlund (1974), Lin (1998) and Huang and Hsieh (2012). Questions in the survey were modified to target green infrastructure adoption in the local government context with a special care on how the questions are phrased to avoid technical jargons, abbreviations and buzz words. The second part of the survey included close-ended questions regarding basic demographic information and factual data about the respondents' community.

I pre-tested the questionnaire with six professionals working in the planning, engineering and environmental field to confirm the clarity of the questions and validity of the instrument, and made modifications to the wording of some questions as a result. Both the pre-test and final survey was conducted online via Qualtrics survey software. The survey sample included 840 municipal officials who work for engineering, environmental, planning or similar offices of incorporated places (cities, towns and other municipalities) with population of 5,000 or higher in the US Census Bureau's 2010 population estimates. 300 respondents completed the survey, for a response rate of 35.7 percent.

The survey included a list of 12 green infrastructure strategies and asked respondents to identify which, if any, their municipality integrates into local codes or ordinances. The questions about green infrastructure adoption and attributes were worded differently for respondents who selected fewer than six strategies and those who selected six green infrastructure tools or more, to reflect the fact that the latter belong to jurisdictions that have implemented most of the green infrastructure strategies.[7] This paper focuses on 250 complete questionnaires returned by respondents belonging to jurisdictions that have not yet integrated the full array of green infrastructure tools into their codes or ordinances.

The plurality of respondents (89 percent) works in their jurisdiction's public works, engineering or planning department. The majority also have at least 15 years of experience in their role (147 respondents, or 58.8 percent, while 47 (18.8 percent) have 10 to 15 years, 43 (17.2 percent) have five to nine years of experience, and the reminder 13 (5.2 percent) have less than five years of working experience. One of the survey questions asked officials to rate their level of knowledge

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[7] For example, respondents who selected fewer than six green infrastructure strategies were asked to indicate whether they strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the statement: "Funding *would be* an issue should my organization decide to expand or retrofit existing stormwater infrastructure using Green Infrastructure"; while respondents who selected six or more strategies were asked to indicate whether they strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the statement: "Funding *was not* an issue when my organization decided to expand or retrofit existing stormwater infrastructure using Green Infrastructure."

on green infrastructure on a scale from zero to ten. 14.7 percent of participants reported having little or no knowledge (rated their knowledge 0-3), 39.8 percent rated their knowledge 4-6, while the remaining 45.5 percent reported being quite knowledgeable about green infrastructure (rated green infrastructure expertise 7-10).

The majority of respondents, 67 percent, indicated that adoption (or continuous use) of green stormwater infrastructure would be good or very good for their jurisdiction, while 54 percent say they actively support use of green infrastructure in their jurisdiction.

Appendix D reports more detailed survey sample demographic and factual information.

4.3.2. Measurement and constructs validation

All measures for the attribute constructs were drawn from previous studies in both marketing and innovation literatures but were adapted to the specific innovation of green stormater infrastructure. Questions were written using a five-point Likert scale ranging from "strongly disagree" to "strongly agree" and included at least three items for each attribute. The first step in the data analysis was to code the responses from one to five as follows: 1= "strongly disagree", 2 = "disagree", 3 = "neither disagree nor agree", 4 = "agree" and 5 = "strongly agree". Items that were negatively worded were reverse-coded prior to analysis.

To create the constructs for relative advantage, compatibility, complexity, trialability, observability, perceived risk and perceived resources, the related questions were summarized into a series of composite subindices. The objective of the subindices is to provide a summary measure for each attribute combining variables that are assumed to belong to one dimension. To do so, I first checked the statistical association between the variables, and then aggregated the variables with a weighting scheme. The subindices constructs and the number of items per construct are as follows: relative advantage (4); compatibility (3); complexity (5); trialability (3); observability (4); perceived risk (4) and four perceived resources (4).

I used Kendall Tau b as statistical measure of rank correlationto check the association between the ordinal variables. Kendall Tau b, a variant of Kendall tau that corrects for the ties that are frequent in the case of discrete data , provides a dependable reliability index, and an appropriate measure of rank correlation for ordinal data (Smith, Vannest, and Davis 2011). A significant positive value of Kendall tau b is a sign for a positive association between two variables. This is the case for all variables belonging to one of the seven subindices in this study.

I also checked construct validity, the degree to which the chosen set of statements scores reflects the construct that the instrument is intended to measure, for all sub-indices. Internal consistency tests estimate how consistently respondents performed across items within a construct in the scale. The most frequently reported measure of internal consistency reliability in social science is Cronbach's alpha coefficient,[8] which ranges from 0.00 (no consistency) to 1.00 (perfect consistency) (Iacobucci and Duhachek 2003, Burns 2005). The higher the score, the more reliable the generated scale is.[9] The target level of minimum reliability for this research was chosen as 0.70 to 0.80 (Moore and Benbasat 1991, Cook and Beckman 2006).

The Cronbach's alphas for the attributes compatibility, complexity, observability, perceived risk and perceived resources all exceed the acceptable level of 0.70, with relative advantage and perceived risk above 0.80.[10] The coefficient for the trialability construct falls a little short of the acceptable level of 0.60 ($\alpha = 0.57$) as suggested by Hair et al. (1998), and consistently below the target level of 0.70, indicating a lack of reliability. Nonetheless, I decided to retain the construct for the subsequent analysis because of its theoretical relevance. Table 4-1 presents the Cronbach's alphas of the subscales complete with the confidence interval and their individual items, as well as descriptive statistics of the index items (mode and frequency).

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[8] Coefficient alpha computed for categorical items such as Likert response data usually results in a negatively biased estimate of the theoretical reliability (Zumbo, Gadermann, and Zeisser 2007, Iacobucci and Duhachek 2003). Thus, Cronbach's alpha provides a conservative lower bound measure of reliability.

[9] Several scholars recommend different reliability coefficient thresholds. For example, Hair et al. (1998) posit that Cronbach's alpha values from 0.60 to 0.70 are deemed the lower limit of acceptability, while Nunnally and Bernstein (1994) argue that an alpha of more than 0.70 may be acceptable, 0.80 is the minimum thresholds for a satisfactory construct, and 0.90 for an adequate reliability coefficient that indicates the items are homogeneous and measuring the same constant.

[10] Items with inter-item correlations greater than 0.30 and smaller than 0.80, item-total correlations smaller than 0.25 and greater than 0.70, and the effects on alpha if the item were deleted were used to determine which items were candidates for deletion from the scale (Nunnally and Bernstein 1994).

Table 4-1. Cronbach's Alpha and descriptive statistics of grouped items by attribute

Constructs and scale items	Mode	Freq. of the mode	Cronbach's Alpha	95 percent conf. interval
Relative Advantage (RA)			*0.87*	*0.85-0.87*
RA1: I think traditional stormwater infrastructure is more reliable and delivers better results than integrated systems using traditional and Green infrastructure combined.	2	107		
RA2: Integration of traditional grey infrastructure with Green Infrastructure tools could help my jurisdiction to better manage stormwater runoff.	2	153		
RA3: Adoption of Green Infrastructure to complement traditional stormwater management systems would help reduce the amount of stormwater runoff in my jurisdiction.	4	149		
RA4: Adoption of Green Infrastructure complementing traditional stormwater management system in my jurisdiction would reduce runoff pollution.	4	157		
Compatibility (COMP)			*0.71*	*0.65-0.71*
COMP1: Green Infrastructure would be accepted in my community.	4	124		
COMP2: Green Infrastructure is compatible with my jurisdiction's environmental goals.	4	131		
COMP3: Green Infrastructure fits well with the way my jurisdiction tries to manage stormwater runoff.	3	99		
Complexity (CPXTY)			*0.79*	*0.75-0.79*
CPXTY1: I have a difficult time understanding how Green Infrastructure works.	2	154		
CPXTY2: Green Infrastructure tools are easy to learn and implement.	4	106		
CPXTY3: I feel intimidated by new technologies such as Green Infrastructure tools.	2	152		
CPXTY4: I easily learn how new technologies such as Green Infrastructure tools work.	4	156		
CPXTY5: The challenges of learning about Green Infrastructure design and implementation overwhelm me.	2	140		
Trialability (TRIA)			*0.57*	*0.50-0.57*
TRIA1: My jurisdiction could experiment with new Green Infrastructure techniques through small-scale pilot projects before full-scale adoption.	4	123		
TRIA2: Experimenting with pilot Green Infrastructure projects before full-scale adoption is very important.	4	103		
TRIA3: My jurisdiction's personnel has acquired the necessary technical knowledge and experience on Green Infrastructure by implementing tools on a trial basis.	4	107		

Constructs and scale items	**Mode**	**Freq. of the mode**	**Cronbach's Alpha**	**95 percent conf. interval**
Observability (OBS)			*0.79*	*0.75-0.79*
OBS1: It is apparent to me that Green Infrastructure reduces the public cost of stormwater management infrastructure and provides flood control.	4	112		
OBS2: I am aware that other jurisdictions have benefited from utilizing Green Infrastructure to manage stormwater runoff.	4	128		
OBS3: It is apparent to me that the aesthetic qualities of green infrastructure boost property values, enhanced recreation, and improved quality of life.	4	119		
OBS4: I see how Green infrastructure provides valuable wildlife habitat and restore ecosystems.	4	143		
Perceived Risk (PRK)			*0.81*	*0.78-0.81*
PRK1: I have not doubts adoption of Green Infrastructure would provide multiple benefits to my community.	4	118		
PRK2: Research has yet to prove all benefits of Green Infrastructure.	2	108		
PRK3: I am not convinced of the effectiveness of Green Infrastructure.	2	113		
PRK4: Green Infrastructure is an effective approach to stormwater management.	4	145		
Perceived Resources (PRSS)			*0.74*	*0.71-0.74*
PRSS1: Funding would be an issue should my organization decide to expand or retrofit existing stormwater infrastructure using Green Infrastructure.	2	119		
PRSS2: The cost of implementing Green Infrastructure is too high.	3	121		
PRSS3: If my jurisdiction were to expand or retrofit existing stormwater infrastructure using Green Infrastructure, funding would not be an issue.	4	135		
PRSS4: My jurisdiction has the resources to implement Green Infrastructure.	4	115		

Notes

Respondents were asked to choose from the following options: 1=strongly disagree, 2=disagree, 3=neither disagree nor agree, 4=agree, 5=strongly agree.

After checking the constructs validity, I used Principal Component Analysis (PCA) to extract the items factor loading and model the latent variables measured by the observed variables. PCA using correlation matrices (generally Pearson) is a widely used technique of dimensionality reduction that can be employed for scale construction of latent variables as it endogenously categorizes observed variables (items) into fewer latent dimensions (constructs). This method relies on the assumption of multivariate normal joint distributions of items and continuous nature of measurement of both latent and observed variables (Morata-Ramírez and Holgado-Tello 2013, Kirby and Finch 2010, Gnanadesikan 2011). This requirement, however, is violated a priori for Likert-scale response variables, such as those used in this study, which have ordinal properties (Flora, Finkel, and Foshee 2003). Therefore, based on the work of Kolenikov and Angels (2004, 2009), I employed polychoric PCA, which relies on polychoric[11] and polyserial[12] correlations. These are estimated with maximum likelihood, assuming that the observed, categorical items are proxies for underlying continuous normally distributed variables (Morata-Ramírez and Holgado-Tello 2013). Even if the assumption is violated, however, the polychoric correlation has been found to be fairly robust (Holgado–Tello et al. 2010).

I used the First Principal Component (FPC) as a proxy for the common information gauged by the variables included in the sub-indices, measuring each one of the perceived attributes related to green stormwater infrastructure. The first principal component is the weighted sum of the standardized original variables that captures as much of the variance in the data as possible. In this study, the proportion of explained variance by the first principal component is 76 percent for relative advantage, 69 percent for compatibility, 63 percent for complexity, 60 percent for trialability, 68 percent for observability, 71 percent for perceived risk, and 65 percent for perceived resources.

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[11] The polychoric correlation coefficient is a measure of association between two ordinal variables. It is based on the assumption that two latent bivariate normally distributed random variables generate couples of ordinal scores. Categories of the two ordinal variables correspond to intervals of the corresponding continuous variables. Thus, measuring the association between ordinal variables means estimating the product moment correlation between the underlying normal variables (Olsson 1979).

[12] The polyserial correlation measures the correlation between two continuous variables with a bivariate normal distribution, where one variable is observed directly, and the other is unobserved. Information about the unobserved variable is obtained through an observed ordinal variable that is derived from the unobserved variable by classifying its values into a finite set of discrete, ordered values (Olsson, Drasgow, and Dorans 1982).

4.3.3. Data analysis, model development and post-estimation

Through use of regression analysis, this study seeks to find which variables from the policy diffusion framework furnish the best predictors of municipal officials ‘attitudes toward adoption of green stormwater infrastructure. Thus, the dependent variable was the attitudes toward adoption of green infrastructure, measured by a question asking the respondents to rate adoption of green infrastructure on a five-point scale ranging from “extremely bad” to “extremely good” and coded from one to five. The dependent variable (ATTITUDE) was categorized into five ordered levels based on the responses from the attitudes elicitation question. The higher the value, the more positive is the respondent’s attitudes toward adoption of green infrastructure.[1]

The predictors included the composite sub-indexes of relative advantage (RA), compatibility (COMP), trialability (TRIA), observability (OBS), complexity (CPXTY), perceived risk (PRK) and perceived resources (PRSS) as previously calculated. I simultaneously controlled the regression for experience (EXP) and age (AGEGRP). EXP is a dichotomous variable coded as one if the respondent has hands-on experience working on green infrastructure projects as indicated in the survey response, and zero if not. AGEGRP is a categorical variable representing the respondents’ age group.[2]

The reason for including experience as a control variable is that practical experience with the green infrastructure projects could decrease levels of uncertainty associated with adoption. Previous studies of the diffusion of green infrastructure technologies have found that, because of the self-efficacy of professionals with practical experience, they are more inclined to favor and support diffusion and adoption of these innovations (Olorunkiya, Fassman, and Wilkinson 2012). Through the accumulation of experiential knowledge in a particular discipline or techniques, new practices become familiar as the way of thinking and doing becomes established. Professionals with hands-on experience may be in a better position to evaluate options, make better judgment,

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[1] Because the cell corresponding to “extremely bad” contains only three observations, to avoid model instability I further collapsed the categories of ATTITUDE into three levels by grouping together “extremely bad” and “bad” (coded 1) and “extremely good” and “good” (coded 3), with “neither bad nor good” coded as 2.

[2] AGEGRP is a categorical variable coded 1 to 5 (1= 34 years or younger, 2= 35 to 49, 3= 50 to 64, 4=65 years or older).

and reach decisions that reduces potential risk liabilities concerns when it comes to green infrastructure project implementation.

Similarly, AGEGRP controls for demographic characteristics of the respondents. Within the innovation adoption literature, several studies found that individuals' age would negatively affect innovation and change in organizational practice (Damanpour and Schneider 2006). Other researchers, however, argue that age would positively affect organizational innovation and change because more seasoned administrators have greater insight into the process of performance improvement (Kearney, Feldman, and Scavo 2000).

Before estimating any models using the data, I carried out a multicollinearity test among the explanatory variables (the composite sub-indexes described above). Some degree of incidental collinearity between predictor variables, meaning that variables may be collinear by chance, is often present in real world data (for example, when sample size is relatively low.) Potential multicollinearity problems between predictors were assessed by examining the variance inflation factor scores (VIF), which are the amount of the variability not explained by other independent variables (Hair et al. 2009), and the condition number.[3] The results of the tests suggested that that multicollinearity was not an issue. Table E-1 and Table E-2 in Appendix E report the results of the multicollinearity test and condition number, respectively.

Because the dependent variable is discrete in nature, thus violating classic OLS regression assumptions like normality, alternative approaches such as multinomial logit or probit models should be used to model the polychotomous outcomes (Kennedy 2008). The three levels of dependent variable, however, have a naturally logical order and range from lowest level 1 to highest level 3, which could be viewed as resulting from a continuous measure of attitudes toward adoption. In this case, using multinomial logit or probit would not be efficient because these methods do not account for the ordinal nature of the dependent variable (Kennedy 2008). Thus, I chose to use an ordered logit model, which estimates the cumulative probability of being in one category using maximum likelihood estimation.

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[3] VIF scores above five and a condition number greater than 20 are considered worrisome (Greene 1997, Kennedy 2008). All of the VIF values and condition numbers fell within acceptable limits (VIF's smaller than 4.00, corresponding to a tolerance of 0.25, and condition numbers smaller than 9).

The proportional-odds ordered logit model gives a single equation and a single odds ratio for each explanatory variable. The ordinal logistic model can be expressed as:

$$1) \qquad Pr(y_{\mathrm{i}} > j|\boldsymbol{X}) = g(\boldsymbol{X}_{\mathrm{i}}\beta') = \frac{\exp(\boldsymbol{X}_{\mathrm{i}}\boldsymbol{\beta}_{\mathrm{i}}-\phi_{\mathrm{j}})}{1+\exp(\boldsymbol{X}_{\mathrm{i}}\boldsymbol{\beta}_{\mathrm{i}}-\phi_{\mathrm{j}})}\ ,\ j = 1, \ldots, m-1$$

Where $\mathbf{X}_i$= (k x 1) is the vector of observed nonrandom explanatory variables; $\boldsymbol{\beta}$= (k x 1) is the vector of unknown parameters to be estimated; m is the number of categories of the ordinal dependent variable (ATTITUDE, which has three categories: 1= negative, 2= neutral and 3= positive). The parameters of the model $\boldsymbol{\beta}$ and the cut points (ϕ_1 and ϕ_2) are estimated by the method of maximum likelihood (Long and Freese 2005).

One of the assumptions underlying ordinal logistic regression is that the relationship between each pair of outcome groups is the same. In other words, ordinal logistic regression assumes that the coefficients that describe the relationship between, for example, the lowest versus all higher categories of the response variable are the same as those that describe the relationship between the next lowest category and all higher categories. This is called the proportional odds assumption or the parallel regression assumption (Tabachnick and Fidell 2007). Because the relationship between all pairs of groups is the same, there is only one set of coefficients. If this were not the case, a different set of coefficients in the model would be needed to describe the relationship between each pair of outcome groups. I used a post-estimation package to verify the appropriateness of the model. Appendix F reports details about the analysis and tests results.

Ordered logistic regression relies on the assumption that error variances are homoscedastic (Hair et al. 2009). When an ordinal regression model assumes that error variances are the same for all cases when they are not, the standard errors are wrong and the parameter estimates become biased and inconsistent (Williams 2010). Hence, accounting for potential heteroskedasticity is critical and is the central motivation for the heteroskedastic ordinal logit. The heteroskedastic ordinal logit model belongs to a larger class of models known as location-scale or heterogeneous choice models, which estimates the parameters using the maximum likelihood approach as the ordered logistic regression. Heteroskedastic ordered models assume that the error varies systematically across respondent groups and specify the determinants of heteroskedasticity to correct for it. This is accomplished by simultaneously estimating two equations: one for the determinants of the outcome, or choice, and another for the determinants of the residual variance.

The heteroskedastic ordered model can be written as (Williams 2006):

$$2) \qquad Pr(y_i > j|\boldsymbol{X}) = g(\boldsymbol{X}_i\boldsymbol{\beta}'/\sigma_i) = \frac{\exp(\frac{\mathbf{X_i\beta_i}}{\sigma_i} - \phi_j)}{1+\exp(\frac{\boldsymbol{X}_i\boldsymbol{\beta}_i}{\sigma_i} - \phi_j)} \quad , \; j = 1, \ldots, m-1$$

Where $\ln(\sigma_i) = \boldsymbol{Z}_i\,\theta'$, where $\boldsymbol{Z}_i$= vector of explanatory variables that affect the error variance (σ_i) $\boldsymbol{Z}$ could either be a subset of $\boldsymbol{X}$ or a set of new variables not included in $\boldsymbol{X}$**.** This dependence of the error variance on the covariates is therefore captured by a skedastic function $h(\sigma_i) = \exp(\boldsymbol{Z}_i\,\theta')$ that scales the error terms in the standard ordinal logit model (Williams 2010). The heteroskedastic ordinal logit model nests the standard ordinal logit model under the restriction $h = 1$. Hence, it is possible to compare the two models using a likelihood ratio test, and identify the sources of heterogeneity that are statistically significant.

To test for the presence of heteroskedasticity in the model, I ran a stepwise heterogeneous choice regression with the probability to enter the error variance equation set to 0.1 using the module OGLM (Williams 2006, 2010). In addition to the usual coefficient estimates for the explanatory variables, the results of the OGLM model include a second part that shows the variables affecting variances of the error term. The set of variables for the error variance equation identified by the stepwise selection method included observability (OBS) and perceived resources (PRSS), indicating that the two predictors are possible sources of heteroskedasticity in the model.

A likelihood ratio test comparing the heteroskedastic ordinal logit model run with the OGLM routine with the standard ordinal logit model confirms that the standard ordinal logit model can be rejected in favor of the heteroskedastic model (chi-squared=8.18; $p < 0.05$). The McFadden pseudo R-squared has also marginally improved from 0.35 to 0.38, indicating a slightly better fit.

4.4. Regression results

Overall, the heteroskedastic ordinal logit model's pseudo R squared of 0.38 indicates discrete predictive capacity for the model, while the chi-square statistic for the decrease of the log-likelihood shows the overall fit of the model is significant at the one percent level (predictors are not jointly equal to zero). Based on the outcomes of the ordinal regression analysis with significance level set at p=0.05 and p=0.01 (Greene 1997), hypotheses H1, H2, H4, H6 and H7 received support, while H3 and H5 were rejected. Table F-4 in Appendix F reports the output of the OGLM analysis.

The analysis reveals that five predictors and one control variable are statistically significant in explaining and predicting the probability of observations falling into a higher level category of the dependent variable (respondent has a positive attitude toward adoption). The positive significant coefficients mean that the likelihood of positive attitude toward adoption increases with higher perception of the relative advantage, compatibility, trialability and perceived resources. Similarly, the negative significant coefficients indicate that the likelihood of negative attitude toward adoption increase with increasing respondents perceived risk and age.

The parameter estimates for relative advantage and compatibility are significant and have the expected positive sign, providing support for H1 and H2; that is, respondents' attitudes are simultaneously positively influenced by their perception of green infrastructure's relative advantage and its compatibility with their values and existing stormwater practices. More specifically, the more green infrastructures is perceived as beneficial and advantageous, the more positive the respondents' attitude toward adoption is (H1). Similarly, positive attitude toward green infrastructure is enhanced by the perceived compatibility of these strategies with the needs and values of the respondents' community (H2).

This interpretation of the analysis outcomes can be confirmed by examining the odds ratios. Odds ratios of each of the independent variables show the proportional odds for a one-unit increase in their pertinent independent variable on the dependent variable given the other variables are held constant (Table 4-2). The odd ratio of relative advantage (RA) equal to 1.46 means that, with a one unit increase in municipal officials' perceptions of the benefits and advantages of stormwater systems integrating green infrastructure compared to conventional infrastructure, the odds of respondents falling into a higher category of ATTITUDE (*i.e.* positive attitude) versus the combined middle and low categories (negative and neutral attitude) are 1.46 times greater given all the other variables are held constant. Likewise, for a one-unit increase in perceived compatibility (COMP), with odd ratio equal to 1.44, the odds of survey respondents falling into a higher category of ATTITUDE versus the combined middle and low categories are 1.44 times greater given the all the other variables are held constant.

Table 4-2. Heteroskedastic ordinal logit model

Dependent variable=ATTITUDE
1= negative attitude 2=neutral attitude 3=positive attitude

	Odds Ratio	**Std. Err.**	**z**	**P>z**
Relative advantage (RA)*	1.461	0.264	2.09	0.036
Compatibility (COMP)*	1.438	0.236	2.21	0.027
Complexity (CPXTY)	0.827	0.105	-1.49	0.136
Trialability (TRIA)**	1.749	0.358	2.73	0.006
Observability (OBS)	1.451	0.332	1.63	0.103
Perceived risk (PRK)*	0.643	0.142	-2.00	0.046
Perceived resources (PRSS)*	1.305	0.145	2.39	0.017
Experience with GI (EXP)	1.395	0.485	0.96	0.338
Age group (AGEGRP)*	0.623	0.128	-2.30	0.021

N=250
** Significant at the 0.05 level*
***Significant at the 0.01 level*

As shown in the graphs in Figure 4-2 and Figure 4-4, the predicted probability increases for the highest category of ATTITUDE as RA and COMP increase, while the predicted probability of the lowest category decreases as RA and COMP increases. Thus, the more respondents think that green infrastructure retrofitting is strategic and advantageous and lend itself to the attitudes and beliefs of the population to which it is being introduced, the more positive is their attitude toward adoption of green infrastructure.

The coefficient for the predictor TRIA is positive and significant (at p<0.01) in the regression model, supporting hypothesis H4. The trialability predictor's odds ratio of 1.75 means that, with a one unit increase the variable TRIA, odds of municipal officials falling into a higher category of ATTITUDE are 1.75 times greater given the all the other variables are held constant. The predictive margins graphs (Figure 4-4) show that the predicted probability of being in the lowest category of ATTITUDE decreases as TRIA increases, if all other variables are held at their means, while the probability of the highest category of ATTITUDE increases as perceived trialability increases (Figure 4-2).

