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Understanding attitudes toward adoption of green infrastructure: A case study of US municipal officials

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ABSTRACT

The objective of this paper is to develop and test a theoretical model grounded in 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' engineers, 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 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 explaining attitudes toward green stormwater infrastructure adoption.

1. Introduction

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). The engineering and ecological concepts underpinning green infrastructure systems are not entirely new as the base principles have arisen over time from multiple disciplines (Mell, 2008; Wright, 2011; Benedict and McMahon, 2006). However, green infrastructure in practice has appeared as part of a novel, environmentally sensitive approach to stormwater management that uses small-scale, natural or engineered technologies and strategies to infiltrate and recycle stormwater runoff. It entails rain gardens, porous pavements, constructed wetlands, rain barrels, and many combinations of these techniques (USEPA, 2000; Clar, 2001; USEPA, 2010). Other practices include preserving environmentally sensitive site features such as riparian buffers, wetlands, valuable (mature) trees, flood plains, woodlands and areas with highly permeable soils (USEPA, 2000, 2007).

Mixed strategies involving both traditional systems and green infrastructure represent innovative and promising

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approaches to stormwater management at the local level (Jaffe et al., 2010). Several communities nationwide and abroad have sought to integrate green infrastructure into their control plans for stormwater runoff and combined sewer overflows, and many more are or will consider similar strategic investment choices soon (Wise et al., 2010). The city of Chicago, for example, is promoting the use of landscape-based green infrastructure practices to infiltrate and harvest rainwater before it enters the combined sewer and stormwater system. The portfolio of initiatives aimed at making the city greener and more sustainable includes green roofs incentives, tree canopy expansion and use of permeable paving materials in parking lanes and public alleys (USEPA, 2010). In Malmo, Sweden, the neighborhood of Augustenborg underwent a regeneration process that included retrofitting the existing drainage systems with retention ponds, ditches, green roofs and green spaces. The project has resulted in a 50% reduction in stormwater runoff rates, and the increase in green space has improved the overall image of the area (Kazmierczak and Carter, 2010).

Planners and others practitioners are increasingly drawing upon the concepts of green infrastructure and its value for managing stormwater runoff while promoting better urban landscapes, land conservation, and urban regeneration. 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 requires action on many fronts, including in the 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 or the attitudes of local planners, engineers, and other local government staff members involved in making decisions about stormwater management. This paper addresses this gap in the scholarly and green infrastructure literature by analyzing data from a nationwide survey of municipal staff members.

My study framework combines elements of the theory of technology acceptance (Davis, 1989) with aspects of diffusion of innovation theory (Rogers, 2003) and organizational theory (Vasi, 2006; Rogers, 2003; Damanpour, 1991) in a complementary manner to investigate how engineers, planners and other professionals working in US local governments perceive key attributes of green infrastructure. 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' attitudes toward adoption of green stormwater infrastructure. 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). While stormwater managers and other officials 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 issues relating to urban stormwater runoff and thus could become change catalysts (Kahan et al., 2011). Thus, a deeper understanding of factors affecting local government officials' attitudes toward adoption of an innovation is important in for assessing how best to disseminate and implement these technologies. Ultimately, the answers to these questions can help us understand some elements of the processes and factors that drive environmental innovation adoption by local governments.

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 present the analysis results and discuss implications for policymaking and diffusion of green infrastructure.

2. Background

Despite the increasing interest in green infrastructure, most local entities face a number of social, institutional and procedural obstacles that limit adoption, and some policy interventions to promote green infrastructure remain unrealized (Brown, 2005; Brown and Farrelly, 2009; Abhold et al., 2011). Recent studies on green infrastructure identify negative attitude toward adoption and resistance to change as common barrier inhibiting the transition to this sustainable stormwater management system (Abhold et al., 2011; Funkhouser, 2007). As local government staff members may prefer to use well-established engineering practices and rely on systems that have been tested rather than risk trying new alternatives (Abhold et al., 2011; Coffman, 2002; Godwin et al., 2008), it is important to understand factors affecting their attitudes toward adoption to best support dissemination of these practices. Perceived limited financial resources and lack of skilled and knowledgeable staff members, perceived complexity of design and technical components, and poor understanding of the benefits associated with implementation are some of the potential sources of resistance and negative attitudes toward green infrastructure. Yet, while stormwater managers and other officials 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 issues relating to urban stormwater runoff. They thus could become change catalysts (Kahan et al., 2011).

