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Research Paper

# Key Factors Influencing Low Impact Development Adoption by Local Governments

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# 지방정부의 저영향개발 적용에 영향을 주는 요인 연구

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**요 약 :** 본 연구의 목적은 탐색적 연구방법을 통해 지방정부의 LID 적용에 영향을 주는 인자를 밝히는데 있다. 이를 위해서 미국 버지니아주의 지방정부 10곳을 사례조사지로 선정하여 LID 적용정도를 구분하였고, 이에 영향을 주는 요인으로 LID의 특성, 지방정부의 특성, 지방정부의 동기요인, 지방정부 외부의 영향 등을 혁신의 확산이론을 바탕으로 발전시켰다. 지방정부의 LID 적용정도 및 영향인자는 우수관리관련 조례, 회의록, 인터뷰와 그 밖의 지자체 문서를 바탕으로 평가하였다. 연구결과에 따라 높은 LID 적용정도를 보인 지방정부 사례의 경우 해당 지방정부와 지역 커뮤니티에서 LID를 적극적으로 옹호하는 챔피언의 역할이 매우 크게 나타났다. 반면에 중간 및 낮은 정도의 LID 적용상태를 보인 지방정부의 경우는 외부적 요인 즉, 주정부의 강제적 법적규제가 중요한 요인으로 작용했으며 명확한 LID 적용모델에 대한 요구가 높게 나타났다.

**주요어 : 저영향개발, 혁신의 확산, 혁신의 적용, 사례조사**

**Abstract :** The paper reports on exploratory research into the factors influencing adoption of low impact development (LID) regulations by local government. The research uses ten case studies ranging from low to high level adoption of LID in Virginia. Based on the theory of diffusion of innovations, perceived characteristics of LID, characteristics of the adopting local government, motivations of the adopter, and the surrounding organizational context of the adopter are chosen for the key factors influencing on LID adoption. By reviewing the local governments regulations related to stormwater management, meeting minutes, reports and documents, and in-depth interviews, the evaluation of the key factors and the local LID adoption was conducted. As a result, adopters with a high level of LID adoption at the time of the study were heavily influenced by champions of LID within local government and communities. In contrast, moderate level adopters

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and low-level adopters emphasized the importance of external forces like state regulatory mandates and the need for clear models to implement.

Keywords : LID, Diffusion of Innovations, Innovation Adoption, Case study

## I. Introduction

Urban land development has rapidly converted natural land into impervious surfaces (i.e. buildings, roads, parking lots) producing a significant increase in stormwater runoff and nonpoint source pollution to streams and rivers (EPA, 2007). Under natural hydrologic conditions, typically less than 10% of rainwater turns into stormwater runoff (Kloss, 2006). However, conventional management treats stormwater as a nuisance (Alexander and Heaney, 2002) and heavily relies on an engineering based end-of-pipe treatment to remove stormwater runoff (Randolph, 2004). In the 1990s, a potential paradigm shift emerged from an engineering-based approach to low impact development(LID) infiltration-based techniques and strategies (Randolph, 2004) to overcome the shortcomings of conventional stormwater management by a new perspective and more effective runoff control with decentralized on-site methods.

In early 1990s, LID was developed in Prince George's County, Maryland and became a significant change in stormwater management tradition in the United States. The US Environmental Protection Agency (EPA) defines LID as "a site design strategy with a goal of maintaining or replicating the predevelopment hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape (EPA, 2000)." LID considers stormwater runoff as a resource to protect by using natural hydrological patterns to prevent or reduce the impact of development (EPA, 2000; PGCDER, 1999; NRDC, 2001). In contrast to conventional stormwater management, LID involves a more complex bundle of practices and techniques that vary in importance based on characteristics of the site and the watershed. LID includes a suite of structural and nonstructural stormwater management practices. First, bioretention or rain gardens, grass swales, rooftop gardens and rain barrels are the most frequent structural technologies used to control excessive stormwater runoff on-site. Bioretention and grass swales have multiple functions for detention, retention, and water quality improvement for stormwater runoff (Coffman, 1998). Bioretention, pervious pavements and grass swale practices have proved to be effective in retaining runoff volume and filtering pollutants on sites (Dietz, 2007).