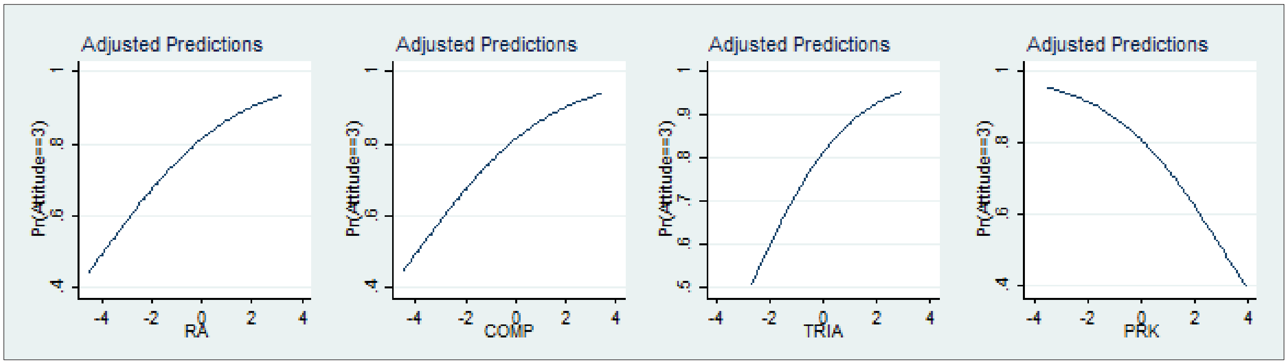

Figure 4-2. Predictive margins showing how probability of membership to the higher category of ATTITUDE (positive attitude) varies as one predictor changes while the other variables are held at their mean.

As expected and in accordance with the diffusion of innovation literature, the coefficient of perceived risk is significant (at p<0.05), meaning that respondents' perception of risk associated with green infrastructure adoption has a negative effect on attitudes, supporting H6. The odds ratio equal to 0.64 indicates that the odds of having a high value of ATTITUDE (positive attitudes) versus the combined middle and low categories are 0.64 times lower as PRK increases given the other variables are held constant (Table 4-2). Again, one can see this clearly in the graphs of the adjusted predictions in Figure 4-2, Figure 4-3 and Figure 4-4.

The predicted probability of respondents falling into a higher category of ATTITUDE decreases as the degree of perceived risk associated with green infrastructure adoption increases. At the same time, the predicted probability of respondents falling into the lower category of

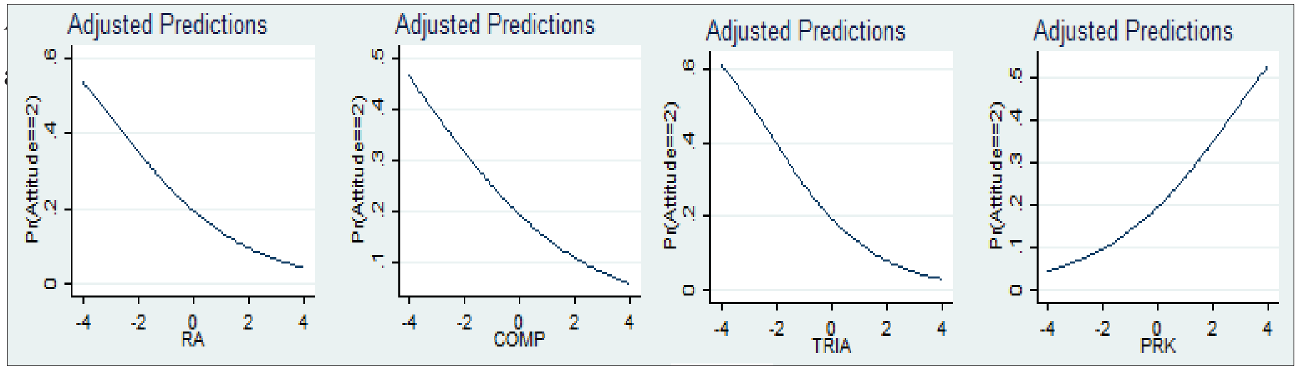

Figure 4-3. Predictive margins showing how probability of membership to the middle category of ATTITUDE (neutral attitude) varies as one predictor changes while the other variables are held at their mean.

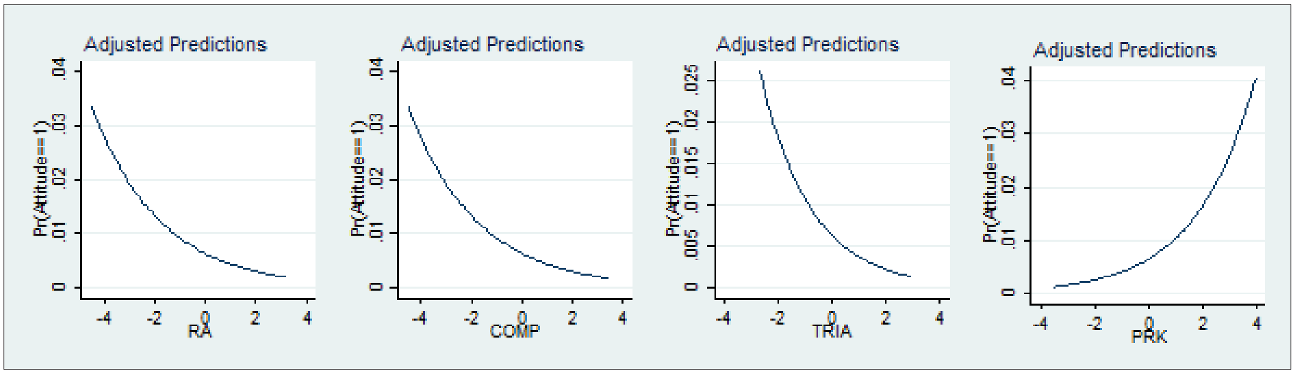

Figure 4-4. Predictive margins showing how probability of membership to the lower category of ATTITUDE (negative attitude) varies as one predictor changes while the other variables are held at their mean.

The coefficient of the perceived resources' predictor is positive and statistically significant at the 0.05 level, supporting H7. Each unit increase in the perceived resources (PRSS) predictor is associated with 30 percent (odds ratio= 1.3) increase in the odds of survey respondents falling into a higher category of ATTITUDE (*i.e.,* a positive attitude toward adoption) versus the combined middle and low categories while the all the other variables are held constant. The predicted probability of having a positive attitude toward adoption (*i.e.*, being in the highest category of ATTITUDE) grows as the perceived resources variable (PRSS) increases (Figure 4-5). When PRSS reaches a certain value, however, the predicted probability graph reaches a plateau and then declines slightly, meaning that any additional increment of perceived resources does not contribute to increasing the probability of the respondents' positive attitude toward adoption.

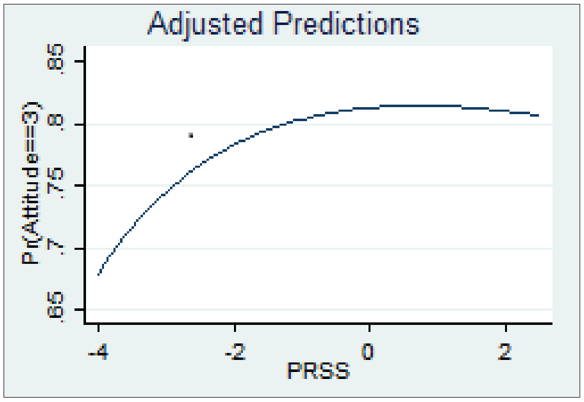

Figure 4-5. Probability of membership to the higher category of ATTITUDE (positive attitude) varies as the perceived resources variable changes while the other variables are held at their mean.

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The coefficient for the control variable AGEGRP is negative and significant at the 0.05 level. The odd ratio equal to 0.62 means that with a one unit increase in the age group, the odds of respondents falling into a higher category of ATTITUDE (positive) versus the combined middle and low categories (negative and neutral) are 0.62 times smaller given all the other variables are held constant. The adjusted predictions graphs (Figure 4-6) show that for respondents in the age groups 2 to 4 (35 years and older), the probability of being in the higher category of ATTITUDE decrease as age increases. The opposite is true, however, for age group increasing from one to two.

The regression results do not support hypotheses H3 and H5, as the coefficients of the predictors for complexity and observability are not significant. Finally, the coefficient of the predictor measuring practical experience with green infrastructure is not significant, meaning that we cannot reject the hypothesis that the variable does not influence respondents' attitudes toward adoption.

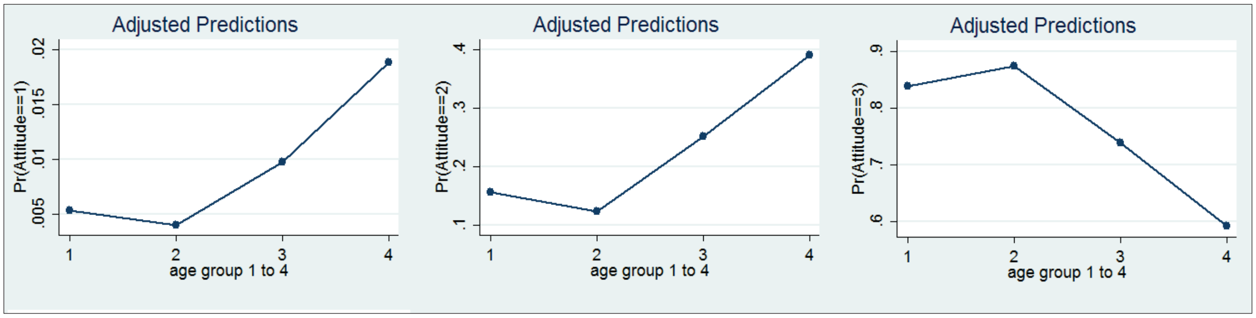

Figure 4-6. Probability of membership to the different categories of ATTITUDE (1=negative, 2=neutral, 3=positive) for ages groups 1 to 4, with other variables held at their mean.

4.5. Discussion

This research represents a contribution to the diffusion of innovation literature by exploring the applicability of Rogers' theory of innovation diffusion as it relates to measuring the perceived attributes of green infrastructure. In the context of green infrastructure studies, this study fills a theoretical gap by uncovering relevant factors that influence municipal officials' attitudes toward adoption using an empirical data set based on a nationwide survey across the US.

The analysis demonstrated several major findings relating to the appropriateness of using this resarch model to predict municipal officials' attitudes toward green infrastructure. Outcomes of this analysis uphold the general findings of the diffusion of innovation studies discussed in the previous section.

Perceived relative advantage and compatibility of green infrastructure with existing practices and values and of the respondents' community influence respondents' attitudes toward adoption of these stormwater management tools. Specifically, the more respondents think that green infrastructure retrofitting is strategic and advantageous and lends itself to the attitudes and beliefs of the population to which it is being introduced, the more positive is their attitude toward adoption.

These findings are accord with the diffusion of innovation scholarly literature that consistently reports relative advantage and compatibility as two of the most influential predictors of adoption across multiple disciplines (Meuter et al. 2005, Yi et al. 2006). Similarly, several studies on adoption of green infrastructure tools find that perceived benefits and compatibility with prospective adopters' community values strongly influence the adoption decision-making process, thus positively influencing attitudes toward adoption (Entrop and Dewulf 2011, White 2010, Calkins 2005, Johnson and White 2010).

Trialability emerged as another statistically significand predictor of attitudes toward adoption of green infrastructure. Individuals that have the chance to experiment with an innovation may serve as a vicarious experience of the innovation for others (such as neighboring jurisdictions) and may further influence their attitudes and decision-making process about the innovation (Rogers 2003). A system lack of trialability, on the contrary, may negatively affect attitudes of potential adopters and ultimately hinder adoption. The decentralized nature of green stormwater infrastructure and its flexibility allows for experimentation through demonstration projects without full scale commitment. Professional who design and implement green infrastructure as a pilot project the first time, could repeat the process the second time in a much easier way.

As expected and in accordance with the diffusion of innovation literature, respondents' perception of risk associated with green infrastructure adoption has a negative effect on attitudes. The perceived degree of uncertainty regarding cost effectiveness, hydrological performance and efficacy (Thurston 2011, Pincetl 2010, 2007, Abhold et al. 2011, Calkins 2005) measured by the risk construct serves to reduce the level of positive attitude toward green infrastructure adoption. This finding is consistent with green infrastructure studies that found how multiple layers of risk and risk aversion by professionals cause resistance to transitioning to alternative approaches to stormwater management (Roy et al. 2008, Brown 2005, Winz, Trowsdale, and Brierley 2013). Liability concerns, performance uncertainty, insufficient understanding of design and maintenance cost affect attitudes toward green infrastructure and ultimately hinder adoption (Abhold et al. 2011, Roy et al. 2008).

Financial concerns about long and short term green infrastructure cost or lack of funds and technical expertise have been consistently reported as barriers to adoption of green infrastructure in the literature (e.g. in Abhold et al. (2011), Wise et al. (2010)). Therefore, I expected the perception of technical and financial capability to be correlated to respondents' attitudes regarding green infrastructure adoption. Diffusion theory and research expectations regarding perceived resources were upheld by the analysis results, as I found a statistically significant positive association between perceived resources and attitudes toward adoption of green infrastructure.

The level of perceived resources has a direct positive impact on attitudes toward adopting green infrastructure as suggested by the fact that the predicted probability of having a positive attitude toward adoption grows as the perceived resources predictor increases (Figure 4-5). When the variable reaches a certain value, however, the predicted probability graph reaches a plateau and then declines slightly, and any additional increment of perceived resources does not contribute to increasing the probability of the respondents' positive attitude toward adoption. A possible explanation is that, beyond a certain level of perceived resources, financial and technichal capitals availability are not a concern, so this factor does not impact the shaping a favorable or unfavorable attitude toward adoption. For those respondents belonging to larger and more well-off jurisdictions with greater financial and professional capital security (higher reported PRSS), perception of resources availability does not influence their attitudes toward green infrastructure.

Several diffusion studies have examined the relationship between demographic characteristic, such as age, and innovation adoption in public administration (*e.g.*, Damanpour and Schneider (2008). As noted earlier, some scholars argue that individuals' age would negatively affect innovation and change in organizations (Damanpour and Schneider 2006). Others, however, suggest that because more experienced administrators have greater insight into the process of performance improvement, age would positively affect innovation and change (Kearney, Feldman, and Scavo 2000).

The analysis results show that respondents in the age groups 2 to 4 (35 years and older), the probability of having a strong positive attitude toward adoption decrease as age increases. The opposite is true, however, for age group increasing from 1 to 2. The output of the regression analysis may reflect the fact that long-tenured professionals who have been relying on conventional infrastructure to manage stormwater are not convinced of the efficacy of green infrastructure and are more reluctant to engage with and accept this different approach. By contrast, younger engineers and planners, who have been trained more recently and have a more current technical knowledge, may be more receptive to adopting new ideas and strategies for stormwater management, as innovation entails some risk and younger managers are more willing to take risk (Damanpour and Schneider 2006). In the realm of green infrastructure, resistance to change has been consistently reported as a barrier to adoption (Abhold et al. 2011, Coffman 2002).

Observability did not appear to be a statistical significant predictor. A possible explanation why observability has not emerged as a significant factor is lack of construct development (i.e. the survey questions were not clear or did not measure the target attribute), or because of the confusion with the trialability construct. Although trialability and observability are supposed to be theoretically distinct constructs (Rogers 2003), empirical studies found that they may overlap

(Driscoll and Dupagne 2005). A study by Hurt and Hibbard (1989), for example, found that observability did not differentiate from trialability. If a potential adopter of green infrastructure is able to experiment with pilot projects, results may be visible to others, so he can further serve as a vicarious trial for those who are able to observe the innovation. It is possible this concept creates confusion for respondents who may not have had direct experience with green infrastructure but still think green infrastructure can be experimented on a limited basis since others have done so. This blurs the distinction between the constructs that could perhaps be simplified by having observability factor as the overarching factor with a subcomponent being trialability when relevant to the study.

Complexity and experience also did not emerge as significant predictors of attitudes. This may a consequence of the study sample comprising mostly professionals working at engineering and planning offices who may have atypical skills and knowledge to understand green infrastructure concepts. Two-thirds of them (64 percent) have some level of experience working on green infrastructure projects either in their current or past job. Practical involvement in green infrastructure design and implementation may increase familiarity, which subsequently would enhance and facilitates understanding of the technical concepts. However, respondents with theoretical knowledge only may also perceive green stormwater management systems as technically straightforward because of their level of technology self-efficacy.

Overall, the analysis findings indicate that engineers, planners and other local jurisdiction officials who think that green stormwater infrastructure is advantageous, compatible with their community values, and can be implemented on a trial basis, and who believe their jurisdiction has the resources to implement this approach to stormwater management, are more likely to accept green infrastructure. The findings also show that older professionals and those who perceive green infrastructure as risky, are less likely to accept this stormwater management approach. Thus, these six independent variables are statistically significant discriminant factors that can categorize municipal officials' negative, neutral or positive attitudes toward adoption of green stormwater infrastructure.

4.6. Conclusions

This paper complements the many studies built off of Rogers (2003) original work and adds theoretical knowledge on the diffusion of innovation. While yielding some useful insights on the relationship between green infrastructure attributes and attitudes toward adoption, the design of this research has some limitations. The attributes' items are measured on a Likert scale, which may be subject to central tendency biases (respondents tend to avoid extremes), acquiescence response bias (respondents agree with statements as presented), or social desirability bias (respondents portray themselves or their group in a more favorable light). In addition, because of time, budget, and resources constrains, the chosen study sample size is relatively small, and may misrepresent the population. Further, only those who were willing to take part or had time to fill out the questionnaire were those included in this study. To the extent that respondents' propensity for participating in the study is correlated with the substantive topic of the study, there is self-selection bias in the resulting data.

This research showed that the expanded Rogers' diffusion of innovations model only partially explains municipal officials' attitudes toward green infrastructure. The practical implications of this research are based on the empirical findings that illustrate the ability for the perceived attributes of an innovation to indicate if local jurisdiction officials are willing to accept stormwater green infrastructure. Three attributes - relative advantage, compatibility, and trial ability- were found, together with perceived resources, perceived risk and age, to be statistically correlated with attitudes toward adoption of green stormwater infrastructure. In using outreach strategies to educate professionals about green stormwater practices it is important to understand the factors that might influence individuals' attitudes and decisions to adopt green infrastructure. For example, because advantages and efficacy of green infrastructure may not be readily visible and easily perceived by potential adopters, community and professional resistance to change can span long periods, and perceived risk associated with green infrastructure may hinder adoption. Social change and acceptance of stormwater innovations is an on-going challenge for all cities.

One of the most effective approaches to making professional comfortable with green infrastructure innovations could be a gradual introduction of these practices and encouraging local jurisdictions to reach out to one another as well as use the Internet and overseas examples as resources. Educators of green stormwater infrastructure as well as state or federal agencies and organizations looking to promote green infrastructure may find it helpful to research and provide a wide range of approaches and methods to overcome compatibility issues in an effort to encourage creative thinking for how green infrastructure can work in any location. While it is encouraging to note that 45 percent of officials had good knowledge of green infrastructure concepts, the fact that 15 percent reported little or no knowledge indicates that an opportunity exists to promote awareness and provide education to the municipal staff community. Based on the role that knowledge plays in forming attitudes towards and innovation (Rogers 2003), proponents of green infrastructure should not overlook the unique opportunity to shape a positive opinion towards these strategies. It is also important to consider the potential consequences for failing to engage officials who have yet to gain a working knowledge of green infrastructure. The more observations made available by adopters, the more knowledge, concepts and education local jurisdictions will have at their disposal to create their own set of practices and stormwater management system.

The focus of this study is the relationship between perceived green infrastructure characteristics and attitudes toward use of these strategies to manage stormwater runoff. Additional research is needed to address how other factors, such as organizational, environmental and personality traits affect individuals' perspectives toward green infrastructure. Intrinsic motivation, for example, has been emerging as a factor-influencing attitudes regarding adoption of innovation. Overall, the results of this investigation suggest that efforts to further refine the attribute scales for use in predicting receptiveness of green stormwater infrastructure are needed.

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5. Using TAM and diffusion theory to understand attitudes toward adoption of green infrastructure: a case study of US municipal officials

Abstract

The objective of this paper is to develop and test a theoretical model grounded on technology acceptance, diffusion of innovation and organizational theories to identify factors that influence attitudes of local jurisdiction officials toward adoption of green infrastructure for stormwater management. The hypotheses are tested using survey data on green infrastructure collected from 256 local governments engineer, planners and other municipal officials across the US. Findings of structural equation modeling analyses partially support a hypothesis regarding the link between innovation characteristics and attitudes toward adoption, revealing that perceived usefulness has a significant direct influence on attitudes. They also do confirm significant indirect effects of perceived compatibility, perceived internal readiness and perceived ease of use of green infrastructure on respondents' attitudes toward adoption. The contributions of this paper are two-fold. First, this study assesses the applicability of a model combining elements of technology acceptance, diffusion of innovation and organizational theory to predict municipal officials' attitudes toward green infrastructure. Second, it uncovers relevant innovation attributes for explaining attitudes toward green stormwater infrastructure adoption.

5.1. Introduction

Attitudes toward an innovation can facilitate or limit the adoption and implementation of new technologies (Damanpour 1991, Frambach and Schillewaert 2002). In fact, attitudes can be a precursor to the decision of whether to try a new practice and influence decision processes regarding innovation (Frambach and Schillewaert 2002, Rogers 2003). Thus, a deeper understanding of factors affecting local government officials' attitudes toward adoption of an innovation is important in considering how best to disseminate and implement these technologies.

The theoretical framework of this paper combines elements of the theory of technology acceptance (Davis 1989b) with aspects of diffusion of innovation theory (Rogers 2003) and organizational theory (Vasi 2006, Rogers 2003, Damanpour 1991) in a complementary manner to understand factors affecting attitudes toward green stormwater infrastructure adoption. The study focuses on the association between green infrastructure characteristics and attitudes of engineers, planners and other professionals working in the public sector, specifically in US local governments. This addresses two research needs. First, the study assesses the applicability of elements of the diffusion of innovation theory and technology acceptance model to predict attitudes toward green infrastructure adoption. Second, it investigate how perceived attributes and resources relate to personal respondents' attitudes.

The rest of the paper is structured as follows. I first develop direct and moderating hypotheses for the relationship between green infrastructure, the characteristics of officials and their jurisdictions, and attitudes toward adoption. Then, I test the hypotheses by analyzing the data obtained from a nationwide survey of engineers, planners, and other officials in local jurisdictions across the US. At the end, I propose an outcome from the models that increases understanding of the influential factors of attitudes toward green infrastructure.

5.2. Problem statement and theoretical background

5.2.1. Understanding attitudes toward green infrastructure

Green infrastructure planning is quickly gaining political momentum in both planning theory and planning policy-making in the US and abroad (Wise et al. 2010, Wright 2011, Struck et al. 2010). Several communities nationwide have sought to integrate green infrastructure into their control plans for combined sewer overflows, and many more are or will be facing similar strategic investment choices soon (Wise et al. 2010).

Even though the engineering and ecological concepts underpinning green infrastructure systems are not entirely new, the base principles have arisen over time from multiple disciplines (Mell 2008, Wright 2011, Benedict and McMahon 2006), and green infrastructure represents part of a novel, more environmentally sensitive approach to storm water management (Spatari, Yu, and Montalto 2011, Roy et al. 2008). Managing stormwater runoff with the aid of green infrastructure strategies requires a significant paradigm shift away from conventional methods toward a more sustainable site design in the planning phases (Dietz 2007, Spatari, Yu, and Montalto 2011). While traditional stormwater management systems are designed to mitigate runoff short-term problems by expediting the conveyance of stormwater off-site, green infrastructure systems aim at preserving the predevelopment hydrology of a site using multifunctional landscape features that encourage infiltration, evaporation and detention of urban runoff close to its source (Roy et al. 2008, Hager 2003, Niemczynowicz 1999).

Several communities nationwide have sought to integrate green infrastructure into their control plans for combined sewer overflows, and many more are or will consider similar strategic investment choices soon (Wise et al. 2010). However, despite the recognized environmental, social and economic benefits and the increasing interest in green infrastructure, most local entities face a number of social, institutional and procedural obstacles that limit the adoption of this type of initiative, and potential policy interventions to promote green infrastructure adoption remain not fully realized (Brown 2005, Brown and Farrelly 2009, Abhold et al. 2011).

Recent studies on green infrastructure identify negative attitudes toward adoption and resistance to change as common barrier that inhibits the transition to this sustainable systems (Abhold et al. 2011, Funkhouser 2007). As city staff members may prefer to use well-established engineering practices and tend to rely on systems that have been tested and used in past experiences rather than taking the risks of trying new alternatives (Abhold et al. 2011, Coffman 2002, Godwin 2008), it is important to understand factors affecting their attitudes toward adoption to best support dissemination and implementation of these practices. Stormwater managers and other officials lack the authority to unilaterally adopt and implement green infrastructure, but they do have the ability to educate citizens and political leaders about the value of green infrastructure in mitigating issues relating to urban stormwater runoff and thus could become change catalysts (Kahan, Jenkins-Smith, and Braman 2011). Perceived limited financial resources and lack of skilled, experienced and knowledgeable staff members, perceived complexity of design and technical components, and poor understanding of the benefits associated with implementation are some potential sources of resistance and negative attitudes toward green infrastructure explored in this paper.

5.2.2. Theory background

Researchers have taken advantage of the Diffusion of Innovation (DOI) theory to understand whether an individual or organization will adopt one of many new products, processes or policies (*e.g.*, Matisoff (2008), Sharp, Daley, and Lynch (2011), Zeldin, Camino, and Mook (2005). An innovation is an idea, practice or product that is perceived as new by the unit of adoption (Rogers 2003, Faber 2002). Within an organization, successful and continuous adoption of an innovation requires acceptance by the employees (Frambach and Schillewaert 2002), who evaluate the new product and, based upon this evaluation, form a positive or negative *attitude* toward it (Rogers 2003).

Among other factors, innovation adoption theory links the formation of a favorable or unfavorable attitude toward adopting an innovation to the characteristics of the innovation itself (Rogers 2003, Walker 2006). To examine this more closely, it is necessary to distinguish between an innovation's ''primary attributes'' (characteristics that are intrinsic to an innovation, such as actual cost), and ''secondary attributes'' (characteristics as perceived by the individual adopter, such as the *perception* of cost) (Moore and Benbasat 1991). Primary attributes enable differentiating innovation between organizations, while secondary attributes enable differentiating innovations within organizations (Damanpour and Schneider 2008). This study is concerned with the second construct, and investigates if the perceived attributes of an innovation affect how the members of an organization evaluate the new product and influence their attitudes and propensity to adopt (Ostlund 1974, Rogers 2003). The perceived benefits, including economic advantages, that an innovation offers have an important effect on the organizational adoption. Other characteristics that influence the adoption decision include perceived compatibility, complexity, observability, and trialability of the innovation (Rogers 2003).