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 et al., 2011; Zeldin et al., 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

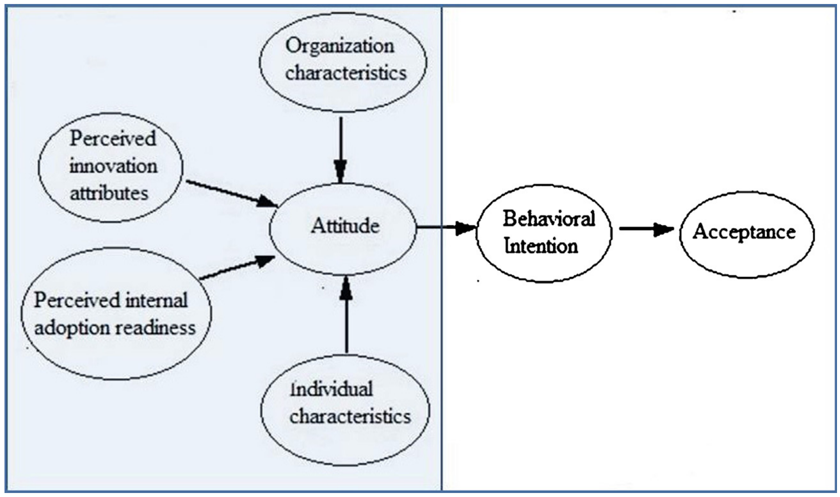

Fig. 1 – Conceptual framework of the role of attitudes in innovation acceptance.

adopting an innovation to the characteristics of the innovation itself (Rogers, 2003; Walker, 2006). The perceived benefits 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). Davis (1989) has advanced one of the most influential models of intra-organizational acceptance,[1] the Technological Acceptance Model (TAM). Specifically, TAM posits that *perceived ease of use* and the *perceived usefulness* of a new technology influence consumers' *attitudes* toward using a new technology, which in turn directly influences intentions to use the technology. The conceptual model in Fig. 1 illustrates the role of attitudes in green infrastructure acceptance and provides a useful heuristic by: (1) identifying factors likely to influence local officials' attitudes toward adoption, and (2) illustrating the role of attitudes in acceptance of green infrastructure.

This paper focuses on the relationships highlighted on the left side of the figure, or the association between diffusion of green infrastructure, elements of the technology acceptance model, and attitudes of engineers, planners and other professionals working in local US government offices. As implied in Fig. 1, attitudes toward adoption are influenced by individual respondents' 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 directly and positively affect attitudes, while the effect of internal adoption readiness is mediated by the other determinants.

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

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

3. Research hypotheses and models

3.1. *Effects of perceived ease of use and perceived usefulness*

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, 1989). 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). 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. With TAM, Davis (1989) defines PU as the degree to which adopters believe an innovation can be integrated into their daily activities (Kleijnen 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. 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 to the green infrastructure innovation context, 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:

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.

3.2. *Effect of perceived internal adoption readiness and compatibility*

Perceived internal adoption readiness (IR) in the present context represents the degree to which local public officials believe their jurisdiction is prepared to adopt and exploit green stormwater infrastructure (Gao et al., 2012; Chwelos et al., 2001). I 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 et al., 2012) and (2) the perceived availability of financial resources to support adoption (Iacovou et al., 1995; Gao et al., 2012; Parasuraman, 2000; Sharma et al., 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.

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, which reduces the rate of adoption and implementation (Olorunkiya et al., 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. Therefore, I hypothesize:

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.

The diffusion of innovation literature suggests compatibility (CO) with an innovation 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). 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, to solve 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 socioeconomic (*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. I hypothesize that:

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.