To date, LID studies have focused on hydrological performance and economic benefits of individual LID practices and have shown the effectiveness of LID practices in retaining pollutants and preserving natural hydrologic function of a site (Dietz, 2007). However, implementing LID practices involves multiple stakeholders (SEMCOG, 2008) and the process of LID adoption is likely to be complex and warrants exploratory investigation. The range of goals across key stakeholders contributes to the complexity of LID adoption, at least during this early phase of diffusion. For example, developers and builders focus on the economic feasibility of the development, which favors regulatory clarity and timely approvals (NAHB,2003). LID practices requiring more time or uncertainty for approval

are likely to impede widespread LID adoption (Lebarron, 2007). Lower development costs would potentially offset time delays. Home owners (buyers) influence development decisions through the value they place on the environmental amenities and performance of their property and subdivision (NAHB, 2003). And local government elected officials, planning staff, engineering staff and plan reviewers are intensely involved in LID adoption (SEMCOG, 2008; NAHB, 2003).

Most of all, local building codes and zoning ordinances have been identified as major impediments to LID adoption (Landers, 2004; EPA 2007; MacMullan and Reich, 2007). Nowacek *et al*.,(2003) interviewed key players in stormwater management and found that the outdated existing municipal ordinances were the barriers to adopt infiltration stormwater. Landers (2004) and MacMullan and Reich (2007) argue that local building codes and zoning ordinances are often the major hurdles to LID adoption even though LID is gaining more favor from many jurisdictions. Delays are primarily due to the complex and time consuming process of amending or creating local codes and ordinances in favor of LID adoption (NRC, 2008). According to the Center for Watershed Protection (2008), existing local codes and ordinances often impose inflexible standards such as overly wide residential streets, expansive parking lots and mass clearing and grading of forested areas. At the same time, local codes often give developers little or no incentive to conserve natural areas.

In much of the U.S., local governments have the direct responsibility to regulate land use and implement stormwater management regulations, even though state and federal governments might mandate standards for stormwater management. Therefore, local governments play a pivotal role in implementing stormwater management through local policies, guidelines, ordinances technical materials, inspections, enforcement and evaluation to control stormwater runoff from land development activities (VADCR, 2009).

Localities can implement LID through zoning and subdivision ordinances, stormwater ordinances, comprehensive plans, and incentive programs. Also, LID practices and strategies can be used as an implementation tool for a community's plans for greenways, recreation, stormwater, and watershed management. But the first step is the locality's adoption of LID policies and practices.

Ultimately, the findings of this study will benefit potential localities in the U.S. as well as other countries considering LID adoption. For example, the environmental problems due to urbanization are getting worse in Korea and government agencies have adopted LID as an option to improve urban water cycle and adapt to climate change. However, LID adoption in Korea is still in a beginning stage and there is little research about planning and policy perspective of LID for effective implementation (Kang *et al*, 2014). To help understand more about LID adoption by local government, we established a scale of low, moderate and high levels of LID adoption and then explored these questions: 1) Why do localities adopt LID? 2) How do localities adopt LID and what are the major factors influencing their level of adoption?

## II. Literature Review

### 1. Determining the Level of LID Adoption by Local Governments

LID represents a complex innovation that

Table 1. Evaluation criteria of LID adoption

| Types of LID adoption | Details | Code for LID adoption |
|---|---|---|
| LID usage in local code | Word count of the term"low impact development" and "LID" in local codes and ordinances; details of LID specifications in local code | (1) 1-2 times<br>(2) Great then 2, less than 10 times<br>(3) Greater than 10 times |
| LID in manuals | Developed or updated technical and design manuals for local LID implementation: technical details presented in manuals and localities' usage of their manuals | (1) LID included as a part with limited usage<br>(2) LID included as a part with moderate usage<br>(3) Great detail in local LID manuals; amended to update the facts and guidelines of LID |
| LID projects | Amount of adopted LID projects or practices (e.g., bioretention, green roofs, porous pavers, grass swales, biofilters) | (1) At least 1 project<br>(2) Difficult to measure but many LID projects<br>(3) Every project or over 100 projects |
| LID task force | Establishment/involvement of a technical advisory group or a task force to support the Planning Commission or the Board of Supervisors. | (1) General T/F interested in LID<br>(2) General T/F discussing LID<br>(3) T/F formed to support LID adoption |
| Incentives | Incentives to promote LID | (0) Absence (1) Presence |
| LID uses and encourage-ment | Mandatory (regulations) or Voluntary (developers' requests) LID uses<br>Encouraging LID with passive attitude: local officials offering LID as an option<br>Encouraging LID with active attitude: local officials promoting LID in every projects | (1) Passive/Voluntary<br>(2) Active/Voluntary<br>(3) Active/ Mandatory |

From Code to score: (1) = 1 point (2) = 2 point (3) = 3 point

involves a suite or bundle of practices rather than a dichotomous choice to adopt or not adopt LID. LID can be adopted in various scales and stages from demonstrating LID practices like bioretention, grass swale, and green roofs and site design strategies on a site to adopting LID policies and making institutional changes in codes and regulations (SEMCOG, 2008). For determining LID adoption level by localities, the following six criteria were used to determine the level of LID adoption by local government (Table 1). All six criteria are weighted equally and a summative score was used to categorize localities into high, moderate, and low levels of LID adoption.