The innovation adoption process is a sequence of stages a potential adopter passes through before acceptance of a new product, service or idea (Rogers 2003). With respect to organizational adoption process, two main phases may be distinguished: initiation and implementation, with the innovation adoption occurring in between the two stages (Frambach and Schillewaert 2002). In the initiation stage, the organization becomes aware of the innovation, evaluates the new product and forms an attitude towards it. This phase encompasses awareness, consideration, and intention sub-stages. In the implementation stage, the organization decides whether to purchase and make use of the innovation (Frambach and Schillewaert 2002).

The attitude literature provides a useful theoretical framework to understand and define the linkages between beliefs about adopting (and using) the innovation (*i.e.* the innovation characteristics), attitudes, acceptance and the eventual adoption/rejection decision. Davis (1989b) advances one of the most influential models of intra-organizational acceptance,[1] the Technological Acceptance Model (TAM). The TAM concept was developed by drawing on various elements of expectancy, self-efficacy, behavioral decision-making, and innovation diffusion theories. The model postulates that acceptance of a new technology or an innovative product is influenced by innovation-related characteristics of the product as perceived by individual users (the aforementioned "secondary attributes"), including *perceived usefulness* and *perceived ease of use*. The *attitude* formed based on these attributes influence consumers' intentions to use the technology or product (Davis 1989b). Specifically, TAM posits that ease of use and the perceived usefulness of a new technology influence consumers' attitudes toward using the technology, which in turn directly influences intentions to use the technology (Davis 1989b). Several studies have shown that the TAM has an acceptable predictive validity when measuring the usage of innovations such as new information and communication technologies (Venkatesh 2000, Chuan-Chuan Lin and Lu 2000, Moon and Kim 2001).

As noted above, attitudes toward an innovation can be a facilitating or limiting factor in the dissemination and implementation of new technologies such as green stormwater infrastructure. The conceptual model in Figure 5-1 illustrates the role of attitudes in green infrastructure acceptance and provides a useful heuristic in two ways: (1) it identifies factors likely to influence local officials' attitudes toward adoption; (2) it illustrates the role of attitudes in acceptance of green infrastructure.

This paper focuses on the relationships highlighted on the left side of the graph, or the association between diffusion of innovation, elements of the technology acceptance model, and attitudes of engineers, planners and other professionals working in local US government offices. As implied in Figure 5-1, attitudes toward adoption are influenced by individual respondents'

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[1] Intra-organizational acceptance refers to acceptance at individual level within an organization (Frambach and Schillewaert 2002).

and organizations' characteristics, perceived green infrastructure attributes, and perceived adoption readiness. These factors can increase or decrease the likelihood that green infrastructure practices will be implemented as intended. Specifically, I postulate that respondents' and organizations' characteristics and perceived innovation attributes have a direct positive effect on attitudes, while the effect of internal adoption readiness is mediated by the other determinants.

I develop and describe the constructs in this heuristic model in more details in the next section.

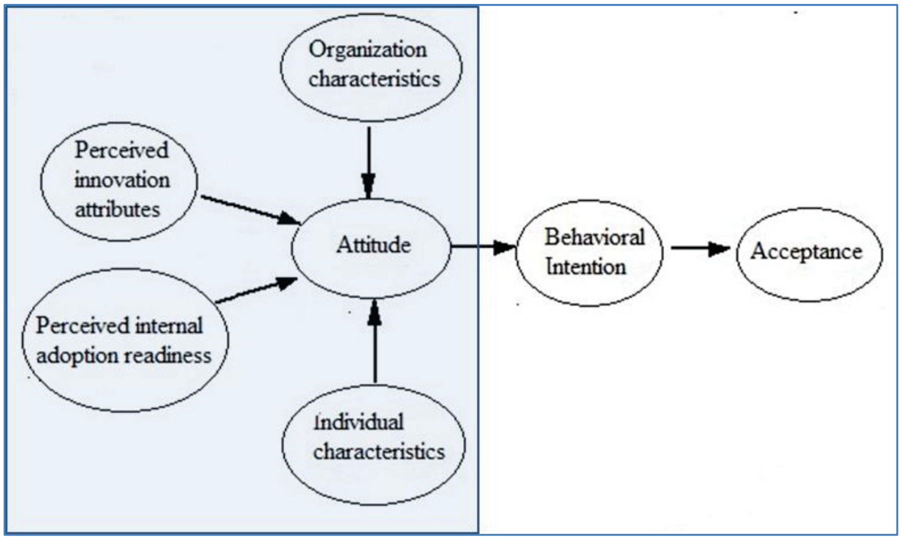

Figure 5-1. Conceptual framework of the role of attitudes in innovation acceptance

5.3. Research hypotheses and research models

I use a theoretical model combining elements of technology acceptance, diffusion of innovation and organizational theories to investigate the predictors of local jurisdiction officials' attitudes toward green stormwater infrastructure.

Based on the literature review in the previous section, I operationalized the conceptual model of Figure 5-1 and tested 11 key hypotheses relating to the relationship between attitudes toward adoption and perceived ease of use and perceived usefulness, perceived internal adoption readiness and compatibility, and individual survey respondents' characteristics and municipalities' features.

The remaining of this section describes the logic behind the development of the research hypotheses and model.

5.3.1. Effects of perceived ease of use and perceived usefulness on attitudes toward adoption

The technology acceptance model specifies the causal relationships between innovation characteristics, user perceptions ease of implementation and usefulness, and behavioral impacts. Overall, the TAM provides an informative representation of the mechanisms by which technology design choices influence user acceptance (Venkatesh 2000, Davis 1989b). According to TAM, the perceived ease of use (EU) is the degree to which an individual believes that using an innovation would be free of effort (Davis 1989b). Empirical tests for the original TAM model found that perceived ease of use exerts a positive influence on perceived usefulness (PU) (Venkatesh and Morris 2000). Other things being equal, the easier an innovation is to use, the more useful it can be (Venkatesh 2000).

The conceptual model of Hee-dong *et al.* (2004) and the theoretical model of Walczuch, Lemmink and Streukens (2007), for example, indicate that users perform well in tasks when they do not need to expend much effort to understand the innovation. In the context of green stormwater infrastructure, perceived ease of use is the degree to which these practices are perceived as easy to understand and implement. If respondents do not need to expend significant effort on understanding green infrastructure, they may develop a more favorable attitude toward these practices. Thus, ease of use should have a positive impact on attitudes toward green stormwater infrastructure adoption (the TAM model proposes that perceived ease of use predicts acceptance).

The TAM model describes perceived usefulness based on how much a system adds to the user's job performance. More specifically, Davis (1989) defined PU as the degree to which adopters believe an innovation can be integrated into their daily activities (Kleijen et al., 2004). The greater the innovation's usefulness, the greater will be its capacity to help the organization achieve its strategic objectives and meet its performance goals. Empirical studies have validated that positive perceptions of the benefits of technological innovation provide an incentive for the use of new technologies (Chau and Tam, 1997; Ramamurthy et al., 1999).

Because local jurisdiction officials work as professionals with organizational commitment and share a motivation to serve the public interest, we can assume that they would be motivated to adopt innovations that have a high positive impact on the community, everything else being equal (Moon 2000, Houston 2000). By readapting this definition for the innovation with which this study is concerned, green infrastructure, I formulate the following operational definition of PU: the extent to which respondents believe that implementation of green stormwater infrastructure would improve the outcomes of local jurisdictions' stormwater management practices and enhance performance of existing stormwater systems.

Based on the above discussions, I posit the following hypotheses on the relationship between perceived ease of use, perceives usefulness and attitudes toward green infrastructure adoption:

H1 Perceived ease of use of green infrastructure tools has a positive influence on perceived usefulness.

H2 Perceived ease of use has a positive influence on attitudes toward green infrastructure adoption.

H3 Perceived green infrastructure usefulness has a positive influence on respondents' attitudes.

5.3.2. Effect of perceived internal adoption readiness and compatibility

Perceived internal adoption readiness (IR) in the present context represents the degree to which respondents believe their jurisdiction is prepared to adopt and exploit green stormwater infrastructure (Gao, Leichter, and Wei 2012, Chwelos, Benbasat, and Dexter 2001). The construct measures the local jurisdictions' perceived degree of technical sophistications and financial resources available to implement adoption. Specifically, we can view it as (1) the perceived internal ability among the stormwater management and planning or engineering team to comprehend green infrastructure tools (Meuter et al. 2005, Gao, Leichter, and Wei 2012) and (2) the perceived availability of financial resources to support adoption (Iacovou, Benbasat, and Dexter 1995, Gao, Leichter, and Wei 2012, Parasuraman 2000, Sharma, Citurs, and Konsynski

2007). According to the innovation diffusion theory, greater knowledge, more experiences, and stronger technical competences (Rogers 2003) may allow early adopters to perceive the same technology to be easier and less challenging to use than late adopters.

Several studies have empirically demonstrated the positive association between the prevalence of technical experts and adoption of new technologies (Raymond 1985,Gao, Leichter, and Wei 2012). Organizations that already possess the know-how about a technology have the ability to better evaluate the benefits, disadvantages, costs, and requirements that have to be taken into account for adoption (Premkumar, Ramamurthy, and Crum 1997). Conversely, local governments with more limited technological knowledge may perceive the innovation as too complex (Premkumar and Roberts 1999). Furthermore, organizations with more knowledge about the technological innovation are more likely to implement an aggressive technology adoption strategy (Lee and Jung 2007).

This construct's emphasis is on the technical capability as well as the financial ability of potential adopters when considering adoption of an innovation. Because resource security allows adopters to be more confident and able to deal with uncertainty associated with innovations (Rogers 2003, Savage 1985), perceived resources positively relate to the rate of adoption or innovativeness (Driscoll and Dupagne 2005, Lin 1998). More availability of financial resources may increase an organization capacity to afford an innovation, bear the cost of implementation, absorb its possible failure, and explore new ideas in advance of an actual need (Damanpour 1991).

I suggest that the link between internal organizational readiness and attitudes is mediated by the former's positive impact on perceived ease of use and perceived usefulness. Unfamiliarity with any innovation increases the magnitude of risks and uncertainty concerns, which reduces the rate of adoption and implementation (Olorunkiya, Fassman, and Wilkinson 2012). In contrast, jurisdictions that have the internal resources and ability to comprehend the innovation will have a lower level of uncertainty, hence a lower level of perceived complexity that, in turn, increases the likelihood of adoption.

In the diffusion of innovation literature, compatibility (CO) has been consistently reported as one of the most influential predictors of innovation adoption across multiple disciplines (Rogers

2003, Damanpour and Schneider 2008, Meuter et al. 2005, Vasi 2006). The examination of organizational contexts in this study of green infrastructure acceptance includes organizational compatibility, which refers generically to the degree to which jurisdictions perceive a technological innovation as consistent with existing operating practices, beliefs and values, past experiences, and needs.

Local government officials identify necessities and search the organization's environment to find innovations that could meet the community's needs, and then decision makers assesses the feasibility of a particular innovation, such as green infrastructure, in solving these problems (Vasi 2006). Thus, greater compatibility between organizational policy and technological innovation is preferable because it allows innovation to be interpreted in more familiar contexts (Rogers 2003).

Because of its flexible and multifunctional nature, green infrastructure may be implemented in a variety of urbanized and rural environments and designed to meet specific socio-economic (*e.g.*, neighborhood revitalization) and environmental goals of individual communities. Local government officials involved in environmental activities possibly are already familiar with the engineering and ecological concepts underpinning green infrastructure systems, and could perceive these strategies as familiar and relevant to their environmental needs. To the extent that engineers and planners already possess the knowledge and capacity to handle green infrastructure tools, and to the degree that local ordinances and soil morphology allow implementation, green infrastructure is potentially compatible with any jurisdiction.

Based on the discussion above, I hypothesize that:

H4 Perceived internal readiness for adoption has a positive influence on the perceived ease of use associated with implementing green infrastructure.

H5 Perceived internal readiness for adopting green infrastructure has a positive effect on the perceived usefulness associated with implementation.

H6 Compatibility of green infrastructure with the adopting community’s goals and values has a positive influence on internal readiness.

H7 Compatibility of green infrastructure with the adopting community's goals and values has a positive influence on perceived ease of use.

H8 Compatibility of green infrastructure with the adopting community's goals and values has a positive influence on perceived usefulness of green stormwater infrastructure.

H9 Compatibility of green infrastructure with the adopting community's goals and values has a positive influence on attitudes towards green stormwater infrastructure.

Figure 5-2 summarizes the research model (Model 1), which includes hypotheses H1 to H9.

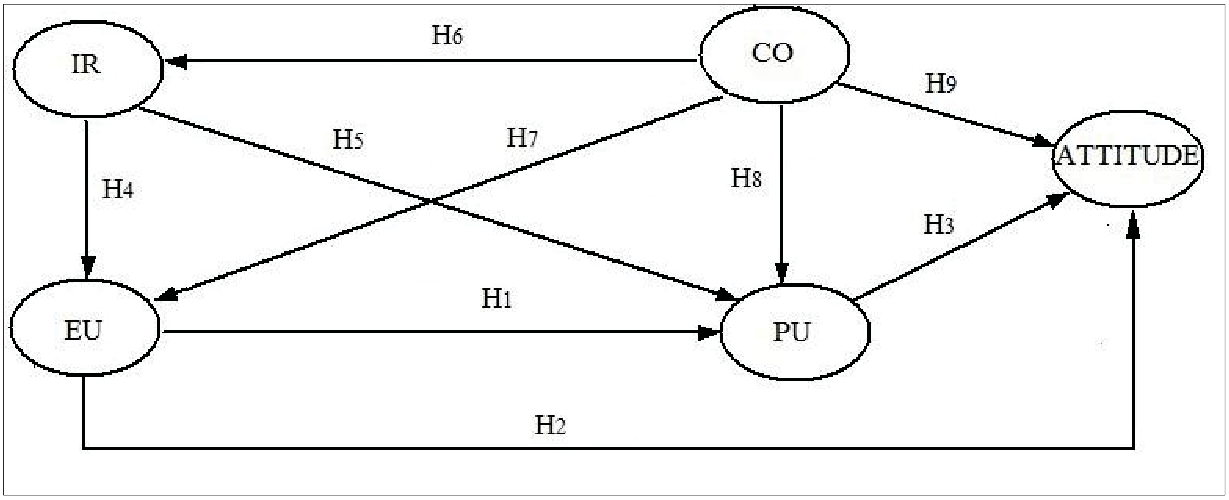

Figure 5-2. Research Model 1

Notes

ATTITUDE: attitudes of survey respondents toward green infrastructure adoption
IR: perceived internal readiness
EU: perceived ease of use
PU: perceived usefulness
CO: perceived compatibility

5.3.3. Effects of individual and organizational characteristics

Individual demographic variables, such as age (AGE), may influence public knowledge and perception of green infrastructure options across the respondents and impact attitudes. Within the innovation adoption literature, several studies have found a negative relationship between age and innovation acceptance and change in organizations (Damanpour and Schneider 2006). Other researchers, however, argue that age positively affects organizational innovation and change because more experienced administrators have greater insight into the process of performance improvement (Kearney, Feldman, and Scavo 2000).

In the context of stormwater management, I suggest that younger engineers and planners, who have been trained more recently and may have more current technical knowledge, are more receptive to using new ideas and strategies such as green infrastructure. Innovation entails a level of uncertainty and younger managers are usually more willing to take risk (Damanpour and Schneider 2006). In contrast, long-tenured professionals who have been relying on conventional infrastructure to manage stormwater may not be convinced of the efficacy of green infrastructure and thus be reluctant to engage with and accept this different approach.

In addition to individual attributes, organizational characteristics have been found to influence the adoption decision (Damanpour and Schneider 2006,Frambach and Schillewaert 2002). Among the characteristics at the organizational level, size (SIZE) has consistently been reported in the literature to influence the propensity to adopt. Most studies have found a positive relationship between size and innovation adoption, with larger cities generally being more capable of learning from other cities, less concerned about economic competition, and less likely to resort to policy imitation (Shipan and Volden 2008, Kern, Koll, and Schophaus 2007). In addition, larger cities may spread the costs of new technology over a larger population and tax base, which means larger governments are more likely to be early adopters of an innovation (*e.g.*West 2004).

Prior work also suggests that larger organizations may also perceive greater need to adopt innovations to support and improve their performance (Frambach and Schillewaert 2002). On the other hand, other studies have found that smaller organizations are more flexible and innovative, resulting in an enhanced receptiveness towards new products (Frambach and Schillewaert 2002). These apparently contradictory results may be largely attributable to the correlation of organization size with other variables, such as structure, which has been found to either facilitate or inhibit innovation adoption. Zaltman et al. (1973) propose that more formalized and centralized organizations (often larger firms) are less likely to initiate innovation adoption decisions, but are better equipped to implement an innovation.

Based on the above discussion, I expect that:

H10 Respondents' age has a negative influence on their attitude toward green infrastructure adoption.

H11 Size of municipality (used as a proxy for size of local government agency) has a positive effect on attitude toward green infrastructure adoption.

Figure 5-3 summarizes the full model (Model 2), which includes hypotheses H1 to H9, and the relationship of individual and organizational characteristics with attitude (hypotheses H10 and H11).

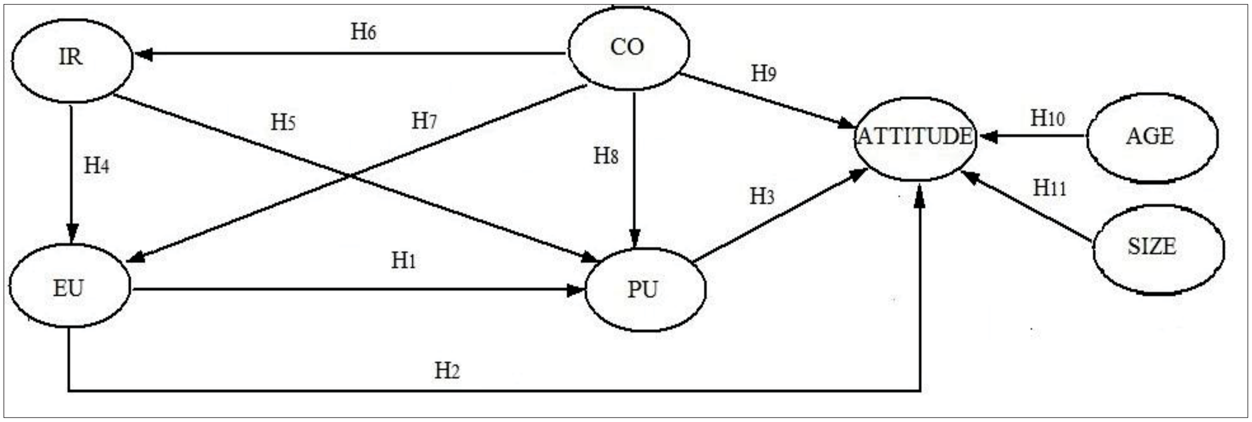

Figure 5-3. Research Model 2

Notes

ATTITUDE: attitudes of survey respondents toward green infrastructure adoption
IR: perceived internal readiness
EU: perceived ease of use
PU: perceived usefulness
CO: perceived compatibility
AGE: age of respondents
SIZE: size of jurisdiction

5.4. Research method

5.4.1. Data collection and research instrument development

The data-gathering instrument in this study consists of a three-section questionnaire. The first section contains definitions of terms used in the instrument, as well as factual questions about the respondents' work office and jurisdiction. The second section contains items used to measure the independent variables assumed to affect attitude. The third section contains questions relating to demographic characteristics of the respondents.

To ensure validity of the scales, all research variables were measured using multiple-item scales and adapted from previous DOI and TAM studies with wording changes to tailor them to the green stormwater infrastructure context. In particular, the scales for three innovation attributes (perceived usefulness, ease of use and compatibility) were measured using items adapted from Moore and Benbasat (1991), Karahanna, Straub, and Chervany (1999), Driscoll and Dupagne (2005). The items to assess perceived internal readiness were adapted from Gao, Leichter, and Wei (2012), Chwelos, Benbasat, and Dexter (2001) and Parasuraman (2000).

Attitude towards adoption of green infrastructure (the independent variable) was measured using forward-looking statements that capture respondents' thoughts and perceptions toward adoption and use of green stormwater infrastructure. The scale was developed based on previous studies (*e.g.*, Lin 2011) and following recommendations of Ajzen and Fishbein (1980), who suggested that attitude could be predicted from the salient consequences for a person toward the behavior (in this study, adopting green infrastructure.)

Each of the study constructs (perceived internal readiness, usefulness, ease of use, compatibility and attitude) was measured by items coded on five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). To ensure clarity and face validity of the questions, I pre-tested the questionnaire with six professionals working in the planning, engineering and environmental field. Both the pre-test and final survey were conducted online via Qualtrics survey software. The sampling frame for the survey included 840 municipal officials who work for engineering, environmental, planning or similar offices of incorporated places (cities, towns and other municipalities) with population of 5,000 or higher in the US Census Bureau's 2010 population estimates. A total of 300 respondents returned the survey, for a response rate of 35.7 percent. However, 256 returned questionnaires containing complete data constitute the sample used in this paper.

5.5. Data analyses and results

I chose to use structural equation modeling to test the effectiveness of Model 1 and Model 2 in predicting local officials' attitude toward adoption of green infrastructure. Structural equation modeling is a statistical technique that takes a confirmatory (*i.e.*, hypothesis testing) approach to the analysis of a structural theory bearing on some phenomena. This technique was deemed appropriate for its ability to simultaneously examine a series of dependence relationships, especially when there are direct and indirect effects among the constructs within the model as shown in Figure 5-2 and Figure 5-3 (Hair et al 2009).

Following the recommendations of Anderson and Gerbing (1988) and Mueller and Hancock (2008), I tested the structural equation models using a two-stage process. First, I used confirmatory factor analysis (CFA) to test the dimensionality, reliability, and convergent and discriminant validities of the measures. Then, I used path analysis to test the hypotheses of the two research models empirically.[2]

5.5.1. Analysis of the measurement model

I evaluated the factorial structure of the model using confirmatory factor analysis, where items are analyzed as categorical measures with a Maximum Likelihood (ML) estimator.[3] The

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[2] A two-steps process is recommended over an all-in-one process because when the model is separated into its measurement and structural portions, misspecifications in the former can be identified and addressed before assessing the structure among latent constructs (Mueller and Hancock 2008).

[3] This method relies on the assumption of multivariate normal joint distributions of items and continuous nature of measurement of both latent and observed variables (Morata-Ramírez and Holgado-Tello 2013, Kirby and Finch 2010, Gnanadesikan 2011). Likert-scale response variables, such as those used in this study, have ordinal properties that violate the requirement a priori for ML (Flora, Finkel, and Foshee 2003). However, several scholars found that ML performs quite well with moderately skewed/kurtotic, and ordered categorical variables with five or more categories (Muthén and Kaplan 1985, Beauducel and Herzberg 2006, DiStefano 2002). Muthén and Kaplan (1985), for example, argue that, if most variables have univariate skeweness and kurtosis in the range of 1.0 to -1.0, not much distortion is to be expected and parameter estimate bias appears non-existent, while ML results for a kurtosis only case shows no distortion of chi-square or parameter estimates and only a slight downward bias in estimated

objective of the CFA is to examine construct validity by exploring the extent to which the correlations between the constructs variables could be explained by the five domains (perceived internal readiness, compatibility, ease of use, usefulness and attitude toward adoption).

Before proceeding with CFA, I checked the variables' distribution and skewness to verify if the assumptions of the ML method are met. Based on the guidelines ofRazali et al. (2012),[4] I found most of the study variables in this study to be relatively symmetric, and a few (five out of sixteen) only moderately skewed. In addition, the Shapiro-Wilk and Shapiro–Francia tests suggest that five out of 16 variables are normally distributed. Although ML chi-squares may be slightly inflated in the presence of non-normality, the presence of some relatively normal indicators can mitigate this inflation (Benson and Fleishman 1994). Given the approximately symmetrical shape of the distribution of the construct variables (demonstrated by the low skewness values), and the presence of normally distributed variables, I concluded that that use of ML in the confirmatory factor analysis in this study is appropriate.[5]

5.5.2. Constructs development

As previously described, all measures for the attribute constructs were drawn from studies in DOI and TAM literatures, and adapted to the specific innovation of green stormwater infrastructure. Relevant questions in the survey had a five-point Likert scale response, ranging from 1="strongly disagree" to 5="strongly agree" and each constructs in the CFA included at least three items.

I conducted a series of confirmatory factor analyses and eliminated items that were not statistically significant on their factor loading or that had a large correlated error with other indicators (Netemeyer, Bearden, and Sharma 2003). In addition, I examined the fit of each

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standard errors. Rhemtulla, Brosseau-Liard, and Savalei (2012) suggest using robust ML with categorical data when there are five or more categories, sample size is small, and category thresholds are approximately symmetric.

[4] Razali et al. (2012) suggest that variables with skewness value of between 0.5 and 1 or between -1 and -0.5 are considered to have moderately skewed distribution, whereas skeweness values between 0.5 and -0.5 indicate relative symmetry.

[5] Table H-2 in Appendix H shows the result of CFA with robust errors, which are only slightly different from the values of CFA with standardized errors in Table H-1 (also in Appendix H).

construct and its variables individually to identify weak items.[6] All of the R-squared values[7] of the construct variables are greater than 0.3, indicating a high level of association between the indicated dependent variable and the model's linear prediction (StataCorp 2013). After eliminating weak variables, each construct comprises three indicators, which Hair et al. (2009) suggest as acceptable. Table 5-1 shows the individual factor loading of the three indicators for each construct.

Finally, I assessed internal consistency, convergent and discriminant validity of the construct. Appendix G reports details of the analyses.