Fig. 2 summarizes the research model (Model 1), which includes hypotheses H1–H9.

3.3. *Effects of individual and organizational characteristics*

Individual demographic variables, such as age (AGE), also 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 et al., 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.

Organizational characteristics also have been found to influence the adoption decision (Damanpour and Schneider,

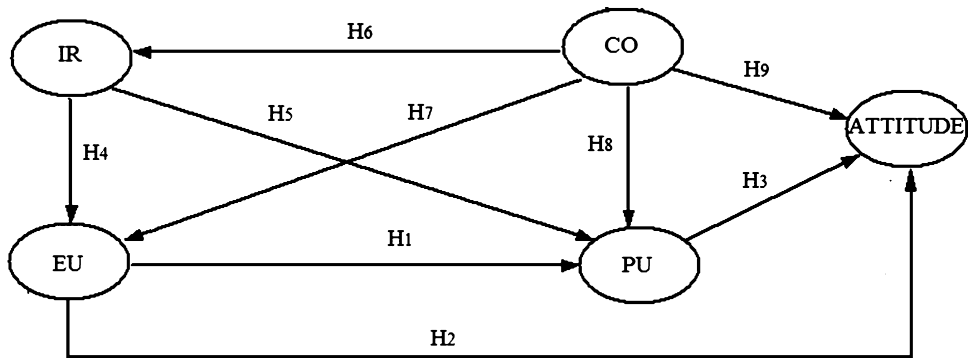

Fig. 2 – Research Model 1. ***Notes*****: ATTITUDE: attitudes of survey respondents toward green infrastructure adoption. IR: perceived internal readiness. EU: perceived ease of use. PU: perceived usefulness. CO: perceived compatibility. H*****n*****: hypothesis number.**

2006, Frambach and Schillewaert, 2002). Among the characteristics at the organizational level, the literature has consistently reported that the size (SIZE) of the organization influences the propensity to adopt. Most studies of policy diffusion among cities 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 et al., 2007). In addition, larger cities can 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).

Based on the above literature, 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.

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

4. Research method

4.1. *Data collection and research instrument*

The data-gathering instrument of this study consists of a three-section questionnaire. The first section contains definitions of terms used in the survey, as well as factual questions about the respondents' work office and jurisdiction. The second section presents items used to measure the independent variables assumed to affect attitudes. The third section includes 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.[2] 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.[3] Table 1 includes the survey's questions used to construct the scales.

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). 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 5000 or higher in the US Census Bureau's 2010 population estimates. A total of 256 returned questionnaires containing complete data constitute the sample used in this paper.

5. Data analyses approach

I used 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

[2] The scales for three innovation attributes (perceived usefulness, ease of use and compatibility) were measured using items adapted from Moore and Benbasat (1991), Karahanna et al. (1999) and Dupagne and Driscoll (2009). The items to assess perceived internal readiness were adapted from Gao et al. (2012), Chwelos et al. (2001) and Parasuraman (2000).

[3] 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).

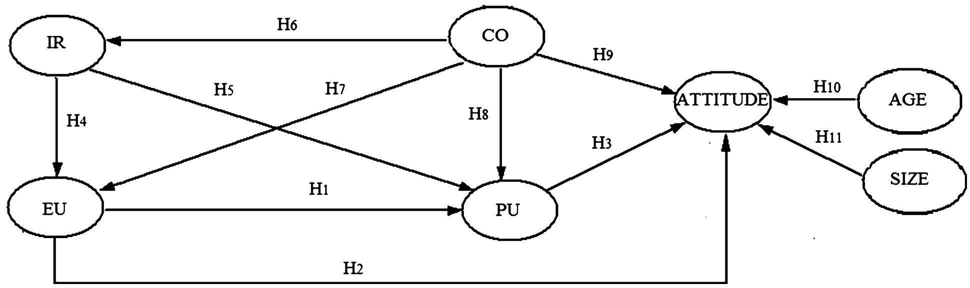

Fig. 3 – Research Model 2. *Notes*: ATTITUDE: attitudes of survey respondents toward green infrastructure adoption, IR: perceived internal readiness, EU: perceived ease of use, PU: perceived usefulness, CO: perceived compatibility, AGE: age of respondents, SIZE: size of jurisdiction, H*n*: hypothesis number.

structural theory bearing on some phenomena. This approach allows a simultaneous examination of a series of dependence relationships, including when the kinds of direct and indirect effects among the constructs exists within the model as shown in Figs. 2 and 3 (Hair et al., 2009).