## 2. Identifying Key Factors to Innovation Adoption

Research on diffusion of innovations has addressed determinants of innovation adoption, the rate of innovation adoption, and regional diffusion. Previous researchers (Daley & Galand 2005; Matisoff , 2008; Vasi, 2006; White & Boswell 2006) have identified two main models for the factors influencing innovation adoption in organizations. The first, the internal determinants model, posits that the degree of innovation adoption is dependent on internal organization characteristics, such as resources, organizational structure, and size. The second, the regional diffusion model focuses on the external forces and environmental context affecting the adoption decision of an organization. As a result, this study considers both the internal determinants models and regional diffusion models to determine key factors of LID adoption, including motivations for adoption, characteristics of the innovation (LID), characteristics of the adopting organization (local government), and organizational context. Based on innovation adoption and policy adoption theories, this study establishes four major constructs to measure factors influencing LID adoption by local governments: motivations, innovation characteristics, organizational characteristics, and orga-

Table 2. Four categories of variables

| Motivations to adoption | Innovation characteristics | Organizational characteristics | Organizational context |
|---|---|---|---|
| • Frustration with conventional stormwater management<br>• A response to severe environmental problems<br>• Emphasis on Environmental protection<br>• Expectation of better results with LID<br>• A reputation for being innovative<br>• Doing the right thing | • Perceived complexity of LID<br>• Relative advantage (hydrologic/economic/environmental/ aesthetic benefits/ other long term benefits)<br>• Presence of pilot projects | • Responsible authority/agency<br>• Financial, technical, educational, and human resources (Staff numbers; Staff expertise; Funding capacity; education program; workshop)<br>• Presence of LID champion | • Horizontal influence: neighborhood locality pressure<br>• Vertical influences (Federal/ State level regulations/ incentives)<br>• Pressure from environment organizations and interest group<br>• LID model code uses |

nizational context (Table 2).

Motivation is one of the driving forces for the adoption and implementation of innovations. For instance, the relative advantage of the innovation in terms of cost or functionality is often considered to be the primary motivation to adopt (Rogers, 2003). In the policy arena, Berry and Berry (1999) suggest problem severity is an important motivational factor as more severe problems can prompt public officials to adopt innovative solutions. Walters (2002) provides an extensive list of motives in the adoption of government funded initiatives and innovations, including frustration with the status quo, response to crisis, focus on prevention, an emphasis on results, adaptation of technology, and an inclination to do the right thing. A variety of motives can influence the decision to adopt an innovation. Therefore, this study investigates six motivations which are assumed to be relevant with LID adoption as shown in Table 2.

For the characteristics of innovations influencing adoption, several factors have been found to influence adoption (Damanpour, 2009; Frambach, 2002; Koebel, 2006; Tornatzky & Klein, 1982; Walker, 2006). According to Rogers (2003), five key characteristics of innovation affect the rate of adoption: observability, relative advantage (reflecting costs and functionality), compatibility, trialability, and complexity. This study focuses on the perceived complexity of LID, the relative advantage of LID (its hydrologic, economic, environmental, aesthetic advantages), and the observability of LID through pilot projects and demonstrations.

Organizational characteristics influencing adoption can be categorized as human resources, organizational structure, organizational culture and decision process, and market context (Koebel, 2004). Berry and Berry (1999) also argue that policy diffusion strongly depends on the economic, political, and social characteristics of the organization that adopts a policy. As part of the organizational culture and decision process, innovation champions play an important role in advancing a new idea in an organization (Howell & Higgins, 1990; Rogers, 2003). The presence of a charismatic individual advocating an innovation may provoke an organization to overcome indifference or resistance to a new idea. Champions can have multiple channels of influence on innovation adoption depending on their position of influence and level of control over the adoption decision. Therefore, this study investigates three major organizational characteristics such as the presence of a lead agency responsible for LID, organizational resources, and the presence and role of LID champions in local governments.

At last, the adoption of an innovation is not an independent process separate from its organizational context (Daley and Galand, 2005). For example, states are influenced by the federal government and by other state governments in adopting new policies. Berry and Berry (1999) identified the importance of horizontal and vertical external factors influencing policy adoption by states. In horizontal diffusion, states learn about different policies from other states, states compete with each other for resources and prestige, and public pressure may force a state to adopt a policy that neighboring states have adopted. Vertical diffusion reflects the influence of the federal-state-local hierarchy (or similar vertical relationships), and can operate in both a top-down and bottom-up direction. Regarding LID adoption, the US Environmental Protection Agency(Federal level) encourages municipalities to incorporate LID in meeting the National Pollutant Discharge Elimination System (NPDES) requirements (Landers, 2004) and the Virginia Department of Conservation and Recreation (State level) is also promoting the use of LID as an alternative and supplement to existing stormwater programs.