5.5.3. Model fit

A number of indices are available to assess the goodness of fit of the model. In general, reporting of multiple fit indices is common practice when evaluating a model goodness of fit (Hooper, Coughlan, and Mullen 2008). Kline (2011) recommends the use of the chi-squared test, the root mean square error of approximation (RMSEA), the comparative fit index (CFI), and standardized root mean square residual (SRMR), since these indices have been found to be the most insensitive to sample size and model misspecification (Hooper, Coughlan, and Mullen 2008).

The chi-squared statistic measures the discrepancy of fit between the sample and the fitted covariance matrix, serving therefore as an indicator of overall model fit (Barrett 2007). When determining a model appropriateness, a lower value of the calculated chi-squared statistic indicate a better model fit, and a good model fit would provide an insignificant result at a 0.05 threshold significant p value (Barrett 2007). If p-value is smaller than 0.05, we reject the proposed model, and if p-value is exceeds 0.05, we accept the proposed model. For this reason, the chi-squared statistic is often referred to as either a badness of fit or a lack of fit measure (Hooper, Coughlan, and Mullen 2008).

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[6] Hooper, Coughlan, and Mullen (2008) suggest that items with low multiple R-squared (less than 0.20) should be removed from the analysis as this indicates very high levels of error.

[7] R-squared represents the fraction of variance explained by each indicator (StataCorp 2013).

Table 5-1. Confirmatory factor analysis results

Construct	**Cronbach's Alpha**	**Std. loading**
Attitude toward GI (ATTITUDE)	*0.80*	
AT1: Considering the pros and cons of Green Infrastructure for stormwater management, I believe adoption of these tools in my jurisdiction in the near future would be…*		0.76
AT2: Considering the pros and cons of Green Infrastructure for stormwater management, I believe adoption of these tools in my jurisdiction in the near future would be…**		0.69
AT3: I have not doubts adoption of Green Infrastructure would provide multiple benefits to my community.		0.83
Perceived usefulness(PU)	*0.78*	
PU1: Integration of traditional grey infrastructure with Green Infrastructure tools could help my jurisdiction to better manage stormwater		0.87
PU2: Adoption of Green Infrastructure complementing traditional stormwater management system in my jurisdiction would reduce runoff		0.61
PU3: Green Infrastructure retrofitting could enhance the effectiveness of stormwater infrastructure in my jurisdiction.		0.81
Ease of use (EU)	*0.72*	
EU1: I have a difficult time understanding how Green Infrastructure		0.72
EU2: The challenges of learning about Green Infrastructure design and implementation overwhelm me.		0.65
EU3: Green Infrastructure tools are easy to learn and implement.		0.77
Compatibility (CO)	*0.72*	
CO1: Green Infrastructure is compatible with my jurisdiction's environmental goals.		0.76
CO2: Green Infrastructure would be accepted in my community.		0.57
CO3: Green Infrastructure fits well with the way my jurisdiction tries to manage stormwater runoff.		0.70
Internal readiness (IR)	*0.76*	
IR1: If my jurisdiction were to expand or retrofit existing stormwater infrastructure using Green Infrastructure, funding would not be an issue.		0.73
IR2: Green Infrastructure implementation does not constitute a resources burden more than expanding conventional stormwater infrastructure.		0.69
IR3: My jurisdiction has the resources to implement Green Infrastructure.		0.73

Fit indices: χ^2=99.28 (df=79), p= 0.0612, RMSEA=0.031; CFI=0.986, TLI=0.981, SRMR=0.042

Notes:
*: Respondents were asked to complete the statement choosing from a scale of 1 to 5, with 1=extremely good and 5=extremely bad.
**: Respondents were asked to complete the statement choosing from a scale of 1 to 5, with 1=extremely beneficial and 5=extremely harmful.
RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI: Tucker-Lewis index; SRMR = standardized root mean square residual.

A value of RMSEA smaller than 0.06 is acceptable, with values less than 0.03 representing an excellent fit (Steiger 2007). CFI values greater than 0.95 and SRMR value less than 0.08 have served as rules of thumb of acceptable fit (Hu and Bentler 1999).

The model fit indices shown in Table 5-1 demonstrate that the overall statistics for the model are acceptable, with all of the indices satisfying the criteria for good fit. Chi-Square = 99.28, df =79, p= 0.061, RMSEA = 0.031, CFI = 0.986, and SRMR = 0.042. Thus, the data set support the five-dimension, 15-item model.

5.5.4. Analysis of structural Model 1

With a finalized measurement model in place, the structural phase consists of replacing the nonstructural covariances among latent factors with the hypothesized structure that is of main interest, and then reanalyzing the data (Mueller and Hancock 2008, Anderson and Gerbing 1988). The structural model is the *path* model, which relates independent to dependent variables (Hair et al. 2009).

The first step in interpreting the results of the structural model includes reviewing fit indices, which provide evidence on how well the model fits the data. If the model fits the data well enough, a second step involves reviewing the feasibility of each path (relationship between variables) in the models by examining whether the weights are statistically and practically significant. Practical significance is evaluated on the basis of whether the effect size estimation (the R2) regarding a given path in the models is large enough (Hair et al. 2009).

The overall fit of the structural Model 1 is acceptable, with chi-squared statistic of 101.19 (df=80), which does not reject the null hypothesis of an overall good fit (p= 0.055). The RMSEA 0.032, CFI 0.985 and SRMR=0.042 indicate that this model fits the data fairly well. When comparing these new data-model fit results to those from the final CFA model, it appears that the introduction of restrictions did not significantly erode data-model fit as the fit indices barely changed. Individual standardized loading values also remain almost unchanged. Table 5-2 shows the parameter estimates for hypothesized effects along with significance levels.

Table 5-2. Empirical results of Model 1

Hypothesis	Relationship	Std. coef.	Std. error	z	P>|z|	Results
H1	EU→PU	0.199	0.096	2.070	0.038	Supported
H2	EU→ATTITUDE	0.094	0.065	1.430	0.152	Not supported
H3	PU→ATTITUDE	0.790	0.083	9.440	0.000	Supported
H4	IR→EU	-0.017	0.084	-0.200	0.839	Not supported
H5	IR→PU	0.298	0.083	3.590	0.000	Supported
H6	CO→IR	0.391	0.089	4.390	0.000	Supported
H7	CO→EU	0.310	0.089	3.470	0.001	Supported
H8	CO→PU	0.633	0.102	6.200	0.000	Supported
H9	CO→ATTITUDE	-0.006	0.085	-0.080	0.939	Not supported

N=256

Notes:

EU: perceived ease of use; PU: perceived usefulness; IR: perceived internal readiness; CO: perceived compatibility; ATTITUDE: attitude toward adoption.

Based on the analysis results, hypotheses H1, H3, H5, H6, H7 and H8 received support, while H2, H4 and H9 were rejected. Perceived ease of use has a significant and positive paths to perceived usefulness (H1, β=0.148, t=2.08), while its impact on attitude toward adopting green infrastructure is not significant (H2, β =0.082, t=1.38). The parameter estimate for the path from perceived usefulness to attitude is significant and has the expected sign, providing support for H3; that is, respondents' attitudes toward adoption of green infrastructure are influenced by perceived usefulness, which in turn is influenced by the perceived ease of use associated with these tools.

The parameter for the path from perceived internal readiness to perceived usefulness is significant and has a positive sign (β =0.258, t=3.82) supporting H5, while the parameter from perceived internal readiness to perceived ease of use is not significant. Therefore, respondents' perceived internal readiness to adoption has a direct effect on perceived usefulness associated with green stormwater infrastructure implementation, but it does not have any significant influence on their perceived ease of use of green infrastructure tools, thus rejecting H4.

Compatibility has a significant and positive path to internal readiness (H6, β =0.391, t=5.18), perceived ease of use (H7, β =0.359, t=3.95) and perceived usefulness (H8, β =0.547, t=7.67) of green infrastructure, while the parameter estimate for path from compatibility to attitude is not significant (H9, β =-0.006, t=-0.08). That is, perceived compatibility of green infrastructure simultaneously influences usefulness, ease of use and internal readiness as perceived by municipal officials.

5.5.5. Analysis of structural Model 2

Model 2 includes all factors from Model 1 and two additional variables that relate to attitude: AGE (of respondents) and SIZE (of jurisdiction). AGE is a categorical variable representing each respondents age group and coded 1 to 5 (1=24 or younger, 2= 25 to 34, 3=35 to 49, 4=50 to 64, 5=65 years or older). SIZE is a continuous variable representing the 2010 population of each respondent's jurisdiction as reported by the 2010 US Census Bureau.

Fit indices of the model were measured as follows: chi-squared test = 158.07, p=0.01; CFI = 0.966, TLI = 0.957, and SMSR = 0.056. All measure except the chi-square test indicate a positive, significant model, although compared to the fit indices of Model 1, Model 2 fits the data overall consistently worse than Model 1.

As in Model 1, hypotheses H1, H3, H5, H6, H7 and H8 received support, while H2, H4 and H9 were rejected, with the path coefficients remaining substantially the same. The parameter estimate (β =-0.069) for the path from age to attitude is significant, but only at the $p< 0.1$ level, and has the expected sign, providing support to H10. Therefore, as respondents' ages increase, their attitude toward adoption of green infrastructure becomes less favorable. The parameter estimate for the path from size of jurisdiction to attitude in not significant (β =-0.03), meaning that H11 was rejected. Table 5-3 shows the standardized coefficients and significance levels in structural Model 2.

Table 5-3. Empirical results of Model 2

Hypothesis	Relationship	Std. coefficient	Std. error	z	P>|z|	Results
H1	EU→PU	0.199	0.096	2.060	0.039	Supported
H2	EU→ATTITUDE	0.108	0.066	1.530	0.120	Not supported
H3	PU→ATTITUDE	0.777	0.082	9.39	0.000	Supported
H4	IR→EU	-0.015	0.084	-0.190	0.850	Not supported
H5	IR→PU	0.297	0.083	3.580	0.000	Supported
H6	CO→IR	0.394	0.089	4.400	0.000	Supported
H7	CO→EU	0.310	0.089	3.470	0.001	Supported
H8	CO→PU	0.634	0.102	6.200	0.000	Supported
H9	CO→ATTITUDE	-0.012	0.086	0.150	0.882	Not supported
H10	AGE→ATTITUDE	-0.049	0.030	-1.650	0.099	Supported
H11	SIZE→ATTITUDE	-0.034	0.041	-0.830	0.406	Not supported

Notes:

EU: perceived ease of use; PU: perceived usefulness; IR: perceived internal readiness;

CO: perceived compatibility; ATTITUDE: attitude toward adoption; AGE: age of the respondents; SIZE: population of respondents' jurisdiction.

5.6. Discussion and conclusions

This research represents a contribution to the literature on green infrastructure by integrating theoretical perspectives on technological innovation to identify factors that influence attitude of engineers, planners and other municipal officials toward adoption of green infrastructure for stormwater management. Three main theories, technology acceptance model, diffusion of innovation, and organizational theory underpinned the models in the study. To the best of my knowledge, this paper is the first study to test the applicability of elements of these theoretical frameworks to predict municipal officials' attitude about adopting green infrastructure. In the context of green infrastructure, this study fills a theoretical gap by developing the research model and evaluating it using an empirical data set based on a nationwide survey across the US.

While the study yielded some useful insights, the generalizability of certain findings is limited by the specific type of innovation studied. That is, the confirmed relationships among key constructs might not hold for other innovations and further research is necessary to establish whether the pattern of effects that I observed is generalizable when applied to other environmental innovations. In addition, the study focuses solely on planners, engineers and other staff working at local jurisdictions in the US. While these actors are involved in stormwater management decision making, they are not solely responsible for the adoption of green infrastructure. Elected officials, designers, contractors and the community at large also play a role in changes to the regulatory environment.

Furthermore, this paper represents only a partial investigation of selected important antecedents to attitude toward adoption of green infrastructure. Acceptance of technological innovation is multi-dimensional, and it involves a number of context-specific aspects that arise from the differences in motivations, the role of the user, and the nature of the enabling technology. This complexity points to the need to use instruments based on both surveys and in-depth interviews when exploring similar topics.

Regardless of its limitations, this study demonstrated several major findings. These relates to the appropriateness of using innovation attributes to predict municipal officials' attitude toward green infrastructure.

First, the results indicate that attitude toward green infrastructure adoption is influenced by perceived usefulness, while the impact of perceived ease of use of green infrastructure technologies on local officials attitude is not significant. This may imply that green stormwater infrastructure usefulness as perceived by local officials will play a more influential role on adoption of green infrastructure than the simplicity of implementing these tools. However, because the study sample comprises mostly professionals working at engineering and planning offices who may have atypical skills and knowledge of green infrastructure, this result may also be the consequence of the level of self-efficacy of the respondents. Local officials with theoretical and/or experiential knowledge of green infrastructure may perceive this system as technically straightforward, so the perceived ease of use may not influence their attitude toward adoption.

Second, the analysis shows that the perceived environmental, engineering and ecologic benefits of systems that integrate green stormwater infrastructure (Keeley et al. 2013, Kloss 2008, Wise et al. 2010, Thurston et al. 2003) influence respondents' attitudes toward adoption. This agrees with several empirical studies that found that positive perceptions of the benefits of technological innovation provide an incentive for the use of new technologies (Chau and Tam, 1997; Ramamurthy et al., 1999). The greater an innovation's usefulness, the greater will be its capacity to help an organization achieve its strategic objectives and meet its performance goals.

Third, perceived usefulness is positively affected by perceived ease of use, which is in turn positively influenced by compatibility. Yet, while compatibility of green infrastructure systems with a community's environmental goals and values has a significant positive effect on perceived usefulness and perceived internal readiness, it does not appear to affect attitudes toward adoption. These findings suggest that the link between compatibility and attitude is not direct, but mediated by the former's positive impact on perceived usefulness and perceived internal readiness. The more a respondent thinks that green infrastructure retrofitting lends itself to the values and beliefs of the community to which it is being introduced, the more likely the respondent will develop a favorable attitude because he/she can interpret green infrastructure strategies in a familiar way and feel ready to adopt them.

Fourth, the analysis suggests that perceived internal readiness to adoption of green infrastructure has a significant effect on perceived usefulness associated with these tools. This implies that if respondents feel confident about possessing the skill and resources to adopt green infrastructure, they demonstrate a more favorable perception of the benefits associated with implementation, because they are better positioned to evaluate the outcomes of using these strategies to manage stormwater runoff. In contrast, unfamiliarity with an innovation increases the magnitude of risks and uncertainty concerns, which in turn reduces the rate of adoption and implementation (Olorunkiya, Fassman, and Wilkinson 2012).

Green infrastructure is a relatively new approach to stormwater management, and the lack of sufficient performance data and design standards makes it difficult to confirm its effectiveness and reliability (Roy et al. 2008, Abhold et al. 2011). City staff may tend to prefer well-established engineering practices and trust systems that have been tested and used in past experiences rather than trying new alternatives. In the realm of green infrastructure, resistance to change has been consistently reported as a barrier to adoption (Abhold et al. 2011, Coffman

2002). This is particularly true for more seasoned professionals, who may be more conservative when considering the risks of replacing conventional gray infrastructure with new green solutions. By contrast, younger engineers and planners, who have been trained more recently and thus may have a more current technical knowledge, appear more receptive to adopting new ideas and strategies for stormwater management. Adopting an innovation entails some risk and younger managers are often more willing to take risk (Damanpour and Schneider 2006). This reasoning is supported by the analysis finding that age has a significant negative impact on respondents' attitudes toward adoption of green infrastructure.

The technology acceptance model and diffusion of innovation theories elements included in this analysis appear largely applicable to the investigation of municipal officials' attitudes toward green infrastructure adoption. The results support the construct validity and internal consistency of the research model. Significant items of each construct reflected the strength of municipal officials' attitude toward green infrastructure. Therefore, the individual constructs can be adapted for a researcher's particular interest, and may be an effective tool for policy makers, developers, and researchers.

Overall, compatibility with existing operating stormwater practices, values and needs emerged as a significant attribute that greatly influence respondents' perceptions of the benefits and easiness associated with the use of green infrastructure tools, and their perceived readiness to adopt these stormwater management techniques. Outcomes of this research indicate that younger engineers, planners and other local jurisdiction officials who think that green infrastructure strategies are useful because they reduce runoff pollution and improve efficacy of stormwater management systems have a more favorable attitude toward adoption of these practices.

Based on these findings, there is a great opportunity to build targeted policies and programs to support diffusion of green infrastructure by increasing the understanding of this innovation. Among the potential strategies to promote the expansion of green infrastructure in the US, the completion of high profile projects demonstrating these technologies is a crucial approach to improving awareness. Similarly, education and outreach programs clearly articulating the advantages of green infrastructure systems can improve adoption by encouraging people to understand these technologies as being compatible with their systems of values and beliefs and reducing uncertainty associated with adoption. Finally, younger professionals who may already have a positive attitude toward adopting green infrastructure could be recruited to champion these tools, increasing both their and the public's awareness and knowledge of the issues facing stormwater management and the benefits of integrating green infrastructure into conventional stormwater systems.

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6. Understanding adoption of green infrastructure strategies by US municipalities

Abstract

Despite extensive research investigating policy diffusion among states, little literature has examined the diffusion of innovative environmental practices among local governments and none focused on green infrastructure. This study increases the understanding of green infrastructure adoption at the local level by using a negative binomial regression model to test the influence of demographic, economic, environmental, and political – institutional predictors on the number of green infrastructure strategies adopted by US municipalities. Descriptive and regression results indicate that the expected number of green infrastructure tools adopted by a community increases significantly with the presence of a strong champion and environmental interest groups within a community, and that other variables related to demographic and environmental characteristics are also significant predictors.

Furthermore, this research contributes to the sparse literature on diffusion of innovation at the municipal level, and advances the dialogue on green infrastructure planning by suggesting a model to identify localities with most of the attributes that predict use of green infrastructure, but where adoption lags expectations. This can help design efficient and effective local plans and incentives calibrated to local environmental, economic, and sociopolitical conditions.

6.1. Introduction and research approach

This study contributes to the growing body of literature on green infrastructure and policy diffusion by assessing the current level of adoption of green infrastructure strategies at the local level in the US, and by investigating the diffusion process of this novel planning approach among local governments.

Regardless of the large number of papers focusing on diffusion of policy innovation among states, little scholarly literature has investigated the diffusion of innovative environmental practices among local jurisdictions and, to the best of my knowledge, none has examined green infrastructure specifically. Drawing upon theories of policy diffusion, diffusion of innovation and organizational innovation, my research provides an opportunity to test assumptions about the drivers of policy innovation applied to the domain of local governments.

This study relies on a survey with responses from 293 US municipal officials. These responses are combined with secondary data from the 2010 US Census, the 2010 American Community Survey (ACS) 5-year estimate and other sources and analyzed using a negative binomial regression model to estimate the impact of 11 demographic, political-institutional, economic, and environmental variables on the adoption of green infrastructures.

For the purposes of this paper, any regulatory, administrative, and educational or outreach activities that require, support or encourage the implementation of a specific green infrastructure strategy is interpreted as adoption of that tool by the local jurisdiction. The extent of green infrastructure planning is evaluated in terms of the number of different green tools and strategies for stormwater management that municipalities included in local plans, policies or regulations. This study, however, does not differentiate between superficial and deep adoption, or whether the policy is adopted by name only or changes in practices and regulations do occur. Evaluating and comparing the strength or effectiveness of the specific adopting policies, while certainly a topic worthy of future investigation, is not the purpose of this analysis.

The supposition of this paper, using the policy diffusion framework, is that a strong correlation exists between a range of explanatory factors, both external diffusion variables and internal jurisdiction economic, demographic and environmental determinants and the breadth of interest in green infrastructure approaches as measured by the number of green infrastructure tools adopted by a municipality. For the purpose of this paper, adoption of green infrastructure refers to the presence of a policy, plan or program supporting green infrastructure strategies (superficial adoption).

The research questions that guide this paper are:

- What factors have a positive influence on adoption of green infrastructure planning at the local government level?
- Is adoption determined by internal characteristics (*e.g.*, socio-economic status, political orientation)?
- Is adoption driven by external factors (*e.g.*, federal stormwater regulations)?

The results of this study both add to the spare literature on the diffusion of environmental management practices among local governments and provide an empirical base for understanding and promoting adoption of green infrastructure practices.

The rest of the paper is organized as follows. First, I provide a brief background and review of relevant literature on diffusion of innovation, and delineate testable hypotheses derived from this theoretical framework (sections 6.2 and 6.3). Second, I detail the research design by discussing data collection, variable operations, and data analysis procedures and presenting descriptive statistics (section 6.4). Third, I present and discuss the results of the negative bivariate regression analysis (section 6.5). Finally (sections 6.6 and 6.7), I discuss the study limitations and implications of results and provide suggestions for future research to enhance understanding of how internal and external determinant variables influence local adoption of green stormwater infrastructure.

6.2. Theory background

6.2.1. Diffusion theory overview

This study is grounded on theories of policy diffusion—the process by which policy innovations spread across governments— a framework that has been applied and tested in a variety of disciplines over the last 30 years. Existing research on policy diffusion suggests many possible diffusion mechanisms that could help explain green infrastructure planning adoption by US municipalities.

Numerous scholars have focused their research on the dynamics of policy diffusion at the state level, which Jones-Correa (2000) described as the study of "why states may adopt policies when they do and in particular why there may be differences in the speed and rate of adoption among states". This entails diffusion across both time and space, with scholars examining temporal variations as well as geographical patterns of diffusion. For example, Gray (1973) and Mooney and Lee (1999) found that a pattern of temporal diffusion can be drawn from the social learning model. First, one or two leader states adopt a new policy, while other states wait to see the results before evaluating the policy rate of success. Over time, additional states adopt the policy, and as its benefits become evident and widely known, more and more states adopt it with increasing frequency. Eventually, after the majority of the states adopt the policy in a relatively short time, the last few laggards adopt the policy over a more extended period of time (Gray 1973, Mooney and Lee 1999).

Early work on the diffusion of policy innovations focused on developing innovation scores for states to establish their relative innovativeness (Walker 1969) and explaining variances in patterns of adoption such as the interaction between pairs of adopters and non-adopters (Gray 1974). Contemporary scholars have employed more elaborate models focusing on the various factors that predict or explain the probability or *likelihood* of adoption.

For a specific policy, the literature on the determinants of the policy diffusion process typically divides the process into internal factors and external factors (Gray 1994, Berry and Berry 1990, Berry and Berry 1999, Matisoff 2008). Explanations based on the internal determinants model contend that state policymakers respond to internal characteristics of their state environments when crafting policy, while external factors capture the geographic interactions among states, external policy networks, and vertical influences from the federal government that influence policy innovation (Gray 1994, Fredriksson and Millimet 2002). Stated more precisely, the internal determinants model views political, economic, and social characteristics of a state as the major factors influencing policy adoptions (Canon and Baum 1981, Grossback, Nicholson-Crotty, and Peterson 2004). Studies on state and sub-national policy adoption have identified a variety of internal determinants that influence the diffusion of policies and programs across jurisdictions. This includes internal factors that characterize the adopting organization, such as demographic composition, wealth, availability of resources, and grass-root support, all of which empirical evidence shows correlate with innovation across many types of organization (Mohr 1969).

In contrast, external or regional factors capture the geographic interactions among states, external policy networks, and vertical influences from the federal government that influence policy innovation. While most of the early diffusion studies focuses on either approach, more recently, contemporary scholars have employed more elaborate models incorporating internal determinants and external effects (*e.g*. Berry and Berry 1990, Berry and Berry 1999, Chandler 2009, Daley 2007). Integrating the array of relevant predicting variables into a coherent framework, Wejnert (2002) suggests that the factors that influence an entity's decision to adopt a particular innovation can be grouped according to whether they relate to: (1) the innovation itself; (2) the innovator; or (3) the context in which the innovation occurs.

The characteristics of the specific innovation and the availability of suitable policy models represent key factors in determining successful diffusion. For environmental policy innovations, problem-structural preconditions are of high concern. Thus, regulatory patterns can impose themselves only for problems that are easy to handle, that can attract strong grass-root support, and for which tried and tested technical solutions already exist (Kern, Jörgens, and Jänicke 2005). Existence of specific environmental issues to be addressed can help diffusion of environmental policy innovations. However, comparative studies have shown that problems of long-term degeneration whose effects are not directly visible cannot be easily placed on the political agenda (Jänicke and Jörgens 1998, Kern, Jörgens, and Jänicke 2005).

In addition to innovation's attributes, characteristics of the adopting organization influence the innovation adoption decision (Damanpour 1991). Among other factors, organization size has repeatedly been found to be positively related to innovation adoption (Martínez-Ros and Labeaga 2002). Larger organizations may generally feel more need to adopt innovations in order to support or improve their activities and productivity. On the other hand, it is argued that smaller organizations are more flexible and innovative themselves, resulting in an enhanced receptiveness towards new products. These mixed findings on the role of size may be largely attributable to size's correlation with other organizational variables, such as structure, strategy and culture. Zaltman, Duncan and Holbek (1973) propose that more formalized and centralized organizations (often the larger firms) are less likely to initiate innovation adoption decisions, but are better equipped to actually implement innovations.

Finally, the context in which the diffusion occurs influences the innovation adoption process. Environment characteristics such as geographical proximity and a societal structure with shared beliefs and values promote faster spread on the innovation and earlier acceptance by adopters (Wejnert 2002).

6.2.2. Local government level diffusion studies

Diffusion of policy innovations is concerned with predicting or explaining patterns of policy adoptions among different political jurisdictions. While applied at both the state and local government level (Walker 1969), the majority of the studies in the cross-jurisdiction diffusion literature concentrate on state policy innovations (Daley and Garand 2005, Berry and Berry

1999), leaving the determinants and patterns of local level policy diffusion less explored by scholarly research. Thus, it remains unsettled if patterns of diffusion and determinants of policy adoption at the state level remain consistent at the local level.

Moreover, the studies that do examine local level policy diffusion have been rather limited both in the scope of the study and in the policy area. These include, among others, work on the diffusion of city level gun control (Godwin and Schroedel 2000); city level adoption of anti-smoking laws (Shipan and Volden 2008); city-level diffusion of Climate Change Protection(CCP) membership (Vasi 2006); county-level CCP membership (Zahran et al. 2008); city level living wage adoption (Martin 2001); county level siting of prisons as an economic development tool (Hoyman and Weinberg 2006); diffusion of Local Agenda 21 policies in Germany (Kern, Koll, and Schophaus 2007).