Following the recommendations of Anderson and Gerbing (1988) and Mueller and Hancock (2008), I began the structural equation model assessment with a confirmatory factor analysis (CFA) to test the dimensionality, reliability, and convergent and discriminant validities of the measures,[4] where items are analyzed as categorical measures with a Maximum Likelihood (ML) estimator.[5] Its objective 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). 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.

The confirmatory factor analyses eliminated items that were not statistically significant on their factor loading or that had a large correlated error with other indicators (Netemeyer et al., 2003). In addition, I examined the fit of each construct and its variables individually to identify weak items. All of the R-squared values[6] of the construct variables are greater than 0.3, indicating a satisfactory 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 1 shows the individual factor loading of the three indicators for each construct.

Finally, I assessed internal consistency, convergent and discriminant validity of the constructs. 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, with significant items of each construct reflecting the strength of municipal officials' attitudes toward green infrastructure. The model fit indices shown in Table 1 demonstrate that the overall statistics for the model are acceptable, supporting the five-dimension, 15-item model.

5.1. *Analysis of structural Model 1*

With a finalized measurement model in place, the second phase of the structural modeling—the *path* model to relate independent to dependent variables (Hair et al., 2009)—consists of

[4] A two-steps process of CFA followed by path analysis is recommended in structural equation modeling over an all-in-one process. 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). Before proceeding with CFA, I checked the variables' distribution and skewness to verify if the assumptions of the ML method are met. 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. Based on the guidelines by Razali et al. (2012), who suggest that variables with skewness values between 0.5 and −0.5 indicate relative symmetry, 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.

[5] 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). 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 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 standard errors.

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

Table 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...[a]		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...[b]		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 runoff.		0.87
PU2: Adoption of Green Infrastructure complementing traditional stormwater management system in my jurisdiction would reduce runoff pollution.		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 works.		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: $\chi^2 = 99.28$ (df = 79), $p = 0.0612$, RMSEA = 0.031; CFI = 0.986, TLI = 0.981, SRMR = 0.042.

Notes: RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI: Tucker-Lewis index; SRMR = standardized root mean square residual.

[a] Respondents were asked to complete the statement choosing from a scale of 1–5, with 1 = extremely good and 5 = extremely bad.

[b] Respondents were asked to complete the statement choosing from a scale of 1–5, with 1 = extremely beneficial and 5 = extremely harmful.

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). After doing so, the overall fit of the structural Model 1 is acceptable, since 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 2 shows the parameter estimates for hypothesized effects along with significance levels.

Based on the analysis results, six of the nine hypotheses in the conceptual framework are significantly supported. Ease of use of green infrastructure technologies, internal readiness of the adopting jurisdiction and compatibility of green infrastructure with local operating practices all have a positive influence on the perceived usefulness of such techniques. Perceived usefulness of green infrastructure systems appears to be the only attribute that has a direct positive influence on respondents' attitudes toward adoption.

Perceived ease of use has a significant and positive path to perceived usefulness (H1, $\beta = 0.199$, $p < 0.05$), while its impact on attitude toward adopting green infrastructure is not significant (H2, $\beta = 0.094$, $p > 0.1$). The parameter for the path from perceived internal readiness to perceived usefulness is significant and has a positive sign ($\beta = 0.298$, $p < 0.01$) 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 ($\beta = -0.017$, $p > 0.1$).