## III. Research Method

This research uses multiple cases to investigate the factors affecting LID adoption in local governments. The study was conducted in Virginia, which has 95 counties and 39 county equivalent independent cities. In particular, Virginia supports LID adoption by localities and Virginia stormwater regulations §10.1-603.4(8). states that "Encourage low impact development designs, regional and watershed approaches, and nonstructural means for controlling stormwater". This regulation allows counties and cities in Virginia to utilize LID practices and strategies. As LID is mostly considered in urban areas, only localities with populations greater than 25,000 people were selected (reducing the universe to 48 counties and 18 cities). The local codes and ordinances of these 66 communities were searched using the words "low impact development" and "LID" as evidence of some level of adoption of LID. More specific terms related to elements of LID, such as bioswales or rain gardens, were not searched as we assumed these would not be sufficient indicators of LID adoption without also referencing LID. Based on this search, eight counties (Amherst, Bedford, Chesterfield, Fairfax, Isle of Wight, Roanoke, Stafford, and Spotsylvania) and two cities (Charlottesville and Roanoke City) were selected for further study. Cities and counties in Virginia have generally equivalent powers (cities are completely independent and not within county boundaries). All of the cases fall within Metropolitan Statistical Areas designated by the US Office of Management and Budget. Fairfax County (with over one-million people) is the largest urban jurisdiction within the Washington DC-Baltimore MSA, which also includes the rapidly growing suburban jurisdictions of Stafford (129,000 population) and Spotsylvania (122,000) Counties. Chesterfield County (316,000) is the largest jurisdiction of the Richmond MSA. Roanoke County (92,000) and Roanoke City (97,000) are the core urban areas of the Roanoke MSA. Charlottesville (43,000) is the core city of the Charlottesville MSA. Amherst (32,000) and Bedford (69,000) Counties are in the Lynchburg MSA. Isle of Wight County (35,000) is in the Virginia Beach MSA. The cases represent a diverse set of urban, suburban and peri-urban locations.

Key contacts were identified within each of the case study jurisdictions, including the jurisdiction's chief administrator and the directors of the planning and engineering departments. Initially, 30 key contacts were identified. Based on their referrals of other key local government officials involved with LID adoption, an additional seven contacts were identified. During the communication to identify the appropriate persons to interview, only one or two persons who were knowledgeable about LID were either volunteered or referred for in-depth interviews for each case. Most of the time, local officials with limited knowledge about LID chose not to engage in the interview process. A total of 22 people were interviewed, 20 from local governments, one from an NGO and one from a regional soil and water conservation district. This was not intended to be a representative sample of all of the organizations or people impacted by LID adoption or even influencing LID adoption.

As noted earlier, the number of stakeholders impacted by stormwater management practices is large and diffuse. Our intent was to identify key informants who were centrally involved in LID adoption by the local government. Site visits and interviews were conducted from September 2009 to November 2009. Interviews were successfully conducted in 9 out of 10 localities. In one case (Isle of Wight County), a face-to-face interview was not possible and a mailed questionnaire was used. In addition to these interviews, documents related to LID decisions in the case study communities were reviewed, including local agenda, minutes of meetings, written reports of events, and administrative documents such as progress reports and special reports and manuals.

## IV. Results

### 1. Level of LID Adoption

According to six evaluation criteria, LID adoption in localities shows in three levels as in Figure 1. Spotsylvania and Stafford County adopted high level of LID practices and polices. Fairfax County and Charlottesville City were categorized as localities with medium level of LID adoption. The rest of six localities showed limited level of LID adoption. The details of how LID has adopted in local code and ordinances, manuals, and actual practices are summarized in Table 3.