Table 6-1 presents a summary of relevant diffusion studies at the local level, including main findings and regression methods used to test the hypotheses.

Table 6-1. Summary of local government diffusion studies

Study	Aim	Framework	Regression model	Findings
Hoyman and Weinberg (2000)	Rural prisons siting	Internal and external determinants	Cox proportional hazard	-Demographic characteristics of each county affect the relative likelihood of a prison siting more than its economics. -Human capital and owner occupied housing, population density were positive predictors (counties with dense population and more owner-occupied units were less likely to adopt). -No regional diffusion patterns existed.

Study	Aim	Framework	Regression model	Findings
Goodwin and Schroedel (2000)	Adoption of gun control policies	Regional diffusion	Logit	-Adoption was associated with demographic and political characteristics of the communities, including population density, education, year of city incorporation, political culture, and ethnic makeup. -Regional variables were also significant. Focusing events, the establishment of new interest groups, the presence and strength of regional associations, promotion of a new policy image.
Martin (2001)	Living wage ordinance	New-institutionalist framework	Logit	-Influence of outside networks: political conditions played a larger role in the diffusion and adoption of living wage laws than economic conditions such as urban poverty. -Population size was positively correlated to adoption of living wage. -Two political/geographic variables were significant: Democratic vote and Southern location.
Shipan and Volden (2008)	Adoption of antismoking policies	Vertical and horizontal diffusion	Standard event history analysis, Logit	- Identified 4 mechanisms of diffusion: learning from earlier adopters, economic competition among proximate cities, imitation of larger cities, and coercion by state governments. -Larger and wealthier cities were more likely to act independently. -Cities were more likely to adopt the policies if neighboring cities had done so.

Study	Aim	Framework	Regression model	Findings
Lindblad (2006)	Adoption of performance measures in economic development	Structuralism and agency perspectives (organizational characteristics, local government forms, and external forces)	Multinomial logistic regression	-Organizational characteristics had the greatest impact on adoption (cities with written plans were more likely to adopt). -Interest groups were less important that organizational structure and agency.
Kern, Koll, and Schophaus (2007)	Diffusion of Local Agenda 21 policies	Internal and external determinants		-Diffusion is influenced by pioneering cities, regional diffusion, and "bi-lateral transfer" within metropolitan regions, and through vertical transfers between cities and the Länder (states). -Size and resources of cities influence diffusion.
Vasi (2006)	Participation in cities for climate protection (CCP) program	Diffusion of organizational innovations, sociological theories on social movements	Event history analysis	-Population, form of government, education, organizational resources, political orientation, and environmental orientation are collectively weak predictors. -Per-capita level of education and government expenditures increased the likelihood of CCP membership. -Adoption is influenced by local governments' spatial and administrative proximity to previous adopters. -Environmental degradation is a weak predictor.

Study	Aim	Framework	Regression model	Findings
Zahran, et al. (2008)	County participation in CCP	Collective action	Logit	-Risk vulnerability variables (including total natural hazard casualties between 1960 and 2004, temperature change projected from 2004 to 2099, and coastal proximity) were all found to increase the likelihood of CCP membership. -The socio-economic capacity variables (including voting trends the percent of residents who recycle, and number of non-profit environmental) significantly increased the likelihood of CCP membership. -Percentage of workers in carbon-intensive industries decreased the odds of CCP participation, but hazardous air pollutant emissions per capita were a statistically insignificant variable.

6.3. Hypotheses development

Berry and Berry's (2007) interpretation of the policy diffusion framework suggests that diffusion studies can and should include both external diffusion and internal determinant variables in the analysis. They explicitly recognize that explaining the adoption of any specific policy is likely to require attention to a set of variables that are ad hoc from the point of view of innovation theory but that consider the context surrounding the issue in question. That is, certain variables may be rationally relevant in one policy context, such as large fundamentalist populations for the adoption of lotteries, but not in another.

This research is grounded in the belief that a variety of predictors influences the extent of green infrastructure planning and policy adoption by US local governments. The quantitative analysis of this paper tests hypotheses from the external diffusion and internal determinant literature by examining major factors such as political culture, group influence, and demographics.

6.3.1. Internal factors

6.3.1.1. Demographic characteristics

I expect demographic and political factors to be directly correlated to adoption of green infrastructure planning. Based on prior policy innovation studies at the local level (*e.g*., Shipan and Volden 2005, Godwin and Schroedel, 2000), I hypothesize a high percentage of a jurisdiction's population with a bachelor or higher degree positively influences green infrastructure adoption. Educational attainment has been used as an explanatory variable by several studies in the diffusion literature. Vasi (2006), for example, used an event history analysis model to measure the likelihood that a city would join CCP based on a combination of its intrinsic characteristics and its spatial and administrative proximity to other CCP-members. He found a significant positive correlation between educational attainment and adoption of climate protection measures by US municipalities.

The literature on policy diffusion suggests that size and wealth of a jurisdiction also are positively related to adoption of innovative policies (Kern, Jörgens, and Jänicke 2005, Shipan and Volden 2008). A review of previous innovation research reveals a number of studies that indicate that socioeconomic characteristics of the population, including per capita income, are directly correlated to adoption of innovation. Walker's work, for example, demonstrated that states that are larger, wealthier, and more industrialized adopt innovative policies more quickly than smaller, less affluent states (Walker 1969). In the environmental policy innovation literature at the local level, Kern, Koll, and Schophaus (2007) found that the cities in Germany with "sufficient" financial resources were most likely to adopt Local Agenda 21 policies.

Larger organizations are usually more innovative, partly because of the greater availability of economic and skilled labor resources (Rogers 2003). Communities with adequate capacity and resources are more likely to entail in comprehensive and resource-consuming initiatives, such as green infrastructure planning (West 2004).

Thus, based on the policy innovation studies discussed above, I hypothesize that the size and wealth of a jurisdiction, as measured by the total population and per capita income, are predictors of adoption of green infrastructure initiatives.

Political and voting history is likely to predict adoption of green stormwater infrastructure. Political orientation has been used as an explanatory variable in several studies of state innovativeness in civil rights, welfare, and education policy areas (*e.g.*, Grossback, Nicholson-Crotty, and Peterson, 2004). Democrats and Green Party supporters are typically more likely than Republicans to place a priority on environmental issues, and municipalities with a high percentage of these voters are arguably more likely to adopt policies that protect the environment. In the policy diffusion literature at the local level, Zahran et al. (2008) found that a high percentage of residents who vote for the Democratic Party significantly increased the odds that a municipality would participate in climate protection planning. Democrats are historically more interested in environmental issues, thus I hypothesize that jurisdictions with a larger portion of its electorate voting as Democrats are more likely to adopt green infrastructure.

Based on the previous consideration, this paper seeks to demonstrate that:

H1. The internal determinant variables representing education, wealth and voting history have a positive influence on adoption of green infrastructure strategies.

6.3.1.2. Environmental support and awareness

Policy entrepreneurs are individuals who promote and advocate for policy innovations. Previous studies in the policy diffusion literature highlighted the role that outside actors and policy entrepreneurs can have in influencing local policy adoption decisions (Boyne and Gould-Williams 2005). Mintrom and Vergari (1998) focused on the role of policy entrepreneurs in the diffusion of educational policy innovations. While controlling for other factors, they found that the presence and action of policy entrepreneurs increases the probability of legislative consideration and approval of school choice as a policy innovation. The presence of an innovation champion actively supporting a product, policy or idea, has a major positive influence on adoption within an organization (Driessen 2002, Howell and Higgins 1990).

Local government policy entrepreneurs can either work within government (e.g., high-level city employees or elected officials), or try to affect change outside of the government (e.g., community organizers, leaders of interest groups). Within the local government innovation literature, Zahran et al. (2008) found participation in environmental causes and the number of local environmental organizations per-capita to be among the strongest indicators of membership in CCP. Because citizens and NGO's pressure their own government to adopt the innovative environmental policies of other jurisdictions, I expect that the presence of local environmental community groups and green infrastructure champions will have a positive impact on the adoption of green stormwater infrastructure.

Environmental issues can also drive diffusion of innovative environmental policies. Matisoff (2008), among other scholars, found that motivations for policy innovation include environmental conditions and issues. Severe environmental problems and physical characteristics of localities (such as impervious surfaces) may cause water quality issues that conventional stormwater management does not address, prompting jurisdictions to look for alternative, cost-effective solutions to the problem. Based these considerations, I expect the presence of local environmental issues to be a significant predictor of adoption of green infrastructure.

H2. Environmental issues awareness and the presence of advocacy actors have a positive influence on adoption of green stormwater infrastructure.

6.3.2. External determinants

The external determinants include regional diffusion effects (i.e., the influence of neighboring jurisdictions) as well as other contextual characteristics. They differ from the internal characteristics in that they are not specific to the municipalities in the population sample, but rather are regional characteristics that equally affect the subject municipalities and other surrounding communities.

The regional diffusion model suggests that local governments are more likely to adopt policies and programs that have been adopted by neighboring communities. Berry and Berry (1990) found that successful adoption of state lotteries in nearby states increased the likelihood of adoption in other states. Mintrom (1997) found policy innovation in education more probable in a state adjacent to other states that had adopted or considered a certain policy innovation.

Within the framework of external influences, previous studies have outlined how governments officials interact, through meetings and other types of networks, with public officials of jurisdictions that have already adopted a successful innovation, thereby increasing the likelihood of borrowing the new policy (Gray 1973, Mintrom and Vergari 1998). Instead of synoptically evaluating the advantages and disadvantages of every option to solve a problem, policymakers often look for shortcuts to rational decision-making and emulation of policies of other jurisdictions facing similar problems can provide this (Gray 1994, Mooney and Lee 1999, Walker 1969). Accessibility of information and data about design, benefits and obstacles to green stormwater infrastructure planning through the Internet, conference papers and proceedings, USEPA case studies and other sources facilitate knowledge dissemination and may encourage officials to engage in this type of stormwater management activities. Based on these considerations, I hypothesize that it is not the geographical proximity, but rather the familiarity with successful projects implementation in other jurisdictions that encourage local public officials to experiment with green infrastructure.

State and federal policies influence policy diffusion at the local level. Several studies in the diffusion literature address the vertical transfer of policies from states to local governments, or vice versa. How does state-level action influence city-level innovations? On one hand, it is possible that the state’s adoption of a policy would spur local governments to adopt laws. Looking at national-state vertical diffusion patterns, there is significant evidence that higher levels of government can provide incentives and information that make lower level adoption more likely (Walker 1973; Shipan and Volden 2005). On the other hand, state-level adoptions can remove the incentive for local governments to act at all. Shipan and Volden (2008), for example, found that “coercion by state governments” was a factor in the diffusion of anti-smoking policies among US cities.

In the green infrastructure domain, the relevant state and federal regulations affecting adoption are those pertaining to stormwater management, which in the US is regulated by the National Pollution Discharge Elimination System (NPDES) Stormwater Program. Mandated by Congress under the Clean Water Act, the NPDES is a comprehensive two-phased program for addressing the non-agricultural sources of runoff discharges that adversely affect the quality of the water within the United States. Under this program, municipalities (and other discharging facilities) must obtain permits if they allow their discharges to go directly into any clean water sources. Increasingly, the USEPA and some states are emphasizing reduction in runoff volume in stormwater permits with the control of hydrology as the main objective under this approach. In urban areas, this goal can be realized through implementation of green infrastructure practices that effectively reduce imperviousness and facilitate infiltration. Even though there is not (yet) a federal mandate requiring specific implementation of green infrastructure to comply with the NPDES requirement, the USEPA has expressed enthusiastic support for green infrastructure over the years through publishing a series of documents to support stakeholders interested in introducing green action in projects.

Based on the discussion about external determinants I hypothesize that:

H3. Familiarity with successful adoption of green infrastructure in other municipalities influences adoption among local jurisdiction.

H4. Federal and states mandates, such as the NPDES permit programs, and state and federal laws and incentives have a positive influence on green stormwater infrastructure adoption at the local level.

6.4. Data collection and analysis

6.4.1. Survey

The sample frame for this study included 840 municipal officials who work for engineering, environmental, planning or similar offices of incorporated places (cities, towns and other municipalities) with population of 5,000 or higher in the US Census Bureau's 2010 population estimates. 300 respondents completed the survey, for a response rate of 35.7 percent.

For this paper, 292 returned questionnaires containing complete data were used a sample. Figure 6-1 identifies the distribution of the respondents' jurisdiction across the US.

The plurality of the respondents (44) belong to the USEPA region 5 (Midwest), followed by USEPA region 4 (Southeast), while California is the most represented state with 22 respondents. Table 6-2 shows the distribution of survey respondents and sampling frame by USEPA region.

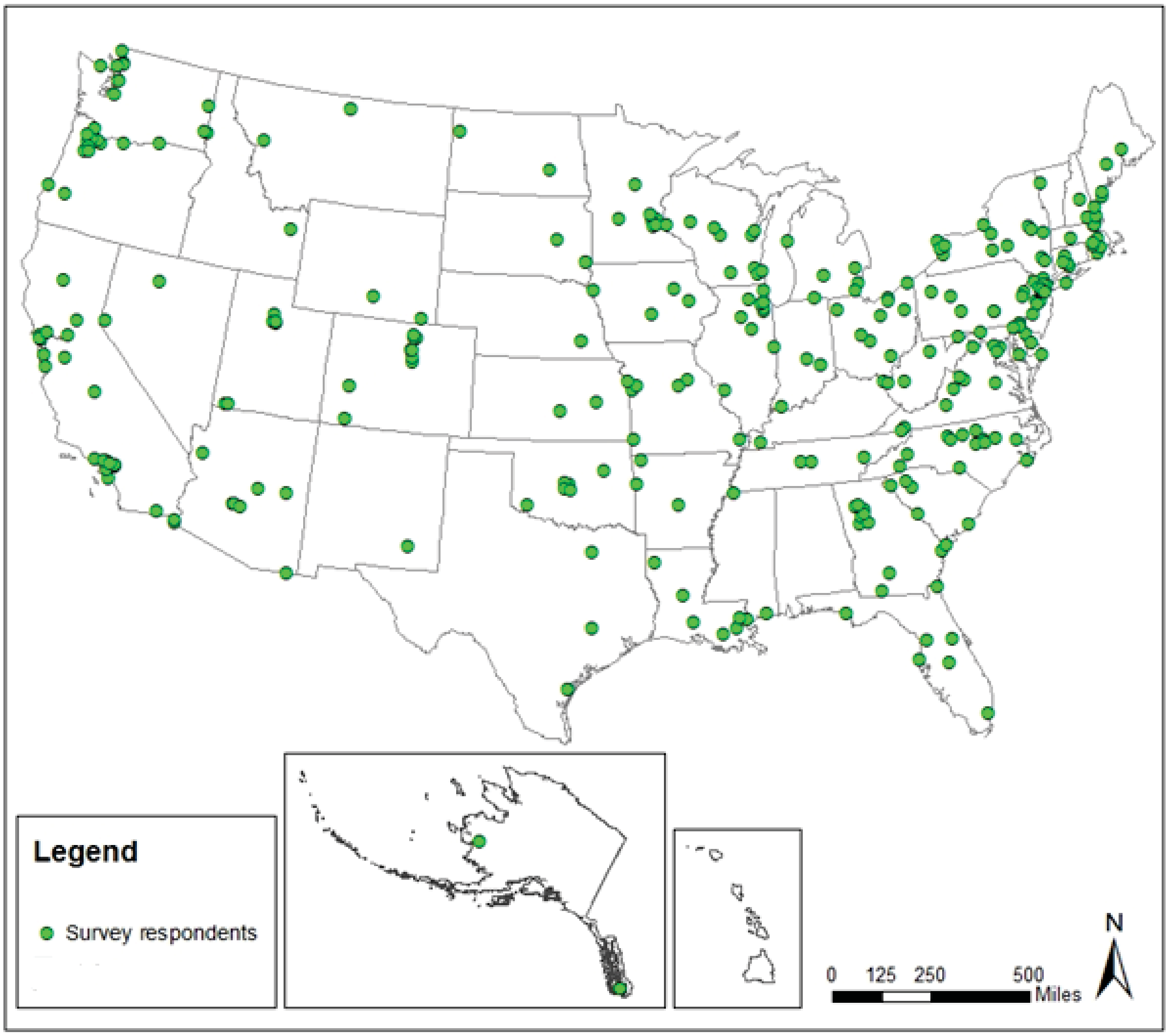

Figure 6-1. Survey respondents

The majority of respondents (89 percent) work in their jurisdiction's public works, engineering or planning department. The majority also have at least 15 years of experience in their role (170 respondents, or 58.0 percent), while 54 (18.5 percent) have 10 to 15 years, another 54 (18.5 percent) have five to nine years of experience, while the remaining 14 (or 5.0 percent) have less than five years of experience.

Table 6-2. Distribution of respondents by USEPA region

USEPA region	States within USEPA region	Survey respondents per USEPA region (percentage)	Sampling frame respondents per USEPA region
EPA 1	CT, ME, MA, NH, RI, VT	32 (10.9)	79
EPA 2	NJ, NY	29 (9.9)	99
EPA 3	DE, DC, MD, PA, VA, WV	30 (10.3)	93
EPA 4	AL, FL, GA, KY, MS, NC, SC, TN	43 (15.0)	130
EPA 5	IL, IN, MI, MN, OH, WI	44 (15.0)	117
EPA 6	LA, AR, OK, NM, TX	20 (6.8)	73
EPA 7	IA, KS, MO, NE	14 (4.8)	51
EPA 8	CO, MT, ND, SD, UT, WY	22 (7.5)	54
EPA 9	AZ, CA, HI, NV	33 (11.3)	100
EPA 10	AK, ID, OR, WA	25 (8.5)	44
	Total	292 (100.0)	100

6.4.2. Dependent variable

The survey instrument included a list of green infrastructure strategies and asked respondents to identify which one, if any, was supported or encouraged by their municipality with a program, policy or other initiative (Table 6-3 lists the green infrastructure tools mentioned in the survey). The responses (number of tools adopted) became the dependent variable in the multiple regression analysis (variable GITools).

When investigating adoption of green infrastructure, different degrees of commitments can be formalized, and a limited dichotomous approach (adoption/non-adoption) cannot address the full complexity of innovation adoption process. Glicks and Hays (1991), for example, distinguish between a “superficial” and “deep” level of innovation adoption. Superficial adoption is essentially a symbolic adoption, while deep adoption involves an extensive commitment of resources through investigatory and enforcement actions. Both degrees of planning engagement, however, can be called adoption and can be treated as functionally equal, even if doing so overlooks the various stages of innovation adoption.

For the purposes of this paper, as mentioned in the introduction, evidence of adoption of a green infrastructure by a jurisdiction is offered by the presence of a program, policy or initiative supporting or encouraging implementation of green infrastructure tools. Therefore, this study is not concerned with distinguishing between “soft” and “deep” adoption, but rather with investigating whether local US governments have started implementing these green stormwater management tools and whether they are embedding the full array of available strategies into policy language. The dependent variable in this analysis is a count data variable that reflects the number of green infrastructure strategies that the respondents’ municipalities require, support or encourage through a program, policy or ordinance. As such, the variable weighs the different green infrastructure equally and is not a measure of the extent of green infrastructure planning effort. The survey instrument included a list of 12 green infrastructure tools and strategies (including “other”) as identified in the pertinent literature, with each strategy coded as 1 if adopted and 0 otherwise. Every respondent could score a minimum of zero to a maximum of 12 adopted strategies.

This count data thus reflect the extent of green infrastructure planning and policymaking measured by the number of available green tools and strategies that municipalities are using to manage stormwater runoff, rather than a method for evaluating and comparing the strength or effectiveness of the adopting policies.

Table 6-3 shows the different green stormwater infrastructure tools included in the survey and the number of municipalities that have adopted them, while Figure 6-2 maps the distribution of scores on the dependent variable (GITools, number of green infrastructure strategies adopted). The majority of the scores fall into the ranges of 0-5. The mean is 4.2, and the standard deviation is 3.1. This map demonstrates the fact that many of the highest-scoring municipalities are located on the west coast (particularly in California) in the northeast Atlantic corridor, and in Southeast region.

Table 6-3. Green infrastructure tools adopted by study jurisdictions

Green infrastructure tool	**Number of jurisdictions with a supporting plan, policy or program**	**Percentage of Jurisdictions with a supporting plan, policy or program**
Green roof	55	18
Rain garden	139	47
Rainwater harvesting (e.g. rain barrels)	118	40
Bio-swales	158	54
Porous pavement	139	47
Planter boxes	83	28
Downspout disconnection	103	35
Land conservation	156	53
Urban tree canopy	153	52
Green parking	74	25
Green street and alleys	58	20
Other	8	3

(*N=292*)

The majority of respondents, 87 percent, indicated that their jurisdiction has a plan or policy supporting the implementation of at least one green infrastructure tool.

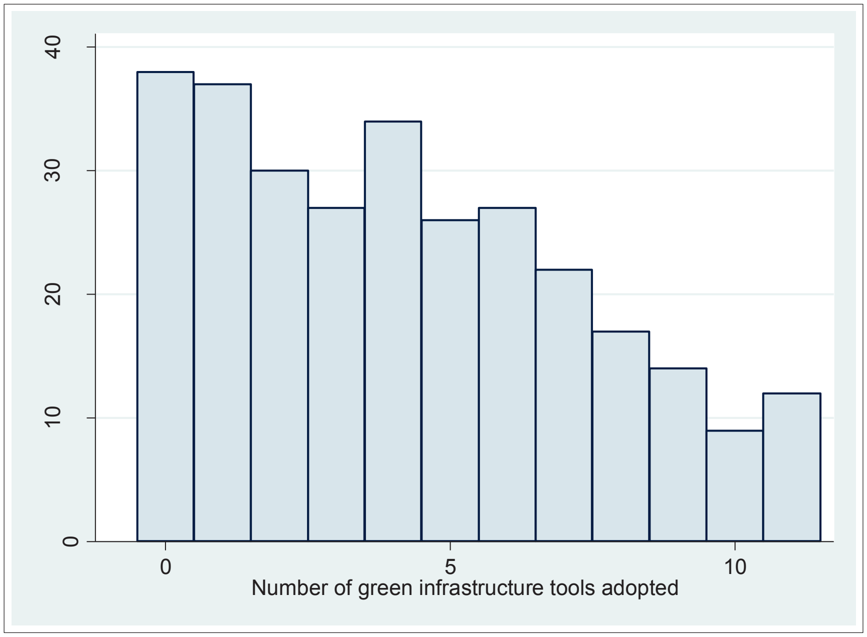

Figure 6-2. Total adopted green infrastructure strategies

Adopted by roughly half of the survey jurisdictions, rain gardens, porous pavement, land conservation, bio-swales and urban tree canopy represent the most common green infrastructure strategies. However, only 31 percent of respondents indicated that their government requires the implementation of green infrastructure policy on either publicly owned property (5 percent), privately owned property (4.5 percent), or both (21.5 percent). In addition, only 16 respondents stated that their jurisdictions have developed a comprehensive green infrastructure plan, suggesting that most local governments have yet to design an interconnected network of green stormwater strategies at the jurisdiction level.

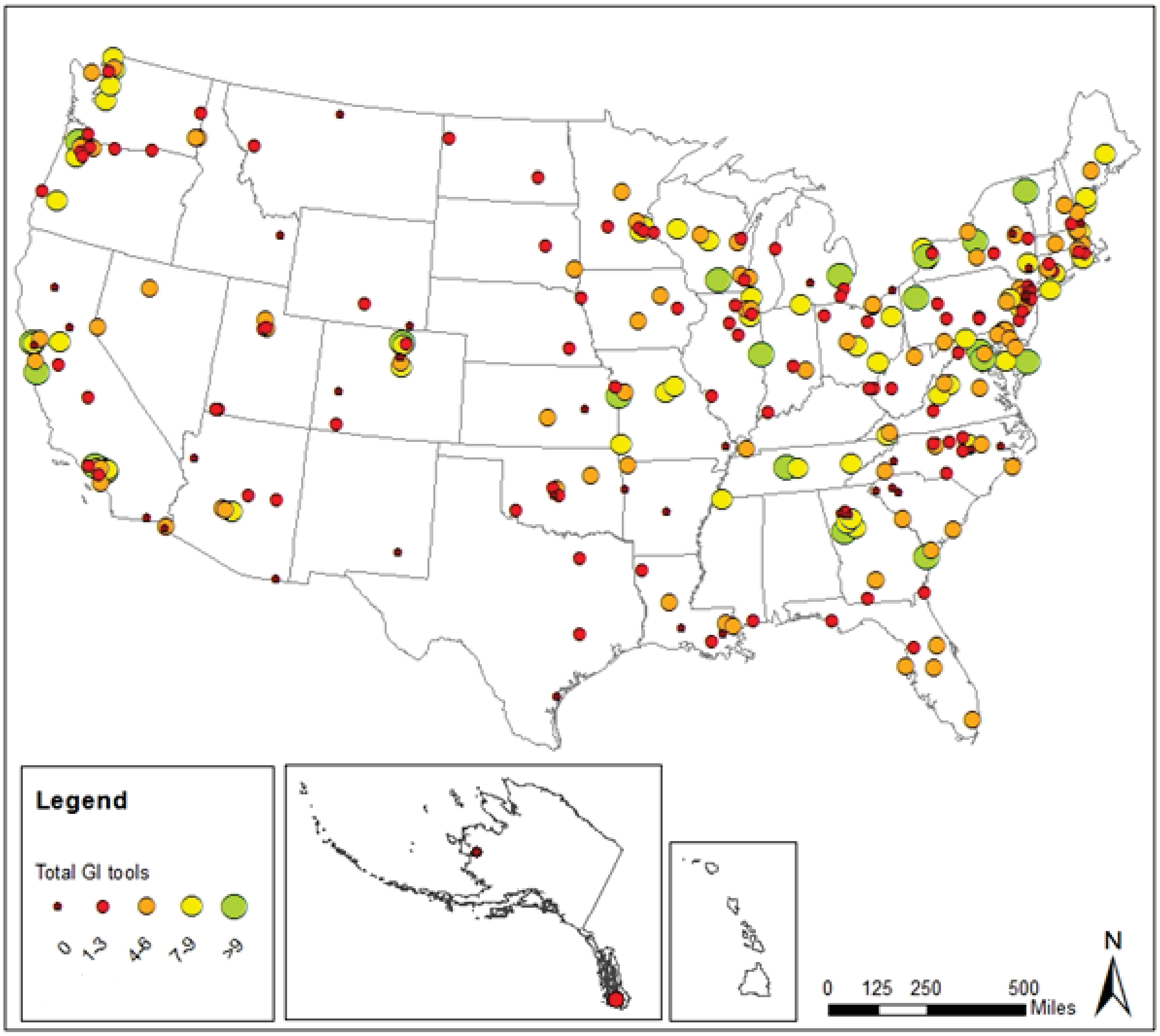

Figure 6-3. Number of green infrastructure tools adopted by jurisdictions

6.4.3. Independent variables

The internal and external determinants examined in this study were chosen based on the literature review on policy diffusion and environmental planning, as described in the previous section (although several additional factors may potentially influence the prevalence of green infrastructure policy making at the local government level). The independent variables not operationalized from the survey results were obtained from secondary data sources such as the 2010 US Census, 2011 American Community Survey (ACS) and others. Table 6-4 summarizes each independent variable and identifies its source and type.