The parameter estimate for the path from perceived usefulness to attitude is significant and has the expected sign (H3, $\beta = 0.790$, $p < 0.01$), providing support for the hypothesis that respondents' attitudes toward adoption of green infrastructure are influenced by perceived usefulness. This in turn is influenced by the perceived ease of use associated with these tools.

Compatibility has a significant and positive path to internal readiness (H6, $\beta = 0.391$, $p < 0.01$), perceived ease of use (H7, $\beta = 0.310$, $p < 0.01$) and perceived usefulness (H8, $\beta = 0.633$, $p < 0.01$) of green infrastructure, while the parameter estimate

Table 2 – Empirical results of Model 1.

Hypothesis	Relationship	Std. coefficient	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

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

for path from compatibility to attitude is not significant (H9, $\beta = -0.006$, $p > 0.1$). That is, perceived compatibility of green infrastructure simultaneously influences usefulness, ease of use and internal readiness as perceived by municipal officials.

5.2. *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 respondent's age group and coded 1–5 (1 = 24 or younger, 2 = 25–34, 3 = 35–49, 4 = 50–64, 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. 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 less strongly than Model 1. Table 3 shows the standardized coefficients and significance levels in structural Model 2.

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 ($\beta = -0.049$) 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 ($\beta = -0.034$), meaning that the size of jurisdiction does not have any effect on attitudes toward green infrastructure adoption.

6. Discussion and conclusions

This research represents a contribution to the literature on green infrastructure policy and practice by integrating theoretical perspectives on technological innovation to identify factors that influence attitudes of engineers, planners and other municipal officials toward adoption of green infrastructure for stormwater management. Several findings related to the appropriateness of using innovation attributes to predict municipal officials' attitudes toward green infrastructure stand out.

First, the results of the study indicate that attitudes toward green infrastructure adoption are influenced by perceived usefulness, while the impact of perceived ease of use of green infrastructure technologies on local officials' attitudes 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 reflect 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

Table 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: attitudes toward adoption; AGE: age of the respondents; SIZE: population of respondents' jurisdiction.

straightforward, so the perceived ease of use may not influence their attitudes toward adoption.

The analysis shows that perceived usefulness of systems integrating green stormwater infrastructure, recognized in terms of ecologic and technical benefits, influences respondents' attitudes toward adoption. This agrees with several empirical studies that found that positive perceptions of the benefits of technological innovations provide an incentive for the use of new technologies (Chau, 1996; 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.

Second, 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 attitudes 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.

Third, 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, which in turn reduces the rate of adoption and implementation (Olorunkiya et al., 2012).

Admittedly, these factors represent only a partial picture of the elements that influence the 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 of using instruments based on both surveys and in-depth interviews when exploring similar topics. In addition, the confirmed relationships among key constructs might not hold for other themes, so further research is necessary to establish whether the pattern of effects that I observed is generalizable to other environmental innovations. Furthermore, 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.

More broadly, green infrastructure constitutes a relatively new approach to stormwater management, and its still emerging, nascent status and lack of sufficient performance data and design standards complicate assessment about its adoption, let alone its effectiveness and reliability (Roy et al., 2008; Abhold et al., 2011). City staff prefer well-established engineering practices and trust systems that have been tested and used in past experiences, rather than try new alternatives. In fact, 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 risks (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.

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, an important opportunity exists 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. The importance of opinion leaders and change agents, often referred to as technology or innovation champions (Howell et al., 2005; Rogers, 2003), should not be overlooked, because they can play a critical role in both the innovation adoption and implementation process (Bulkeley and Betsill, 2003; Krause, 2011). The presence of an innovation champion delivering knowledge transfer at an interpersonal level and supporting a product, policy or idea, has a major positive influence on adoption within an organization (Koebel, 2008; Driessen and Hillebrand, 2002). In general, an innovation champion actively and enthusiastically promoting an innovation's progress through the critical stages is important not only for promoting the technology but also for inviting users into the implementation process (Rogers, 2003). Supporters of green infrastructure can become adoption champions and provide strong technical and/or political leadership to the adopting community pushing forward the diffusion of these stormwater management strategies.

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