For example, Stafford and Spotsylvania Counties extensively adopted LID in their codes,

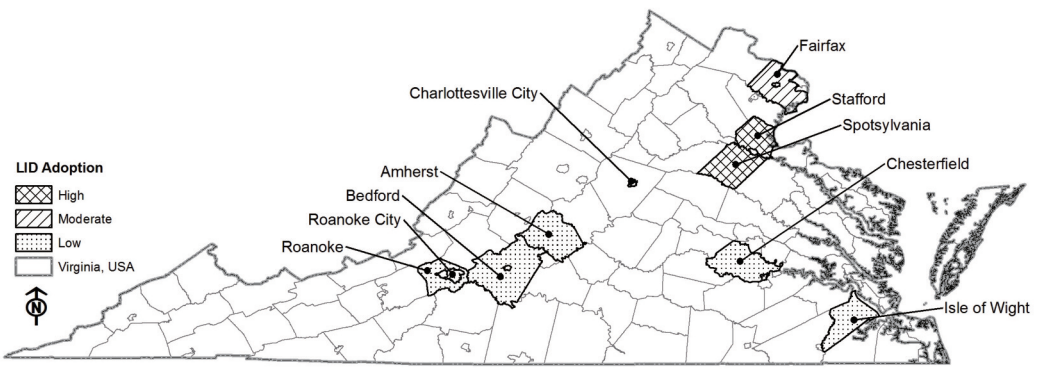


Figure 1. LID adoption levels in localities

ordinances, and manuals. Stafford County strongly promotes the use of LID practices. Chapter 3 of the county's Comprehensive plan (Stafford County, 2003) states, "Low Impact Development (LID) practices should be encouraged for stormwater management." The county further clarifies that it considers LID as the first option for stormwater management in new development projects: "The stormwater management concept plan shall utilize to the maximum extent practicable low-impact development site planning in accordance with the low-impact development design manuals (Section. 21.5-4. Stormwater management plans, emphasis added)." During late 2007 and early 2008, the stormwater management design manual was updated on incentives like waiving curb and gutter requirements for engineered vegetated swales (chapter 22 Subdivisions, Article VII. Streets and sidewalks) and waving parking materials for LID sites with pervious paving blocks and other similar materials (Chapter 28, Zoning ordinances. Article IV. Planned Development and Overlay District).

According to all three officials in Stafford County, the Board of Supervisors changed from voluntary to mandatory LID use in new development. Site development plans have to evaluate the use of LID technologies and implement LID practices to the maximum extent practicable. Thus, developers are required to evaluate LID use and have to show why LID is not suitable on a site if not used. The county also provides demonstration project facilities in the County Administration Center parking lot to show successful adoption of LID practices. In Spotsylvania County, LID is an option to allow sites to be developed without stormwater management ponds. LID language is adopted in two sections of local codes and ordinances. The standalone Stormwater Management Ordinance (Chapter 19A) provides general LID definitions and technical criteria whereas Chapter 20 of the Subdivision Ordinance mostly addresses the maintenance issues of LID. Spotsylvania County employs four references for specifications and standards of LID facilities and utilization (Virginia Stormwater Management Handbook; Spotsylvania County Design Standards Manual; Low-Impact Development Design Strategies: An Integrated Approach ref. EPA 841-B-00-003; Low Impact Development Hydrologic Analysis ref. EPA 841-B-00-002).

The localities with moderate level of LID adoption are the City of Charlottesville and Fairfax County. Both localities refer to LID in their local codes and their technical manuals have more extensive guidance on the use of LID, and actively encourage LID uses. For instance, a City of Charlottesville official stated that "The City took the lead in promoting these measures [LID]. We had community support." Fairfax County's Public Facilities Manual permits six LID practices to be used on developments within the county.

The other six localities were classified with a low level of LID adoption (Roanoke City, Chesterfield County, Amherst County, Roanoke County, Isle of Wight, and Bedford County). Although these localities included LID in local codes and ordinances, the level of specification and guidance was very limited. The localities lacked LID manuals, task forces, and incentives for using LID. Interviewees in two localities (Amherst and Bedford County) were not even aware of the inclusion of LID in their codes and ordinances, which probably reflects the latters' limited references to LID. Attitudes toward

Table 3. Details of LID adoption by local governments (SWM=Stormwater management)