Four independent variables (ID1 to ID4) are grouped as internal characteristics: population, educational attainment, per-capita income, and voting history. I expect each of these self-explanatory variables to positively affect the dependent variable. Variable ID5 measures respondents' environmental awareness in terms of perceived severity of their jurisdictions' environmental problems. To gather information about this topic, survey participants were asked to respond to the following question: "How severe are local environmental problems with water in your jurisdiction on a scale from 0 to 6, with 0 indicating not at all severe, and 6 indicating extremely severe?"

Variable ID6 measures the presence of local environmental interest groups and other NGOs. Data at the county level was downloaded from the National Center for Charitable Statistics website.

Variable ID7 identifies the presence, within the community, of a green infrastructure advocate that supports adoption. This information was obtained with the survey by asking respondents to indicate whether there are key stakeholders and/or a local "champion" (planner, mayor, etc.) in their community who support and promote adoption of green infrastructure. The response options were presented on a Likert scale, with values ranging from 1 for "strongly disagree" to 5 for "strongly agree".

Table 6-4. Independent variables source and description

Explanatory variable	Description	Source
Internal Determinants		
ID1: Population	City population at the time of the nearest census	US Census Bureau 2010
ID2: Percent college graduates	Percent of adults 25 years or older with a bachelor degree or higher	2010 ACS 5-year estimate
ID3: Per capita income	Median income per household, in thousands of dollars	2010 ACS 5-year estimate
ID4: Voting history	Average percent of voters who voted for the Democrat candidate (from county-level voting records for the 2008 and 2012 presidential elections)	Various: The GeoCommunity, http://spatialnews.geocomm.com/features/election2000/; Center for Congressional and Presidential Studies, http://spa.american.edu/ccps/pages.php?ID=12, and others
ID5: Environmental issues awareness	0 to 6 scale	Survey responses
ID6: Environmental interest groups	Total number of environmental nonprofit organizations (county level)	National Center for Charitable Statistics, Core Files, 2010
ID7: Local champion	Likert scale, coded 1-5	Survey responses
External Determinants		
ED1:Familiarity with successful implementation	Likert scale, coded 1-5	Survey responses
ED2: Coastal location	Dichotomous variable indicating if the jurisdiction belong to a coastal county (county level data)	GIS layer by author
ED3: NPDES Phase I&II	Dichotomous variable indicating if the jurisdiction is regulated under the NPDES Phase I or II	Survey responses
ED4: State and federal laws & incentives	Likert scale, coded 1-5	Survey responses

Variable ED1 measures the level of familiarity with successful green infrastructure implementations in other jurisdictions. This study does not offer a comprehensive spatial analysis of regional diffusion patterns for green infrastructure policies. It does, however, acknowledge the potential for regional diffusion by including a measure of municipal officials' familiarity with the outcomes of green infrastructure policy adoption by other communities, thereby introducing the concept of emulation of policies between jurisdictions facing similar problems. A survey question asked the respondents to indicate if they agree or disagree with the statement: "I am aware that other jurisdictions have benefited from utilizing green infrastructure to manage stormwater runoff." The responses were measured on a Likert scale with five response options ranging from "strongly disagree" (coded 1) to "strongly agree" (coded 5).

Variable ED2 is a risk vulnerability variable indicating whether the jurisdiction belongs to a coastal county (thus prone to more frequent flooding), while variable ED3 indicates whether the municipality is regulated under the NPDES (dichotomous variable 0/1.)

Finally, variable ED4 measure the importance of state and federal programs and incentives in influencing a jurisdiction's interest toward adopting green infrastructure, as perceived by public officials. Respondents were asked to indicate their level of agreement with the statement: "Federal and state laws and incentives are very important in my community's interest in green infrastructure." The response options were presented on a Likert scale, with values ranging from 1 for "strongly disagree" to 5 for "strongly agree".

6.4.4. Data screening and analysis

I first screened the data for outliers and missing values by looking for any pairwise or listwise missing values. Then I examined the independent variables for multicollinearity by inspecting the bivariate correlations and calculating the variance inflation factors (VIF).[1] As it is often the case, a small degree of correlation is present among the variables. Particularly, the independent variables measuring income and education had a high correlation coefficient (0.77), indicating potential multi-collinearity problems. Correlations above a threshold of r = 0.7 (Tabachnick and Fidell 2007) are considered high and indicative of possible multi-collinearity among the

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[1] VIF scores above five and a condition number greater than 20 are considered worrisome (Greene 1997, Kennedy 2008).

independent variables. This problem was addressed by testing forms of the models that excluded income or education, as well as versions that included a different functional form of the income variable. The correlations among all the other independent variables did not exceed the r = 0.7 threshold and all of the VIF values were lower than 4.00, corresponding to a tolerance of 0.25 (Hair et al. 2009).

I used the Breusch-Pagan / Cook-Weisberg test and the White's test to verify the presence of heteroskedasticity in the model. Both tests confirmed Homoscedasticity of residuals.

Table 6-5 reports the descriptive statistics of the independent and dependent variables.

Table 6-5. Descriptive statistics of the independent and dependent variables

Explanatory Variable	**Min**	**Max**	**Mean**	**Std. Dev**
Internal Determinants				
ID1: Population	5170	787033	34311.52	59133.49
ID2: Percent College Graduates	2.83	78.14	27.20	15.28
ID3: Per capita income	9064	105236	29525.89	14193.44
ID4: Voting history	0.14	90.07	47.15	17.43
ID5: Mayor	0	1	0.53	0.49
ID6: Environmental issues awareness	0	6	3.60	1.42
ID7: Environmental interest groups	1	528	53.55	96.98
ID8: Local champion	0	3	1.13	0.79
External Determinants				
ED1:Knowledge of successful implementation	1	5	3.81	0.81
ED2: Coastal location	0	1	0.26	0.44
ED3: NPDES Phase I&II	0	1	1.22	0.42

Explanatory Variable	Min	Max	Mean	Std. Dev
ED4: State and federal laws & incentives	1	5	3.70	0.93
GI Tools: Number of green infrastructure strategies supported by a plan or policy	0	12	4.24	3.17

N=292

6.4.5. Validity and reliability

Validity, or the internal logical consistency of a study, is an important consideration in social science research, which is often concerned with gauging concepts that are difficult to define or measure. Construct validity is the extent to which a scale adequately assesses the theoretical concept that the researches says it does, or whether the scale appropriately represents the theoretical constructs underpinning a study. With regard to this paper, all of the determinants included in the analysis have been used in previous studies on diffusion of policy innovations, suggests construct validity is not a concern.

Content validity refers to whether the data are measuring what the researcher claims they are measuring. Most of my data has been gathered from sources such as the Bureau of Economic Analysis or the U.S. Census Bureau, so the face validity of measures such as jurisdiction population and per capita income have already been validated. Content validity concerns, however, could be raised upon variables operationalized with survey data. Measurement error is possible for the variables measured as respondents' perception (e.g. government environmental awareness and relevance of federal and state incentives). The same consideration is true for the dependent variable as the survey respondents may not have been familiar with the specific green infrastructure strategies supported by their jurisdictions' plans and policies.

The reliability of the data used in this study is important for the generalizability of its findings. One way to ensure the reliability is to choose the appropriate statistical technique that fits the theory, research problem, and the shape and distribution of the data. The choice of the analytic tool for the regression analysis is discussed in details in the next section.

6.4.6. Choice of statistical method

The primary objective of the data analysis was to determine the effect of the various independent variables on the number of green infrastructure tools that municipalities have adopted. The dependent variable evaluated in this study is a count variable that can only take on non-negative integer values (e.g., 0, 1, 2, etc.). Linear models such as OLS may not provide the best fit for count variables, as these variables are not continuous and therefore cannot have a normal distribution. The Poisson and negative binomial models are generally considered to be more appropriate methods for count variable data, and the choice between the two methods depends on the nature of the distribution of the dependent variable (Long and Freese 2005).

Negative binomial regression can be used for over-dispersed count data, that is when the conditional variance exceeds the conditional mean, and can be considered as a generalization of Poisson regression since it has the same mean structure as Poisson regression, plus an extra parameter to model the over-dispersion (Long and Freese 2005). If the conditional distribution of the outcome variable is over-dispersed, the confidence intervals for the negative binomial regression are likely to be narrower as compared to those from a Poisson regression model (Long and Freese 2005).

By examining the distribution (Figure 6-4) and dispersion of the dependent variable (mean=4.24, variance=10.05), I concluded that it is over-dispersed.

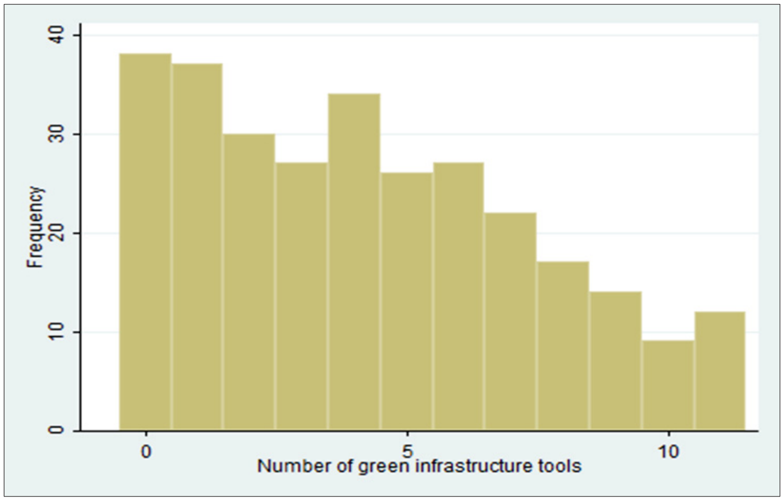

Figure 6-4. Distribution of the dependent variable (number of green infrastructure tools adopted)

As mentioned above, ordinary Poisson regressions have difficulty with overly dispersed data. To confirm that the negative binomial regression is the best-suited analysis method for this data, I ran both a Poisson and a negative binomial regression and compared the results.

The log-likelihood score of the model including all independent variables was lower for the Poisson regression, indicating that it is a less appropriate method for this data (see Table 6-6). The Pearson goodness of fit test result for the Poisson regression indicates that the distribution of the dependent variable does not fit the model well (p value of 0.00). In addition, the over-dispersion parameter in the negative binomial regression significantly differs from zero, also suggesting that the data do not fit a Poisson distribution. Therefore, negative binomial regression is more the more appropriate method for this study dataset and was used for the analysis.

Table 6-6. Log-likelihood and fit test for Poisson and negative binomial regression

Poisson regression	Log-likelihood: -721.68 Goodness of fit test: Pearson goodness-of-fit = 553.9282 Prob. > chi-square=0.00
Negative binomial regression	Log-likelihood: -684.44 Likelihood ratio test of the over dispersion parameter: Chi-square= 74.48 Prob. > chi-square= 0.00

6.5. Regression analysis results

Results of the negative binomial regression are shown in Table 6-7. For ease of interpretation, the table reports the model coefficients as the percentage change in the expected numbers of green stormwater infrastructure tools adopted for a one-unit change in the independent variables and for a one-standard-deviation (SD) change in the independent variables. Table I-1 in

Appendix I shows the results of the regression model in terms of the Incidence Rate Ratio (IRR).[2]

Table 6-7. Percentage of change in count of green stormwater tools adopted

Explanatory Variable	**Per unit change**	**Per standard deviation change**
Internal Determinants		
ID1: Population	0.0	-0.1
ID2: Percent College Graduates *	0.8	12.1
ID3: Per capita income	0.0	-6.9
ID4: Voting history	0.0	0.2
ID5: Environmental issues awareness *	5.9	8.5
ID6: Environmental interest groups **	0.1	12.9
ID7: Local champion **	21.1	20.0
External Determinants		
ED1: Familiarity with successful implementation **	20.9	16.7
ED2: Coastal location	10.8	4.6
ED3: NPDES Phase I&II *	-17.5	-7.9
ED4: State and federal laws & incentives	-4.1	-3.8

N=292

* *Significant at the 0.1 level*

** *Significant at the 0.01 level*

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[2] In a negative binomial regression, the incidence rate ratio is a ratio based on the rate or incidence of counts (of the dependent variable). We can interpret the regression coefficients as incidence rate ratios instead of difference between the logs of expected counts. The parameter estimates, which can be expressed as the difference of two logs (equal to the log of their quotient) can be interpreted as the log of the ratio of expected counts (ratio). Furthermore, what is referred to as a count is technically a rate, *i.e.* the number of events per time (or space). Hence, we could interpret the regression coefficients as the log of the rate ratio, which explains the "rate" in incidence rate ratio (Long and Freese 2005).

The analysis reveals that six variables are statistically significant predictors of the number of green stormwater infrastructure tools adopted by a community. Of the internal determinants variables, the percent of residents with a bachelor degree or higher (ID2), environmental issues awareness (ID5), the presence of environmental organizations (ID6) and a local champion supporting adoption of green infrastructure (ID7) are statistically significant in the regression.

As expected, the estimated count of adopted green infrastructure strategies increases as the number of residents with higher education increases (for every one-standard-deviation increase in the percent of residents with a bachelor or higher degree, the number of green infrastructures tools adopted increases by 12.1 percent). Total population (ID1), per capita income (ID3), the percentage of votes for the Democratic party (ID4) are not statistically significant, so H1 only receives partial support.

The regression output supports hypothesis H2. As Table 6-7 shows, a standard deviation increase of the value of ID6 increases the expected count of adopted green infrastructure strategies by 8.5 percent, while for every additional standard deviation increase of the number of environmental interest groups in the county, the expected number of green infrastructure strategies adopted increases by 12.9 percent. Additionally, ID8 has a strong positive impact on the predicted value of the dependent variable. For each additional leader who supports and promotes green infrastructure adoption, the predicted number of tools adopted increases by 21 percent.

Surprisingly, among the external determinants, I found that ED2 (coastal location) and ED4 (state & federal laws and incentive) are not statistically significant. Variable ED2 is a measure of the percentage of the MSA lying at or below 3.5 meters in elevation, thus is a measure of climate impact risk. ED4 measures the perceived importance of state and federal laws and Laws when considering green infrastructure adoption. Regulations and incentives can provide legal foundations to encourage green infrastructure adoption voluntarily or mandatorily to local communities.

ED1 (familiarity with successful implementation by other jurisdictions) and ED3 (community subject to NPDES requirements) appear statistically significant in the analysis, supporting hypotheses H3 and H4. As expected, the count of adopted green infrastructure strategies is positively associated with the value of ED1. I found that a standard deviation increase in ED1 increases the expected count of adopted tools by 16.7 percent. Somewhat surprisingly, ED3 has a negative impact on the value of the independent variable. Local government designation as MS4 subject to the requirements of the NPDES significantly decreases the expected count of adopted green infrastructure tools by 7.9 percent.

6.6. Discussion

The statistical analysis tested four hypotheses about the characteristics of municipalities that are engaged in green infrastructure planning. Table 6-8 summarizes the results.

In this paper, I sought to predict the adoption of green stormwater infrastructure, measured by the number of tools supported by policies and programs, among municipalities in the US and to investigate whether adoption is driven primarily by local political, demographic, economic, or environmental conditions.

The internal political-social characteristics, which include environmental issues awareness, and community environmental activism (local champion and environmental interest groups), are the most influential variables in the quantitative analysis. This finding is consistent with previous diffusion of innovation literature studies that identified support from the community, political leaders, business, industry, and other institutions to be among the keys for successful implementation of an innovation (Zahran et al. 2008, Vasi 2006).

Table 6-8. Summary of hypotheses and research findings

Hypotheses	**Results**
H1. The internal determinant variables representing education, wealth and voting history have a positive influence on adoption of green infrastructure strategies	Partially supported, only education proved to be a predictor
H2. Environmental issues awareness and the presence of advocacy actors have a positive influence on adoption of green stormwater infrastructure	Supported
H3. Familiarity with successful adoption of green infrastructure in other municipalities influences adoption among local jurisdiction	Supported

H4. Federal and states mandates, such as the NPDES permit programs, and state and federal laws and incentives have a positive influence on green stormwater infrastructure adoption at the local level	Partially supported

The climate protection literature, for example, suggests that municipalities with a history of community environmental activism or environmental awareness are more likely to engage in climate protection planning (Betsill 2001, Bulkeley and Betsill 2005). Zahran et al. (2008) found that participation in environmental causes and the number of local environmental organizations per-capita to be among the strongest indicators of membership in climate protection planning.

The presence of active environmental interest groups that local governments can work with is an important factor advancing green infrastructure adoption. Environmental groups such as The Conservation Fund have invested in recent years to promote and encourage green infrastructure approaches to stormwater management, and may be valuable partners for local jurisdictions by supporting their green planning agenda and increasing community understanding with outreach and education initiatives.

The presence of an outspoken and supportive leader can help spur the adoption of innovative policies and products (Driessen 2002). In general, an innovation champion has an important role in advancing a new idea in an organization and makes a paramount contribution to the innovation by actively and enthusiastically promoting its progress through the critical stages (Rogers 2003). This accords with the regression results, which indicate that the presence of a green infrastructure champion within the community has a positive influence on adoption. A local government staff expert or a strong political leader can advance implementation of green infrastructure by providing technical and/or political guidance to other municipal officials and to the public through the adoption process.

The regression results do not strongly support the hypothesis that demographic characteristics of a community are statistically significant predictors of adoption of green infrastructure, since only education emerges as a statistically significant variable in the analysis. The internal demographic characteristics of population, income, and voting history appear to have no influence over the adoption or pursuit of green infrastructure adoption. This result contrasts with findings of previous studies in the diffusion literature that found jurisdictions' wealth and size to be predictors of environmental innovation adoption (*e.g.*, Vasi 2006, Martin 2001, Shipan and Volden 2008). These unexpected results may be a consequence of the variable nature of the relationship between population, income, and green infrastructure adoption. For example, several of the study jurisdictions with higher than average population and per capita income (*e.g.,* Bristol, CT) have adopted fewer green infrastructure strategies than smaller and less affluent communities (*e.g.,* Mount Vernon, WA). This may reflect the fact that a number of wealthy communities, even if they possess the financial capability of adopting green infrastructure, may be more conservative and thus prefer conventional approaches to stormwater management. In contrast, several less affluent communities may resort to green infrastructure strategies rather than expanding costly grey infrastructure, or simply belong to regions that are traditionally more environmentally progressive such as the Pacific Northwest.

Finally, the regression results indicate that communities regulated by the NPDES are expected to adopt fewer green infrastructure strategies. This contrasts with the hypothesis that stormwater dischargers regulated by the NPDES would make use of green infrastructure to comply with permit terms, limitations and conditions. Green infrastructure on its own will not attain water quality standards in impaired water bodies in urban and suburban areas. However, incorporating green infrastructure into TMDLs can point the way toward implementation actions that can reduce stormwater runoff loads and erosive effects, and help meet pollutant loadings identified in the TMDL (EPA 2008). The analysis results may indicate that, even if green infrastructure planning is becoming mainstream, widespread incorporation of these practices is currently not commonplace and communities may still prefer different approaches to meeting regulatory compliance requirements.

6.7. Conclusions

This study investigated underlying factors that may predict US municipalities' adoption of green infrastructure strategies for stormwater management, as measured by existence of a policy, program or initiative supporting one or more of these tools. Various socio-economic, demographic, and environmental variables were included in the analysis.

While this study provides several insights into the diffusion of green stormwater infrastructure planning at the local scale, several limitations need to be acknowledged.

First, this research has the potential for measurement error in the dependent variables because survey respondents may not have been familiar with the specific strategies and questions in the survey. Measurement error is also possible for some of the independent variables, particularly the variables measured as respondents' perception (e.g. government environmental awareness and relevance of federal and state incentives). The survey respondents may not have been aware of the level of support for green infrastructure planning in their community, or they may not have been comfortable speculating. This type of measurement error could also reduce the reliability of the results, but should not introduce bias.

Second, this model analyzed only a handful of environmental, sociopolitical, and economic variables. Future research should include additional predictors to improve the explanatory power of the model and provide policy-makers a more complete picture and greater insights into green infrastructure adoption across the US.

Third, the dependent count variable used in this analysis is a measure of the diversity of green infrastructure tools supported by a policy or program, and does not account for the extent, effectiveness or thoroughness of each municipality's green infrastructure adoption efforts. The purpose of this study, however, as noted throughout the paper, is to examine the breadth of green infrastructure policy-making in municipalities measured in terms of number of green infrastructure strategies embedded in policies or programs' language, not to evaluate the effectiveness of the policies or the extent of green infrastructure adoption.

The analysis findings point to several ways in which the federal government, states, and advocacy organizations can assist municipalities in adopting green infrastructure policies. There is an opportunity to develop broad scale support for green infrastructure by increasing understanding of this innovation. Among the numerous potential strategies to promote adoption throughout the US is the completion of high profile projects, in a variety of climatic and environmental settings, which demonstrate the implementation and outcomes of these technologies. Such projects should be aggressively promoted and brought into public arena through media campaigns.

Another strategy could be recruiting individuals from local governments, NGOs, and development communities to become green infrastructure champions. As supported by the adoption literature and by the findings of this paper, the presence of strong, charismatic individual who vigorously promotes green infrastructure may help an organization to overcome indifference or resistance and provide technical and/or political leadership during the adoption process.

Non-profit organizations and environmental interest groups play an important role in furthering adoption of green infrastructure programs. In addition to providing technical leadership, environmental groups can help increasing the support base by implementing education and outreach programs targeted to the adopting community. Several organizations throughout the US have already invested considerable resources to promote and encourage green infrastructure approaches to stormwater management, and this valuable partnership with local jurisdictions should be further explored and exploited.

The use of green infrastructure as a mean to help reduce pollutant loads and maintain the natural hydrology of a watershed is clearly on the rise. Overall, by analyzing what factors are predictors of green infrastructure adoption, this research can help build a framework to design incentives and plans suited to specific communities, and pave the way for future research on opportunities for municipalities to overcome institutional barriers to the adoption of these plans and policies.

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7. Findings, recommendations and conclusions

This chapter includes an overview of the research purpose and summary of findings, theoretical and practical implications, study limitations and recommendations for future research.

7.1. Problem statement and research goals

Green infrastructure is increasingly recognized as a valuable approach to urban and regional landscape planning, and has been the subject of lengthy discussion and action in the US, moving closer to the center of both public and intellectual discourse on stormwater management, planning and sustainability (Benedict and McMahon 2006, Randolph 2011). In the past decade, climate change and water quality issues have emerged as key drivers to green infrastructure thinking, particularly in urban areas where the amount of impervious surface profoundly alters natural drainage patterns (Mell 2008). Impervious surfaces contribute to water degradation because they limit infiltration of rainfall and snowmelt, with subsequent increase in volume of water runoff resulting in severe stream bank erosion and water pollution. Strategic green infrastructure planning has been promoted as an innovative approach to managing wet weather in urban landscapes, and as a way of mitigating and controlling climatic change impact in the face of a potential increase in the frequency and severity of extreme events.

Cities across the US are considering integrating green infrastructure tools into federal regulatory programs for municipal separate storm sewer systems, combined sewer overflows, and total maximum daily loads as cost-effective, sustainable, and environmentally friendly means to comply with the Clean Water Act requirements. Due to the relative novelty of green infrastructure, however, proponents of green infrastructure struggle with counteracting negative attitudes and resistance to change. A wealth of literature on attitude change and persuasion in social psychology has continuously lent support for the critical impact of attitude on behavior, information processing and social judgment. In the context of green infrastructure, a deeper understanding of factors that influence the attitude of actors involved in making decisions about stormwater management is paramount to spur diffusion of green infrastructure practices. Yet, little if any scholarly work has investigated how local planners, engineers, and other local government staff members perceive green infrastructure. This research addresses this gap by analyzing results of a nationwide survey of municipal officials' perceptions of green infrastructure.

Building on theories of innovation diffusion and technology acceptance, the purpose of this dissertation is to uncover factors that influence attitudes of local government staff members toward adoption of green stormwater infrastructure, and determinants that drive adoption by local government entities. By doing so, this research informs both the scholarly literature on innovation adoption and green infrastructure policy. From the former perspective, this study tests the applicability of diffusion of innovation and technology acceptance models as they relate to measuring the perceived attributes of green infrastructure. It also promotes understanding of what factors shape the attitudes of local jurisdiction officials. In addition, this research adds to the innovation adoption literature by applying the internal and external determinants framework to the domain of green infrastructure adoption at the local government level. In terms of policy implications, by analyzing what factors are key determinants of green infrastructure perceptions and adoption, this study benefits proponents of green infrastructure who can apply the findings to further effective outreach strategy formulation and policy development.