| Locality | LID Code details(#) | LID manual | LID project | Task force | Incentive | LID uses/ encourage-ment | Overall Adoption (score) |
|---|---|---|---|---|---|---|---|
| Stafford (Urban) | SWM(23) Zoning(2) Subdivision(7) | SWM design manual | Over 100 LID projects | Better Site Design Roundtable | Relaxing standards | Mandatory/ Active | High (16) |
| Spotsylvania (Urban) | SWM(24) Subdivision(4) | Design standard manual, EPA LID manuals | Every project offers LID | Engineer quarterly | None | Voluntary/ Active | High (15) |
| Charlottes-ville City (Urban) | Zoning-Special use permit(8) | City Standards & Design Manual, SWM guidance manual | Many LID cases during rezoning process | Citizen's environmental task force | Development bonus: LID worksheet | Voluntary/ Active | Moderate (11) |
| Fairfax (Urban) | Tree conservation ordinances(1) | Public facilities manual-2007 amendments | Green roof project and many more | Environmental quality advisory group | None | Voluntary/ Active | Moderate (11) |
| Roanoke City (Urban) | SWM(2) Zoning(4) | 2008 SWM design manual | Pervious pavers, bio-retention, green roofs | None | None | Voluntary/ Passive | Low (7) |
| Chesterfield (Suburban) | Zoning-Upper SwiftCreek(7) | None | Filterra | None | None | Voluntary/ Passive | Low (5) |
| Amherst (Rural) | Zoning & subdivision(1) | None | Biofilters, bioretention | None | None | Voluntary/ Passive | Low (3) |
| Roanoke (Rural) | SWM(2) Zoning(2) | None | Pervious pavers, bioretention | None | None | Voluntary/ Passive | Low (3) |
| Isle of Wight (Rural) | Zoning (2) | None | Pervious pavers | None | None | Voluntary/ Passive | Low (3) |
| Bedford (Rural) | Erosion & sediment control (1) | None | None | None | None | Voluntary/ Passive | Low (2) |

encouraging LID were very passive and the interviewees viewed LID as one of the stormwater management options for developers to consider at their discretion.

## 2. Key Factors to LID Adoption

The cases in this study range across the three levels of LID adoption, as already shown. Consequently they can provide some insight into whether the factors influencing adoption vary across the level of adoption at the time of the study (Table 4.). High level adopters can be viewed as the most innovative relative to LID implementation. Examining the factors influencing adoption among these two cases can help understand the leading edge (first-movers) of LID innovation. Similarly, the two moderate level (and six low-level) adoption cases can help understand the factors influencing the next stage of LID diffusion. Table 4 shows all key factors identified by interviewees in high-moderate-low level of LID adoption localities. Also, differences between these cases could help identify changes required to move these groups into the high adopter level.

### 1) Key influencing factors in localities with high level of LID adoption: Stafford County and Spotsylvania County

Interviewees from both of the high-level adopter counties identified three factors as motivations for LID adoption: 1) pressure from significant environmental problems (i.e., drought, big storm, flooding); 2) frustration with conventional stormwater management to control drainage, flooding, and erosion; 3) expectation of better results with LID. In terms of perceived complexity of LID, both counties described LID as simple and straightforward. Among LID's advantages,

hydrologic and aesthetic benefits were considered to have high influence. Interestingly enough, both localities did not put much emphasis on short-term economic benefits of LID. A Spotsylvania official claimed that "Economy—I always put that last, because there is always someone who is going to find something that is more expensive than what they would normally do. They always have that argument but it is when you look at the long term maintenance and everything, it's [LID] a whole lot cheaper and it's really practical."

Moreover, many LID demonstration projects were available locally in these communities (e.g. church properties, county buildings, and residential and commercial development) to promote the advantages of LID. Education and human resources played a critical role in both cases. From the beginning, LID training programs, seminars, and workshops were available to local staff and elected officials. For instance, Spotsylvania County relies heavily on quarterly and semi-annual meetings with local engineers and developers to share information and to educate end-users about LID. According to a Spotsylvania staff member, these regular education meetings provide information about new products and federal/state/local code changes to engineers and developers. Through LID education programs and workshops, local officials could also introduce LID demonstration sites to potential adopters. Most of all, in both localities have strong LID advocates including local board members, planning commissioners, staff members.

In terms of organizational context, both counties recognized pressure from Friends of the Rappahannock (FOR) as a significant factor influencing adoption of LID. For example, the Spotsylvania planning commission meeting minutes (July 17, 2002) showed that FOR encouraged the LID approach to site design and stormwater management to the Massaponax Watershed Planning Study, which was the start of the partnership between FOR and planning staff. FOR also provided LID workshops and education programs to local officials and staff. Vertical pressure for adoption was not noted by any of the interviewees, or in any of the documents examined. Participants in both counties considered their counties as leaders on LID adoption in their region and state, rather than followers of state mandates.

#### 2) Key influencing factors in localities with moderate level of LID adoption: City of Charlottesville and Fairfax County

Protecting streams and the natural environment were key motivations for LID adoption in the City of Charlottesville. A surge of development during the mid-2000s prompted greater concern over stream protection. The city believes that encouraging LID can reduce environmental impacts; the city also promotes a green city image. Similar to the high-adoption cases, Fairfax County adopted LID due to frustration with conventional stormwater management and pressure to use more innovative approaches. Participants reported that the effectiveness of traditional stormwater management methods is being questioned in the county. Both localities perceived LID as complex. For instance, an environmental engineer in the City of Charlottesville said that "Things (LID) are very complex. From a regulation perspective, it's very hard to do because we don't always know the factors over on another side." Regarding Fairfax's adoption of LID in its Public Facilities Manual (PFM), a county staff member said that "It was a fairly large amend-

ment to our PFM" but didn't see it as "any more complex than any other large amendment." Pressure from state and federal mandates was a critical factor in adopting LID for the moderate adopters. Both localities are designated Municipal Separate Storm Sewer Systems (known as MS4) communities and recognized problems with water quality much earlier than other localities. In fact, a Fairfax County staff participant was concerned that "the state is getting ready to adopt regulations that pretty much are going to require [that] we use LID or if developers want to use them and they propose them to meet the water quality and quantity standards we are going to have to accept them. So the state's role is huge; even EPA is getting more active." Championship by environmental NGOs was not a direct factor in LID adoption cited by interviewees, but worked indirectly through task forces in both localities. Both localities said that successful LID adoption from neighboring localities would help them to persuade board or planning commission members to adopt LID locally.

### 3) Key influencing factors in localities with low level of LID adoption: the City of Roanoke, Chesterfield, Amherst, Roanoke, Isle of Wight, Bedford County

For localities in the low adopter category, environmental protection and LID results provide major motives for LID adoption. These localities consider that LID can help conserve good environments, provide amenities by creating more green space with LID, and improve water quality and quantity of streams and rivers to be sustainable. All six counties perceived LID as very complex. For example, all staff members who were interviewed from Amherst County and Roanoke

Table 4. Key factors in LID adoption with adoption level (high-moderate-low)

| Localities \ Factors | | Motivations | | | | | | LID Characteristics | | | | | | | | Local government characteristics | | | | | | | | | | Organizational context | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Comp-lexity | | Advantages | | | | | | Responsible agencies | | | Champion | | | Resources | | | | | | | |
| | | FCS | SEP | EPT | LIDR | BINV | DRT | Low | High | HYD | ECN | ENV | AET | LTB | POP | planning | PW/PU | ENG | staff | BOS | PC/AG | FIN | TECH | EDU | HUM | FSRI | PNGO | NLP | MCD |
| High | Stafford | ○ | ○ | | ○ | | | ○ | | ○ | | | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | ○ | ○ | ○ | | ○ | | |
| | Spotsylvania | ○ | | | ○ | | | ○ | | ○ | | | ○ | | ○ | ○ | | | ○ | | ○ | | ○ | ○ | ○ | | ○ | | |
| Mod | Charlottesville | | | ○ | ○ | | ○ | | ○ | ○ | | ○ | ○ | | ○ | ○ | | ○ | ○ | | | | ○ | ○ | ○ | ○ | | ○ | ○ |
| | Fairfax County | ○ | | | ○ | ○ | | | ○ | ○ | | | | | ○ | | ○ | | | | ○ | | ○ | ○ | ○ | ○ | ○ | ○ | |
| Low | Roanoke City | | | ○ | ○ | | ○ | | ○ | | | ○ | | | ○ | ○ | | | | | | | | | ○ | ○ | | | |
| | Chesterfield | | | ○ | | | | | ○ | ○ | | ○ | ○ | | ○ | ○ | | ○ | ○ | | | ○ | | ○ | ○ | ○ | | | ○ |
| | Amherst | ○ | | ○ | ○ | | | | ○ | ○ | ○ | ○ | | | ○ | ○ | ○ | | | ○ | | | | | ○ | ○ | | | ○ |
| | Roanoke | | | ○ | | | | | ○ | | ○ | ○ | | | ○ | ○ | | ○ | ○ | | ○ | | | ○ | | ○ | | ○ | ○ |
| | Isle of Wight | | | | ○ | | | | ○ | | ○ | ○ | | | ○ | ○ | | ○ | ○ | | ○ | | | | | ○ | | | ○ |
| | Bedford | | | ○ | | | | | ○ | ○ | ○ | | | | | | | | | | | | | | | ○ | | | ○ |

FCS: frustration with conventional method
SEP:Severe Environmental problems
EPT: environmental protection
LIDR: LID results BINV: Being innovative
DRT: doing the right thing

HDY: Hydrology
ECN: Economic
ENV: Environmental
AET: Aesthetic
LTB: Long term benefits
POP: Presence of Pilot projects

PW/PU: Public works /Public utilities
ENG: engineering

BOS: Board of Supervisors
PC/AG: Planning commission /advisory group

FIN: financial
TECH: Technical
EDU: Educational
HUM: Human

FSRI: Federal/ State Regulations /incentive
PNGO: Pressure from NGO
NLP: Neighboring Locality Pressure
MCD: Model code

County stated that various professionals define LID in different ways, causing confusion about the meaning of LID. A Chesterfield County interviewee said that "[LID] is very complex about all the different things and how they come together." The low-adopter localities expressed limited knowledge about the definitions and advantages of LID. The most frequently recognized LID characteristic was economic benefit and LID was seen as a tool for cost saving in development and in long-term maintenance rather than for its performance benefits.