7.2. Summary of key findings

In Chapter Four, I investigated the applicability of Rogers' theory of innovation diffusion as it relates to measuring the perceived attributes of green infrastructure and to predicting municipal officials' attitudes toward adoption of these stormwater management strategies. The results of a heteroskedastic ordinal logit model indicate that the odds of a favorable disposition toward adoption of green stormwater infrastructure are greater for younger professionals and higher perceived levels of resources, relative advantage, compatibility, trialability. They also reveal that complexity and observability are not significant predictors. In addition, officials who perceive a higher degree of risk associated with green stormwater infrastructure appear less likely to have a favorable disposition toward adoption.

In Chapter Five, I developed and tested a theoretical model grounded on technology acceptance, diffusion of innovation and organizational theories to identify factors that influence the attitudes of local jurisdiction officials toward adoption of green infrastructure. Findings of structural equation modeling analyses partially support the hypothesis regarding the link between innovation characteristics and attitudes toward adoption, revealing that perceived usefulness has a significant direct influence on attitude. They also confirm significant indirect effects of perceived compatibility, perceived internal readiness and perceived ease of use on respondents' attitudes toward adopting green infrastructure.

In Chapter Six, I investigated the impact of demographic, political-institutional, economic, and environmental variables on the extent of local green infrastructure planning, as measured by the number of green infrastructure tools adopted. Results of a negative binomial regression analysis indicate that the level of education, environmental awareness, and the presence of a champion and environmental interest groups have a positive direct influence on the expected number of green infrastructure tools adopted by a community.

7.3. Contribution to scholarly literature

This dissertation complements the many studies built upon Rogers (2003) original work and adds to the diffusion of innovation and technology acceptance model empirical literature. To the best of my knowledge, this research is the first study to test the applicability of elements of these theoretical frameworks to investigate municipal officials' perceptions of green infrastructure and adoption by local jurisdictions using data from a nationwide survey. As such, it contributes to the growing body of diffusion of innovation literature by applying this theory to the domain of local government environmental policy.

The elements from the technology acceptance model and diffusion of innovation theories included in this analysis appear largely applicable to the investigation of municipal officials' attitudes toward green infrastructure adoption. However, the results do not support theory in all areas, suggesting that green infrastructure differs from other innovations. Overall, the results confirm that perceived usefulness is a major belief that influences attitude toward green infrastructure use (and eventually lead to acceptance), and that the effect of perceived ease of use on attitude is mediated by perceived usefulness. This finding accords with the work of Davis (1989), who suggests that perceived ease of use could be a causal antecedent to perceived usefulness, as opposed to a parallel, direct determinant of innovation usage. In other words, systems that are easy to use should be systems that are also perceived as useful for people in their jobs. Ease of use can be considered a pre-requisite for useful technologies.

The statistical significance of relative advantage, compatibility, trialability, perceived resources and perceived risk is consistent with much of the prior studies on innovation adoption (*e.g.,* Driscoll and Dupagne 2005, Meuter et al. 2005, Yi, Fiedler, and Park 2006, Ostlund 1974, Lin 1998, Kolodinsky, Hogarth, and Hilgert 2004**)**. I found that green infrastructure attributes of complexity and observability are not statistically significant determinants of municipal officials' attitude toward adoption. This result was unexpected since much of the existing literature on innovation adoption indicates that complexity and observability are predictors of adoption behavior (Ostlund 1974, Ozaki 2011, Pankratz, Hallfors, and Cho 2002, Pannell 2001). However, prior studies also suggest that observability and complexity are weak predictors of adoption (*e.g*., Buonanno et al. 2005, Ostlund 1974), while others suggest that the role of these variables in the adoption process is not clear or not significant (*e.g.,* Lee and Kang 2013**,**Karnowski and White 2002).

With regard to the drivers of green infrastructure adoption, the importance of community environmental activism and local government environmental awareness in the statistical analysis is consistent with prior studies that identify support from the community, political leaders, business, industry, and other institutions to be among the keys for successful implementation of environmental protection innovations (Bulkeley and Betsill 2005, Wheeler 2008, Zahran et al. 2008). The results for the internal demographic characteristics, however, markedly differ from those of previous studies. While education level appear to be a significant predictor of green infrastructure, the statistically insignificant results for income, voting history and population contrast with prior studies that found one or more of these internal demographic variables to be significant indicators of adoption (Vasi 2006, Zahran et al. 2008, Kern, Koll, and Schophaus 2007, Martin 2001). It appears, therefore, that other factors are more important in determining the diversity of green stormwater infrastructure.

Overall, the results of this study provide a useful application of theories of innovation adoption and technology acceptance applied to the domain of green stormwater infrastructure and local government innovation adoption, and paves the way for future research on this topic.

7.4. Implications for practice

This study benefits proponents of green infrastructure who can apply the findings towards effective education and outreach strategy formulation and policy development. The outcomes of this research provide, for example, valuable feedback for the USEPA, or other federal and state agencies and organizations, so they may more effectively promote the diffusion of green infrastructure and assist local governments through the adoption process.

A better understanding of the factors that shape a favorable disposition toward adoption of green infrastructure could spur implementation of these environmentally friendly stormwater management strategies and promote their diffusion more widely. Three attributes - relative advantage, compatibility, trialability- were found, together with perceived resources, perceived risk and age, to be statistically correlated with attitudes toward adoption of green stormwater infrastructure. Based on the analysis, proponents should focus on promoting the relative advantage (and usefulness) of green infrastructure. Rogers (2003) recommended emphasizing the relative advantage of an innovation as individuals pass through the innovation-decision process, as this is when they seek information regarding the innovation's advantages. This is especially important with those innovations, such as green infrastructure, where the relative advantage is not always clear to individuals. With green infrastructure implementation, benefits and desired consequences of adoption may not be immediately seen, and thus, motivation to adopt may be low. Therefore, to emphasize the advantages of stormwater systems integrating both traditional and green infrastructure, it is recommended to establish a communication campaign, activate peer networks, and encourage peer support within the target population.

Perceptions of compatibility and risk associated with green infrastructure adoption should not be overlooked. Although it would be difficult to influence perceptions of compatibility, this attribute appears to be a good indicator of where to focus resources when promoting sustainable stormwater management practices. One of the most effective approaches to making professional comfortable with green infrastructure innovations could be a gradual introduction of these practices, and encouraging local jurisdictions to reach out to one another as well as use the Internet and overseas examples as resources. The completion of high profile projects demonstrating green infrastructure can improve adoption by encouraging people to understand these technologies as being compatible with their systems of values and beliefs, and by reducing uncertainty and perceived risk associated with adoption. The more observations made available by adopters, the more knowledge, concepts and education local jurisdictions will have at their disposal to create their own set of practices and stormwater management system. As the diffusion of innovation literature shows, people gain knowledge about an innovation from their social networks. Therefore, implementing green infrastructure through pilot projects may be a viable way to increase motivation to adopt these strategies. Without knowledge, adoption (and consequently diffusion) does not happen.

Descriptive and regression results indicate that the expected number of green infrastructure tools adopted by a community increases significantly with the presence of a strong champion and environmental interest groups within a community. In addition, results also indicate that younger engineers, planners and other local jurisdiction officials who think that green infrastructure strategies are useful because they reduce runoff pollution and improve efficacy of stormwater management systems have a more favorable attitude toward adoption of these practices. Based on these findings, younger professionals who may already have a positive attitude toward adopting green infrastructure could be recruited to champion these tools. This could increase both their and the public's awareness and knowledge of the issues facing stormwater management and the benefits of integrating green infrastructure into conventional stormwater systems.

There is an opportunity to develop broad scale support for green infrastructure by increasing understanding of these techniques. As more data becomes available, researchers will be able to evaluate the successes and failures of green infrastructure efforts in specific municipalities based on their actual impact on stormwater runoff.

Finally, it is important to reiterate that while engineers, planners and other municipal officials were the focus of this study, they are not solely responsible for the adoption of green infrastructure. While staff members' expertise is important for providing technical support and leadership, elected officials such as the mayor, members of the city council and of the planning commission are important for political support. Contractors, practicing professionals and the community at large also play a role in changes to the regulatory environment. Therefore, change agents should not overlook the larger organization context in the strategy formulation process.

7.5. Limitations and recommendations for future research

This study was designed to provide a better understanding of how local government officials across the US view adoption of green stormwater infrastructure, and to investigate the relationship between the diversity of green infrastructure tools supported by policies or programs in local jurisdictions, and the factors influencing adoption. This was accomplished by analyzing data from a nationwide survey of engineers, planners and other staff members and managers, who shared their impressions of green infrastructure adoption and related activities in their jurisdiction. Compared to other data collecting methods, the survey instrument allowed gathering information that possess a better description of the relative characteristics of the general population involved, therefore offering greater generalization of findings.

Because of the high representativeness brought about by the survey method, this research uncovered statistically significant results and provided useful insights into perceptions and determinants of adoption of green stormwater infrastructure at the local government level. However, several study limitations need to be acknowledged. The following considerations and recommendations offer additional avenues to further understanding of green stormwater infrastructure and environmental innovations adoption.

First, while the diffusion of innovation model appears to be a useful framework to identify significant attitudes predictors, results do not support theory in all areas, suggesting that green infrastructure differs from other innovations. Rogers' model was originally developed to explain the adoption process of discrete items by discrete adopters. The applicability of this framework to investigate attitudes toward adoption of green infrastructure, however, is limited due to the complex nature of green infrastructure and stormwater management. Multiple practices, strategies, and policies constitute green infrastructure, and adoption of these approaches involves several stakeholders, such as developers, citizens, local government officials and environmental groups, and multiple dimensions, including social, political and institutional.

Furthermore, the formation of a favorable or unfavorable attitude toward green infrastructure adoption depends on the attributes of green infrastructure, but also on the individual traits of the survey respondents. Generally speaking, attitude should be interpreted at multiple levels for its complexity. Walmsley and Lewis (1984), for example, suggest attitude comprises three components: (1) cognitive component, involving a person's belief / knowledge about the attitude object; (2) affective component, which involves a person's feelings / emotions about the attitude object; and (3) behavioral (or conative) component, or the way the attitude we have influences how we act or behave. Future studies should seek to develop a framework that includes elements of behavioral theories to further the understanding of attitudes of municipal staff member and other stakeholders toward green infrastructure adoption.

Second, the focus of this study is the relationship between green infrastructure characteristics as perceived by local government staff members and attitudes toward use of these strategies to manage stormwater runoff. As such, measurement error is possible for some of the independent variables measured as respondents' perception (*e.g.*, presence of a green infrastructure champion and government environmental awareness). Survey respondents may not have been aware of the level of support for green infrastructure planning in their community, or they may not have been comfortable disclosing or speculating about the severity of environmental problems in their jurisdiction. Similarly, this research has the potential for measurement error in the dependent variable measuring the number of green infrastructure tools adopted by local jurisdictions, as survey respondents may not have been familiar with the specific strategies and questions in the survey. While these types of measurement error could reduce the reliability of the results, they should not, however, introduce bias.

Third, the regression analysis of local government adoption only included a handful of environmental, sociopolitical, and economic variables. Future research should include additional predictors to improve the explanatory power of the model and provide policy-makers a more complete picture and a greater understanding of the green infrastructure adoption process at the local level. Additional research is also needed to analyze the regional diffusion of green infrastructure adoption, and to address how other factors, such as organizational, environmental and individual characteristics affect individual perspectives toward green infrastructure. In addition, more quantitative studies are needed to uncover obstacles and their effect on the adoption of green infrastructure strategies. Rules and regulations at the local level, for example, can pose challenges to adoption of green infrastructure strategies. Road and zoning ordinances, building and health codes may limit the design and installation of green infrastructure in urban landscapes. Further, the permitting process for green infrastructure implementation may be lengthy and burdensome, causing potential adopter to favor traditional infrastructure projects over green solutions.

Fourth, the dependent count variable used to measure adoption of green infrastructure tools by municipalities captures the diversity of green infrastructure strategies embedded in policy language rather than the strength of adoption. As such, it weighs all green infrastructure strategies equally, and does not account for the effectiveness or thoroughness of each municipality's green infrastructure adoption efforts. Among the green infrastructure tools included in the survey, some are burdensome and contentious undertaking, while others require minimal commitment of financial and technical resources. In addition, full adoption of green infrastructure by local governments entails a complex bundle of activities, policies and programs. Integration of green stormwater infrastructure into local codes and ordinances, creation of design manuals and technical advisory groups, and implementation of fees and incentives to promote green infrastructure indicate a great level of commitment to green infrastructure adoption. Future studies on this topic should develop a framework for evaluating the level of green infrastructure adoption and the efficacy of the green infrastructure policies adopted by local entities.

Fifth, the complex nature of green infrastructure adoption, involving a number of context-specific aspects, points to the need of using research instruments based on both surveys and textured case studies focusing on smaller geographical regions. Additional research should investigate the political environments of adopting communities, and how they influence the adoption process. This could be accomplished with in-depth interviews with key decision makers, elected officials and other stakeholders. Federal and state governments, environmental groups, community organizations and citizens groups indirectly influence adoption by mandates, incentives and public pressure. Opinions and evaluation from government executives will be more thorough and useful to understand the institutional context surrounding green infrastructure adoption process in different regions across the US. For example, most western US states are under the doctrine of prior appropriation, therefore water rights and interstate obligations are a concern when considering green infrastructure adoption. In this context, the legality of green infrastructure techniques for harvesting stormwater (*e.g.*, rain barrels) is questionable, as ownership of stormwater is not clear.

Lastly, a larger survey sample would allow for a more in-depth investigation of the unique sub-dimensions of each of the attributes of green infrastructure. With a larger sample, for example, a researcher could consider which components of relative advantage are the best predictors of intent to adopt. One could also consider each of the non-significant attributes in detail to see, for example, if some aspects of complexity are actually significant predictors of intent to adopt. Additional research is recommended to determine the constructs and to define more precisely the measurement of each. Overall, the results of this investigation suggest that efforts to further refine the attribute scales for use in predicting receptiveness of green stormwater infrastructure are needed.

Appendix A. Survey webpage

2013 Nationwide Green Infrastructure Survey

WELCOME!

This survey asks about thoughts and perceptions of green infrastructure for stormwater management. Its goal is to collect views about this topic from public officials throughout the US. We will use this information to develop a better understanding of experiences with green infrastructure and assess the current state of practice.

Fanny Carlet, doctoral candidate in Planning, Governance and Globalization in the Urban Affairs and Planning program at the National Capital Region campus of Virginia Tech (http://spia.vt.edu/uap), is leading the study. If you have questions about this survey, please contact Fanny at (857) 488-2946 or fanny09@vt.edu.

The questionnaire should take about 10 minutes to complete. Your individual response will remain confidential, and we will release no information that can identify you. Any data that we report will be only aggregated results across survey respondents.

To begin the survey, please click on the following link. It will take you to a website hosted by the Qualtrics survey software that we are using for this project:

CLICK HERE TO TAKE THE SURVEY

Thank you for participating, your input is very valuable to our research!

Want to learn more about green infrastructure?

As defined by the EPA, green infrastructure is an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services. When used as components of a stormwater management system, green infrastructure practices such as green roofs, rain gardens, and vegetated swales can recharge groundwater, provide wildlife habitat, cool urbanized areas, improve air quality, beautify neighborhoods and reduce stress on combined sewer systems. For mor information and case studies visit http://water.epa.gov/infrastructure/greeninfrastructure/.

Contact Information:

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IRB Documentation:

This research project has been approved by the Virginia Tech Institutional Review Board for protection of human subjects.
To access the approval letter, click on the following link: IRB-Approval-Letter

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College of Architecture and Urban Studies
Privacy / Security / Accessibility

Figure A-1. Survey webpage

Appendix B. Survey recruitment letter and postcard

Dear {title, last name},

I am a doctoral student from Virginia Tech focusing on green infrastructure practice as part of my dissertation. My research seeks to understand public officials' experience with green infrastructure for stormwater management and to assess the current state of practice among local governments across the United States.
Because of your role as (title) in (jurisdiction name), I am hoping you will provide some brief feedback regarding green infrastructure practice in your community. Your experience provides a unique perspective that is vital to this research.

In order to collect your feedback, please complete the short survey below. It should take approximately 10-15 minutes to complete. Your responses will be kept confidential and you will not be identified in any products (dissertation, articles, etc.) resulting from this research.

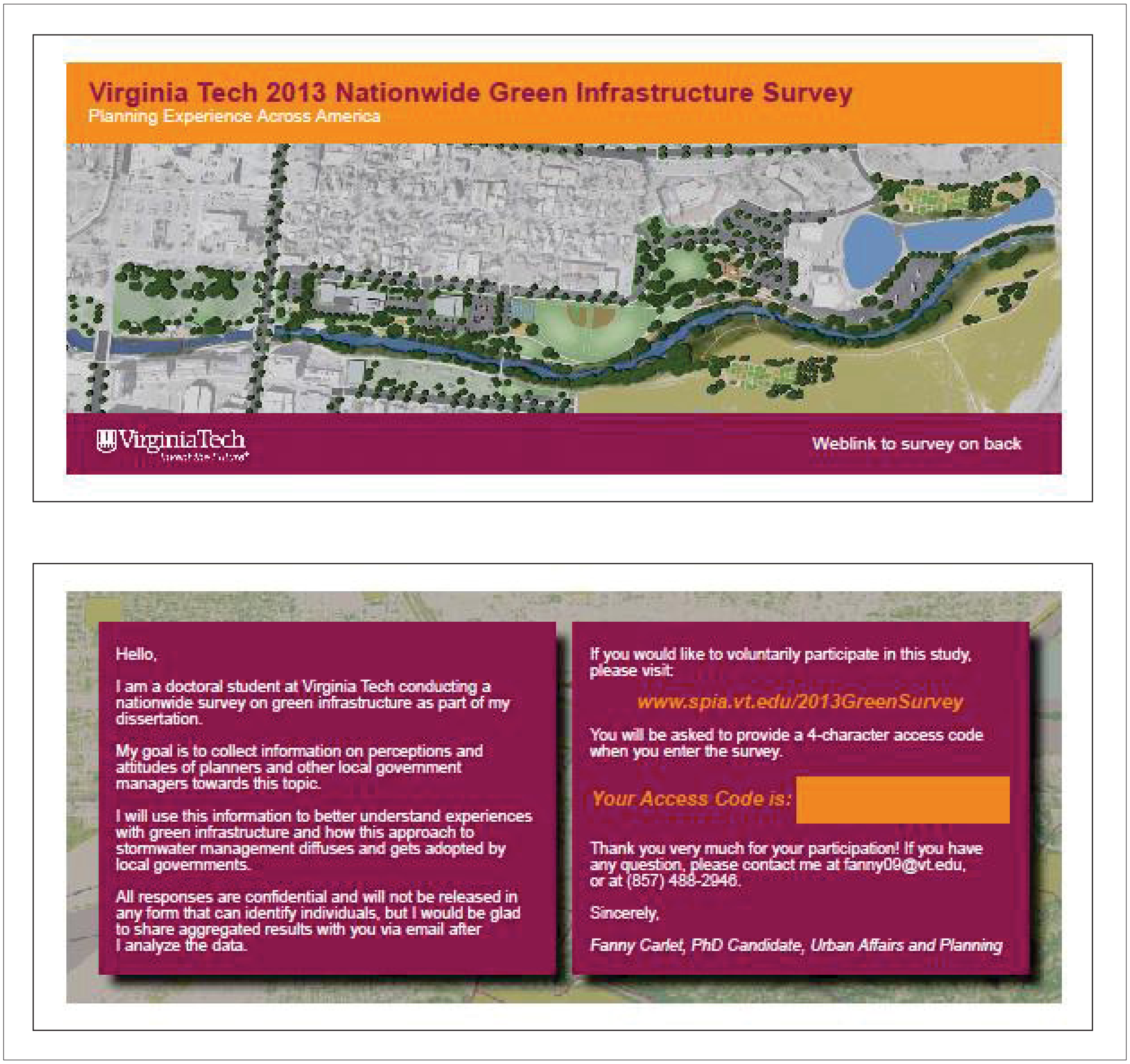
Follow this link to the Survey: {survey link}

Your personal survey access code is: {access code}

The benefit of your participation in this project will be aiding research that increases the understanding of the drivers of green infrastructure practice. If at any point within the survey you do not wish to continue, you may choose to stop.

Please contact Fanny Carlet at fanny09@vt.edu, (857) 488-2946 with any concerns or questions regarding the survey.

Thank you in advance for your consideration and willingness to participate.



Virginia Tech 2013 Nationwide Green Infrastructure Survey

Planning Experience Across America

VirginiaTech

Invent the Future

Weblink to survey on back

Hello,

I am a doctoral student at Virginia Tech conducting a nationwide survey on green infrastructure as part of my dissertation.

My goal is to collect information on perceptions and attitudes of planners and other local government managers towards this topic.

I will use this information to better understand experiences with green infrastructure and how this approach to stormwater management diffuses and gets adopted by local governments.

All responses are confidential and will not be released in any form that can identify individuals, but I would be glad to share aggregated results with you via email after I analyze the data.

If you would like to voluntarily participate in this study, please visit:

www.spia.vt.edu/2013GreenSurvey

You will be asked to provide a 4-character access code when you enter the survey.

Your Access Code is:

Thank you very much for your participation! If you have any question, please contact me at fanny09@vt.edu, or at (857) 488-2946.

Sincerely,

Fanny Carlet, PhD Candidate, Urban Affairs and Planning

Figure B-1 Survey postcard

Appendix C. Complete survey instrument and IRB approval letter

Welcome!

This survey asks about thoughts and perceptions of Green Infrastructure for stormwater management. Its goal is to collect views about this topic from public officials throughout the US. We will use this information to develop a better understanding of experiences with Green Infrastructure and assess the current state of practice nationwide.

We are interested in your personal thoughts on Green Infrastructure, so no working experience or specific knowledge about these tools are needed in order to complete the questionnaire. However, you may choose to forward the invitation and individual Access Code to another manager, planner, engineer or public official within your City Government if you think he/she would be more suited to participate in this survey.

Fanny Carlet, doctoral candidate in Planning, Governance and Globalization with the Urban Affairs and Planning department at the National Capital Region campus of Virginia Tech (http://spia.vt.edu/uap), is leading the study. If you have questions about this survey, please contact Fanny at (857) 488-2946 or fanny09@vt.edu.

The questionnaire should take about 10 minutes to complete. If at any point within the survey you do not wish to continue, you may choose to stop. Your individual response will remain confidential, and we will release no information that can identify you. Any data that we report will be only aggregated results across survey respondents.

Thank you very much for your support!

Q1. Please enter your 4-character survey access code. We use this code to control access to the questionnaire and to avoid duplicate entries. You can find the code in the invitation email, postcard and letter we sent to you in which we also provided the web address for this survey.

Q2. In what state is your community located?

Q3. What level of government do you work for?

- County
- City, town, village or other local
- Other (please specify)

Q4. What type of office or department do you work for?

- Administrative/finance/assessment
- Economic/community development
- Planning/zoning
- Public works/water
- Engineering
- Environmental or natural resources
- Elected official

- Other (please specify)

Q5. What is your position in your office or department?

- administrative/clerical
- technical
- supervisory
- managerial
- other (please specify)

Q6. How many years of professional experience do you have in your field of work (including previous and your current positions)

- less than 2 years
- 2 to 4 years
- 5 to 9 years
- 10 to 15 years
- more than 15 years

Q7. What is your jurisdiction's form of government?

- Council-Mayor (Strong Mayor)
- Council-Mayor (Weak Mayor)
- Council-Manager
- Commission
- Other (please specify)
- I don't know

Q8. Is your jurisdiction subject to Phase II or I stormwater regulations under the U.S. Clean Water Act?

- Yes
- No
- I don't know

We will start the main part of the survey with some questions about Green Infrastructure practices in your jurisdiction and about your personal perspective on Green Infrastructure. Borrowing from the US Environmental Protection Agency's website, we define Green Infrastructure as:

"an adaptable term used to describe an array of products, technologies, and practices that use natural systems - or engineered systems that mimic natural processes - to enhance overall environmental quality and provide utility services. As a general principle, Green Infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff."

When used as components of a stormwater management system, Green Infrastructure practices such as green roofs, porous pavement, rain gardens, and vegetated swales can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits.

We recognize that some of these questions may not be in your area of expertise, but we are very interested in your personal views so please respond as best you can.

Q9. Does your jurisdiction have a program, policy or initiative supporting or encouraging one or more of the following Green Infrastructure tools:

	Yes	No	I don't
green roof			
rain garden			
rainwater harvesting			
rain barrels)			
bio-swales			
porous pavement			
planter boxes			
downspout			
land conservation			
urban tree canopy			
green parking			
green streets and			
other (please specify)			

Q10. What types of incentive does your municipality offer to encourage the use of Green Infrastructure practices on private property?

- Stormwater fee discount.
- Development incentives (zoning upgrades, expedited permitting, etc.)
- Grants.
- Rebates & installation financing.
- Awards & recognition programs.
- Tax abatements.
- Other (please specify).
- There are no incentives mechanisms currently in place.
- I don't know.

Q11. Does your jurisdiction integrate the following Green Infrastructure tools into local codes or ordinances:

	Yes	No	I don’t
green roof			
rain garden			
rainwater harvesting			
rain barrels)			
bio-swales			
porous pavement			
planter boxes			
downspout			
land conservation			
urban tree canopy			
green parking			
green streets and			
other (please specify)			

Q12. Does your jurisdiction require the implementation of Green Infrastructure on

- Publicly owned property.
- Private property.
- Both private and publicly owned properties.
- Neither private not publicly owned properties.
- I don't know.

Q13. Has your jurisdiction adopted one (or more) of the following policies/plans:

	Yes	No	I don’t know
Green Infrastructure plan			
Green infrastructure policy statement			
Sustainability Policy statement			
Sustainability Plan			
Climate Change Policy Statement			
Climate Action Plan			
Community Energy Plan			

Q14. How important is the issue of stormwater management in your community?

- Extremely Important
- Very Important
- Somewhat Important
- Neither Important nor Unimportant
- Somewhat Unimportant
- Very Unimportant
- Not at all Important

Q15. How severe are local environmental problems in your jurisdiction on a scale from 0 to 6, with 0 indicating not at all severe, and 6 indicating extremely severe?

Q16. The following statements are about your individual thoughts and perspective on Green Infrastructure. Please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with each of them.

	Strongly disagree	Disagree	Neither Agree nor disagree	Disagree	Strongly disagree
Green Infrastructure is an effective approach to stormwater management.					
It is apparent to me that Green Infrastructure reduces the public cost of stormwater management infrastructure and provides flood control.					
I am aware that other jurisdictions have benefited from utilizing Green Infrastructure to manage stormwater runoff.					
It is apparent to me that the aesthetic qualities of green infrastructure boost property values, enhanced recreation, and improved quality of life.					
Green infrastructure is undervalued by the development community.					
I see how Green infrastructure provides valuable wildlife habitat and restore ecosystems.					
Green Infrastructure reduces the urban heat island effect and Climate Change offsets.					
Many Green Infrastructure practices filter air and water pollutants.					
Research has yet to prove benefits of Green Infrastructure.					

Traditional grey infrastructures alone manage stormwater runoff more effectively than integrated systems combining traditional and Green Infrastructure					

Q17. We are interested in your personal perspective on the use of Green Infrastructure in your jurisdiction. Please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the following statements. (Display if number of "Yes" in Q11 is less than 6)

	Strongly disagree	Disagree	Neither Agree nor disagree	Disagree	Strongly disagree
My jurisdiction's personnel has acquired the necessary technical knowledge and experience on Green Infrastructure by implementing tools on a trial basis.					
Green Infrastructure would be accepted in my community.					
Funding would be an issue should my organization decide to expand or retrofit existing stormwater infrastructure using Green Infrastructure.					
Local rules and policies are a barrier to adoption of Green Infrastructure in my community.					
Limited appropriate sites for Green Infrastructure implementation (due to soil, space, etc.) is not an issue in my jurisdiction.					
Federal or state laws and incentives are very important in my community's interest in Green Infrastructure.					
I support and promote adoption/continuous use of Green Infrastructure in my jurisdiction.					
Green Infrastructure is compatible with my jurisdiction's environmental goals.					
My jurisdiction could experiment with Green Infrastructure techniques through small-scale pilot projects before full adoption.					

There are key stakeholders and/or a local "champion" (myself, planner, mayor, etc.) in my community who support and promote adoption of Green Infrastructure.					

Q18. We are interested in your personal perspective on the use of Green Infrastructure in your jurisdiction. Please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the following statements. (Display if number of "Yes" in Q11 is equal or greater than 6)

	Strongly disagree	Disagree	Neither Agree nor disagree	Disagree	Strongly disagree
My jurisdiction's personnel has acquired the necessary technical knowledge and experience on Green Infrastructure by implementing tools on a trial basis.					
My community supported and easily accepted Green Infrastructure.					
Funding was not an issue when my organization decided to expand or retrofit existing stormwater infrastructure using Green Infrastructure.					
Local rules and policies are a barrier to adoption of Green Infrastructure in my community.					
Limited appropriate sites for Green Infrastructure implementation (due to soil, space, etc.) is not an issue in my jurisdiction..					
Federal or state laws and incentives are very important in my community's interest in Green Infrastructure.					
I support and promote adoption/continuous use of Green Infrastructure in my jurisdiction.					
Green Infrastructure is compatible with my jurisdiction's environmental goals.					

My jurisdiction experimented with Green Infrastructure techniques through small-scale pilot projects before adoption.
There are key stakeholders and/or a local "champion" (myself, planner, mayor, etc.) in my community who support and promote adoption of Green Infrastructure.

Q19. The following statements are about your personal thoughts and experiences with Green Infrastructure. Please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with each of them.

	Strongly disagree	Disagree	Neither Agree nor disagree	Disagree	Strongly disagree
I have a difficult time understanding how Green Infrastructure works.					
Green Infrastructure tools are easy to learn and implement.					
I feel intimidated by new technologies such as Green Infrastructure tools.					
Experimenting with pilot Green Infrastructure projects before full-scale adoption is very important.					
I easily learn how new technologies such as Green Infrastructure tools work.					
Green Infrastructure techniques are complex.					
It is important for me to get answers to all the questions I have about Green Infrastructure before supporting full adoption.					
I have not doubts adoption of Green Infrastructure would provide multiple benefits to my community.					
The challenges of learning about Green Infrastructure design and implementation overwhelm me.					

Complexity of green Infrastructure influences integration into policy and regulations in my community.	

Q20. We would like to know more about your perspective on cost and risks associated with the use of Green Infrastructure. Please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the following statements.

	Strongly disagree	Disagree	Neither Agree nor disagree	Disagree	Strongly disagree
The cost of implementing Green Infrastructure is too high.					
Green Infrastructure implementation does not constitute a resources burden more than expanding conventional stormwater infrastructure.					
If my jurisdiction were to expand or retrofit existing stormwater infrastructure using Green Infrastructure, funding would not be an issue.					
My jurisdiction has the resources to implement Green Infrastructure.					
I am not convinced about the effectiveness of Green Infrastructure.					
There is not enough information about costs, benefits and risks associated with Green Infrastructure.					
I think traditional stormwater infrastructure is more reliable and delivers better results than integrated systems using traditional and Green infrastructure combined.					
Green Infrastructure techniques are relatively inexpensive.					

Q21. Green Infrastructure may be integrated into existing traditional stormwater management infrastructure. Please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the following statements about the use of Green Infrastructure in your community. (Display if number of "Yes" in Q11 is less than 6)

	Strongly disagree	Disagree	Neither Agree nor disagree	Disagree	Strongly disagree
Integration of traditional grey infrastructure with Green Infrastructure tools could help my jurisdiction to better manage stormwater runoff.					
Adoption of Green Infrastructure to complement traditional stormwater management systems would help reduce the amount of stormwater runoff in my jurisdiction.					
Adoption of Green Infrastructure complementing traditional stormwater management system in my jurisdiction would reduce runoff pollution.					
Adoption of Green Infrastructure to complement grey infrastructure would not improve flood control in my community.					
Green Infrastructure retrofitting could enhance the effectiveness of stormwater infrastructure in my jurisdiction.					
Green Infrastructure fits well with the way my jurisdiction tries to manage stormwater runoff.					

Q22. Green Infrastructure can be integrated into existing traditional stormwater management infrastructure. Its successes or failures, however, may take some time to materialize, and may have yet to become apparent in your community. Regardless, please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the following statements about your expectations. (Display if number of "Yes" in Q11 is equal to or greater than 6)

	Strongly disagree	Disagree	Neither Agree nor disagree	Disagree	Strongly disagree
Complementing traditional grey infrastructure with Green Infrastructure tools is going to help my jurisdiction to better manage stormwater runoff.					
Adoption of Green Infrastructure to complement traditional stormwater management systems is going to reduce the amount of stormwater runoff in my jurisdiction.					
Adoption of Green Infrastructure complementing traditional stormwater management system in my jurisdiction is going to reduce runoff pollution.					
Adoption of Green Infrastructure to complement grey infrastructure is not going to improve flood control in my community.					
Green Infrastructure retrofitting is going to enhance the effectiveness of stormwater infrastructure in my jurisdiction.					
Green Infrastructure fits well with the way my jurisdiction tries to manage stormwater runoff.					

Q23. How informed do you consider yourself to be on Green Infrastructure? Place yourself on a scale from 0 to 10, with 0 indicating not at all informed, and 10 indicating extremely well informed

Q24. From where do you personally get most of your information on Green Infrastructure? Please check all that apply.

- popular press (newspapers, TV, radio, magazines)
- worldwide web or other internet source
- scientific research reports
- research conferences
- colleagues from local public institutions in my jurisdiction
- colleagues from local public institutions in other jurisdiction
- university researchers and analysts

- local non-university, non-agency experts
- personal relationships
- regional or state government agencies
- federal agencies (please specify)
- non-profit organizations
- personal experience and observations
- other (please specify)

Q25. From where do you think you personally get the highest quality information on Green Infrastructure? Please select one.

- popular press (newspapers, TV, radio, magazines)
- worldwide web or other internet source
- scientific research reports
- research conferences
- colleagues from local public institutions in my jurisdiction
- colleagues from local public institutions in other jurisdiction
- university researchers and analysts
- local non-university, non-agency experts
- personal relationships
- regional or state government agencies
- federal agencies (please specify)
- non-profit organizations
- personal experience and observations
- other (please specify)

Q26. Do you have any experience working on Green Infrastructure projects in your jurisdiction?

- Yes
- No

Q27. Do you have any experience working on Green Infrastructure projects in other jurisdictions?

- Yes
- No

Q28. Considering the pros and cons of Green Infrastructure for stormwater management, I believe adoption (or continuous us) of these tools in my jurisdiction in the near future would be

Extremely Good						Extremely Bad
Extremely Easy						Extremely Difficult
Extremely Beneficial						Extremely Harmful
Extremely Likely						Extremely Unlikely

We now would like to ask you a few questions about yourself.

Q29. What is your age?

- 24 or younger
- 25 to 34
- 35 to 49
- 50 to 64
- 65 or older

Q30. What is your gender?

- female
- male

Q31. What is your education background?

- Public administration
- Urban and environmental planning
- Engineering
- City and regional planning
- Business administration
- Architecture
- Forestry/natural resources management
- Other (please specify)

Q32. Please select the highest education level attained:

- Less than high school
- High school or equivalent
- Some college (but no degree)
- Associate degree
- Bachelor degree
- MS, MPA, MBA or other graduate degree
- JD or equivalent
- PhD or equivalent

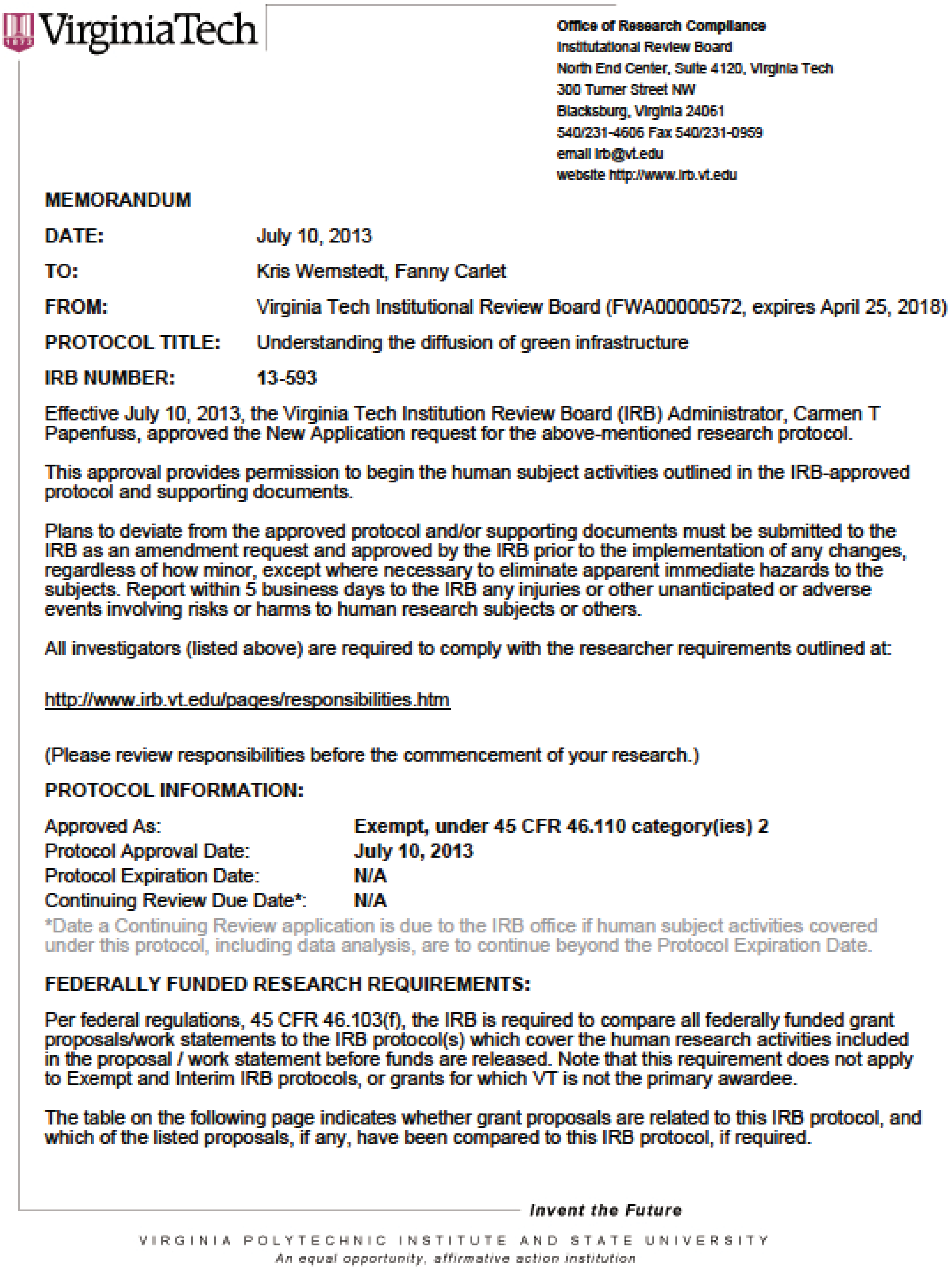
That's it! Thank you for your time and cooperation, we really appreciate your support!

Knowing how much time it took you to complete this survey would help us to improve future survey questionnaires. How much time did it take you to complete this survey (in minutes)?

If you would like us to send you a copy of results from the survey, please indicate your email address or send an email to us at fanny09@vt.edu asking for results.

If you like, please share with us any comments you have regarding the issues addressed in this survey or the survey itself in the space provided.

Virginia Tech IRB approval letter



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MEMORANDUM

DATE: July 10, 2013

TO: Kris Wernstedt, Fanny Carlet

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: Understanding the diffusion of green infrastructure

IRB NUMBER: 13-593

Effective July 10, 2013, the Virginia Tech Institution Review Board (IRB) Administrator, Carmen T Papenfuss, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Exempt, under 45 CFR 46.110 category(ies) 2**
Protocol Approval Date:	**July 10, 2013**
Protocol Expiration Date:	**N/A**
Continuing Review Due Date*:	**N/A**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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Appendix D. Study sample descriptive statistics

Table D-1 Study sample descriptive statistics

Age	**N**	**Percent**
24 or younger	3	1.2
25-34	43	17.2
35-49	96	38.4
50-64	98	39.2
65 or older	10	4.0
Gender		
Male	183	73.2
Female	67	26.8
Level of Education		
Grade School/Middle School 0 0	0	0.0
High School or Equivalent	6	2.4
Some College (No Degree)	13	5.2
Associate Degree	6	2.4
Bachelor’s Degree	135	54.0
MS, MPA, MBA or Other Graduate Degree	87	34.8
JD or Equivalent	1	0.4
PhD or Equivalent	2	0.8
Type of Office		
Economic/Community Development	14	5.6
Planning/Zoning	88	35.2
Public Works/Water	103	41.2
Engineering	31	12.4
Environmental or Natural Resources	4	1.6
Other	10	4.0
Years of Experience		
2 Years or Less	8	3.2
2-4	5	2.0
5-9	43	17.2
10-15	47	18.8
More than 15	147	58.8

Appendix E. Multicollinearity diagnostics

Table E-1. Multicollinearity diagnostics

Variable	VIF	Tolerance	R-Squared
RA	2.79	0.36	0.64
COMP	1.70	0.59	0.41
CPXTY	1.51	0.66	0.34
TRIA	2.17	0.46	0.54
OBS	2.39	0.41	0.58
PRK	3.31	0.30	0.69
PRSS	1.10	0.91	0.09
EXP	1.21	0.82	0.17
AGEGRP	1.06	0.94	0.05
Mean VIF	1.91		

Table E-2. Condition number

Eigenvalue		Condition index
1	3.61	1.00
2	2.68	1.16
3	1.01	1.88
4	0.84	2.06
5	0.68	2.30
6	0.35	3.19
7	0.32	3.34
8	0.23	3.90
9	0.18	4.41
10	0.05	8.21
Condition number		8.21

Appendix F. Ordered logistic regression, proportional odds test and heteroskedastic ordered logistic regression output

Table F-1. Ordered logistic regression results

Variable	Coef.	Std. error	z	p>|Z|
RA	0.47	0.19	2.43	0.015
COMP	0.39	0.18	2.11	0.034
CPXTY	-0.30	0.13	-2.23	0.026
TRIA	0.62	0.21	2.93	0.00
OBS	-0.02	0.19	-0.13	0.90
PRK	-0.59	0.22	-2.62	0.00
PRSS	0.18	0.13	1.44	0.15
EXP	0.26	0.38	0.71	0.47
AGEGRP	-0.58	0.22	-2.56	0.01

Approximate likelihood-ration test of proportionality of odds across response categories:
Chi-squared(9)= 7.28
Prob. > Chi-squared= 0.61

To assess the appropriateness of the model, I used the package OPARALLEL to evaluate whether the proportional odds assumption is tenable (Buis 2013). The post estimation command performs a likelihood ratio test, a score test, a Wald test, a Wolfe-Gould test, and a Brant test comparing the ordered logit model with the fully generalized ordered logit model, which relaxes the parallel regression assumption on all explanatory variables. All of the tests were not significant, indicating that the proportional odds assumption was not violated.

Table F-2. Tests of the parallel regression assumption

	Chi-squared	Degrees of freedom	Prob.>Chi-squared
Wolfe Gould	7.28	9	0.60
Brant	8.54	9	0.48
Score	8.40	9	0.49
Likelihood ratio	7.50	9	0.58
Wald	7.90	9	0.54

Table F-3. Brant test of parallel regression assumption

Variable	Chi-squared	Prob. > Chi-squared	Degrees of freedom
RA	0.00	0.94	1
COMP	0.10	0.75	1
CPXTY	0.65	0.42	1
TRIA	0.84	0.36	1
OBS	0.00	0.99	1
PRK	0.37	0.54	1
PRSS	2.77	0.10	1
EXP	0.18	0.67	1
AGEGRP	0.64	0.42	1
All	8.54	0.48	9

Notes:

A significant test statistics provides evidence that the parallel regression assumption has been violated.

Table F-4. Heteroskedastic ordered logistic regression

	Coef.	Std. error	z	P>|z|
RA	0.37	0.18	2.09	0.03
COMP	0.36	0.16	2.21	0.02
CPXTY	-0.19	0.12	-1.49	0.14
TRIA	0.55	0.20	2.73	0.00
OBS	0.37	0.22	1.63	0.10
PRK	-0.44	0.22	-2.00	0.04
PRSS	0.26	0.11	2.39	0.01
EXP	0.33	0.34	0.96	0.34
AGEGRP	-0.47	0.20	-2.30	0.02
OBS	0.19	0.07	2.45	0.01
PRSS	0.14	0.07	1.98	0.04

Log likelihood= -118, LR Chi-squared (11)= 143.19, Prob.> Chi-squared= 0.00, Pseudo R-squared= 0.37

Appendix G. CFA constructs reliability and validity

I assessed internal consistency of the five constructs using Cronbach’s alpha and evaluation inter-item correlation, which explores whether each item has a higher correlation with the items in its own scale than with those of other scales (item discriminant validity). While the measure of Cronbach's alpha depends on the number of items and sample size when measuring internal consistency, the average inter-item correlation does not (Nunnally and Bernstein 1994). I selected minimum of 0.70 as the lowest acceptable value (Nunnally and Bernstein 1994, Cook and Beckman 2006). Items with inter-item correlation smaller than 0.30 or greater than 0.80.

were candidate for elimination, as values outside this range indicates a modest correlation or redundancy, respectively, and is therefore not desirable (Nunnally and Bernstein 1994). I used Bagozzi, Yi, and Phillips (1991) test[3] to assess the scale discriminant validity. The test provided evidence that constructs are significantly different from one another and further inspections of item cross-loadings are not needed.

Convergent validity was confirmed by determining whether the estimated factor loading of each indicator is significant on its underlying domain (Anderson and Gerbing 1988). The metric for each construct was established by fixing the coefficient for one indicator to 1.00, which becomes the anchor for the latent variable[4]. Other than these fixed loadings, all confirmatory factor loadings were highly significant, with t values ranging from 6 to 15. Therefore, the convergent validity concerns of the 16-item scale were satisfied, suggesting convergent validity was achieved.

Netemeyer, Bearden, and Sharma (2003), however, recommend that for scale development, individual item loadings should be assessed for both statistical significance and magnitude. According to Hair et al. (2009), a rigorous rule of thumb for standardized item-to-factor loading magnitude should be at least 0.5 and ideally 0.7 and higher. Requiring standardize loading to be 0.50 is asking that 25 percent of the variance on the item be shared with the factor. In this study,

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[3] The formula for the discriminant validity is: parameter estimate (phi value) ±1.96 * standard error. If the value is greater than 1.0, discriminant validity has not been achieved and further inspections of item cross-loadings is needed (Bagozzi, Yi, and Phillips 1991).

[4] Since latent variables have no natural scale, models with latent variables require normalization constraints. If constraints are not provided, the model would appear to the software the same as a model with a substantive lack of identification; the estimation routine would iterate forever and never arrive at a solution (StataCorp 2013).

all of the standardized item-to-factor loading magnitudes of each items in the constructs ranged from 0.57 to 0.87, with most loading greater than 0.7. The few lower low loadings were probably due to content overlap and wording redundancy in the survey questions that resulted in correlated measurement error within constructs (Netemeyer, Bearden, and Sharma 2003). Overall, however, these items did not jeopardize the integrity of the constructs, whose averages of completely standardized item-to-factor loading magnitudes varied from 0.66 to 0.76.

Appendix H. CFA, CFA with robust errors and goodness of fit test output

Table H-1. Confirmatory factor analysis results

Measurement	Coef.	Std. error	z	P>|z|
ATTITUDE→AT1	1.000	constrained		
ATTITUDE→AT2	1.006	0.092	10.91	0.000
ATTITUDE→AT3	1.064	0.078	13.64	0.000
PU→PU1	1.000	constrained		
PU→PU2	0.835	0.053	15.63	0.000
PU→PU3	0.755	0.074	10.20	0.000
EU→EU1	1.000	constrained		
EU→EU2	0.969	0.130	7.43	0.000
EU→EU3	0.822	0.118	6.95	0.000
CO→CO1	0.969	0.107	9.03	0.000
CO→CO2	0.786	0.105	7.47	0.000
CO→CO3	1	constrained		
IR→IR1	1	constrained		
IR→IR2	1.091	0.132	8.23	0.000
IR→IR3	0.862	0.101	8.50	0.000

LR test of model vs. saturated: chi-squared(79)= 99.28, Prob.> chi-squared= 0.0612

Table H-2. Confirmatory factor analysis results using robust errors

Measurement	Coef.	Robust std. error	z	P>|z|
ATTITUDE→AT1	1.000	constrained		
ATTITUDE→AT2	1.006	0.111	10.91	0.000
ATTITUDE→AT3	1.064	0.084	12.63	0.000
PU→PU1	1.000	constrained		
PU→PU2	0.835	0.063	13.13	0.000
PU→PU3	0.755	0.087	8.67	0.000
EU→EU1	1.000	constrained		
EU→EU2	0.969	0.146	6.63	0.000
EU→EU3	0.822	0.144	5.69	0.000
CO→CO1	0.969	0.105	9.22	0.000
CO→CO2	0.786	0.113	6.90	0.000
CO→CO3	1	constrained		
IR→IR1	1	constrained		
IR→IR2	1.091	0.168	6.48	0.000
IR→IR3	0.862	0.110	7.78	0.000

Table H-3. Equation-level goodness of fit

Variable	**Variance**					
	Fitted	**Predicted**	**Residual**	**R-squared**	**mc**	**mc-squared**
AT1	0.602	0.354	0.248	0.587	0.766	0.587
AT2	0.756	0.358	0.398	0.473	0.688	0.473
AT3	0.582	0.401	0.181	0.688	0.829	0.688
PU1	0.640	0.485	0.155	0.758	0.870	0.758
PU2	0.509	0.339	0.170	0.665	0.815	0.665
PU3	0.744	0.277	0.467	0.372	0.610	0.372
EU1	0.520	0.268	0.252	0.515	0.717	0.515
EU2	0.600	0.252	0.347	0.420	0.648	0.420
EU3	0.408	0.181	0.226	0.444	0.666	0.444
CO1	0.583	0.337	0.245	0.578	0.760	0.578
CO2	0.677	0.222	0.455	0.327	0.572	0.327
CO3	0.732	0.359	0.372	0.490	0.700	0.490
IR1	0.686	0.354	0.331	0.516	0.718	0.516
IR2	0.573	0.422	0.368	0.533	0.730	0.533
IR3	0.791	0.263	0.310	0.459	0.677	0.459

Notes

mc= correlation between variables and their prediction
mc-squared= Bentler-Raykov squared multiple correlation coefficient

Appendix I. Negative binomial regression output

Table I-1. Negative binomial regression results

Explanatory Variable	IRR (Incidence Rate Ratios)	Std. error	z
Internal Determinants			
ID1: Population	1.00	6.66e-07	0.60
ID2: Percent College Graduates *	1.00	0.004	1.70
ID3: Per capita income	0.99	5.27e-06	-0.99
ID4: Voting history	0.99	0.002	0.01
ID5: Environmental awareness *	1.05	0.032	1.74
ID6: Environmental interest groups **	1.00	0.001	2.87
ID7: Local champion **	1.21	0.048	3.99
External Determinants			
ED1:Knowledge of successful implementation **	1.20	0.058	3.48
ED2: NPDES Phase I&II *	0.82	0.090	-1.70
ED3: Coastal location	1.12	0.106	1.09
ED4: State and federal laws & incentives	0.95	0.048	-0.97

N=292
*   *Significant at the 0.1 level*
** *Significant at the 0.01 level*

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