Champions were not present in the low adopter group. Instead planning and engineering staff were seen as the experts on LID but their role as champions was vague and their knowledge of LID appeared to be very limited. In addition, few technical, financial, educational, and human resources were devoted to LID in these localities. Vertical pressure to adopt could play a significant role for the low adopter group. The biggest concern expressed by interviewees from these localities was in meeting state mandates. If LID can meet the new state stormwater quality requirements, these localities will actively pursue LID adoption. Furthermore, those localities want a toolbox or a model package of LID practices to sell the idea to development community and elected officials. Successful cases from neighboring localities also would help these localities to sway their localities' decisions to adopt LID.

## V. Conclusions and Lessons Learned

### 1. Conclusions

The purpose of the study was to explore the factors influencing the level of LID adoption by localities within Virginia. Key factors in high level LID adoption localities are strong champions (i.e., presence of staff experts for technical and political support and environmental NGOs : Friends of Rappahannock (FOR)), strong LID education programs, and a clear understanding of LID. Especially, individuals from local governments, environmental NGOs, and development communities played critical roles as champions and advocates in the LID adoption process. Early (first-mover) adoption is the period in innovation diffusion when the potential risks of adoption are higher and champions can have the most influence. Moderate-level adopters showed very similar characteristics as the high-level adopters in terms of pressure to respond to environmental problems and dissatisfaction with conventional practice. These communities appear to be responding to a combination of factors influencing adoption and could possibly shift to a high level of adoption with more push from greater advocacy (internal and external to local government), more knowledge gained from early high-level adopters, and more pull from vertical pressure from the state.

A more heavily regulation-driven LID adoption model was found among low-level LID adoption localities. External forces appear to motivate these localities to adopt innovations and they wait for clear requirements to meet and models to follow. State stormwater management mandates were the most important factor influencing the adoption of LID programs and regulations. If the state includes LID in its mandates, these localities would follow the state's lead.

Most of all, crucial adoption factors vary across localities based on different levels of LID adoption. Thus, to make wide-spread adoption of high-level LID practices, localities might require

shifting from champion-driven adoption among very early adopters to diffusion of a clear LID model through knowledge-transfer programs, incentives and possibly mandates once model codes and programs are available.

### 2. Lessons Learned

Diffusion of LID is a dynamic, complex process that is difficult to predict and more difficult to clearly influence. Although bounded by significant limitations, our study points to a few lessons that logically correspond to a diffusion process that gains momentum and changes as adoption shifts from very early innovators to second-movers and then accelerates to gain band-wagon effects. For effective LID promotion and diffusion, this study suggests the following four approaches:

1) A clear definition of LID: A unified definition of LID supported by federal and state governments should be promoted nationwide. A fundamental difference among localities with different levels of LID adoption was how LID was perceived. To increase LID adoption beyond early innovators, it needs to reach of level of standardization that shifts perceptions from complex to standard. The ability of LID to respond to this complexity can be one of its selling points, if it can be standardized with clear models for implementation not just in codes and regulations but in application to site planning. With a clear definition and model, LID can be perceived as a tool for managing environmental complexity.
2) Fostering LID education programs and local collaboration: Most of the low level LID adoption localities express that they are uncertain of LID's hydrological and maintenance effectiveness and have only limited information about LID benefits. Thus, LID education programs should be a key element of a diffusion strategy. In Stafford and Spotsylvania Counties, active LID educational programs involving FOR played a critical role in promoting adoption. Environmental NGOs and federal and state agencies can provide education and training workshops for existing planning and environmental engineering staff. Local government budget constraints limit opportunities to dedicate a staff member to only manage LID issues, so it is often more effective to educate existing staff members about LID.
3) A full spectrum of LID adoption: Except for the two high-level adopters, LID adoption by the localities involved individual practices such as bioretention, grass swales, green roofs, and bio-filters but not comprehensive site level LID strategies. Much of LID adoption tends to focus on individual techniques rather than site planning and design, but LID practices and site design strategies should not be separated if LID is to reach its potential.
4) To meet requirements for existing regulations and programs: High dependency on state mandates is more frequently shown in the cases of low level LID. According to interviews with local officials, state mandates and MS4 are very important factors because they help justify adopting innovative approaches. Many local officials and staff members suggest that if LID becomes a part of the new state stormwater quality requirement it would help in implementing LID more effectively at the local level. It might require the stronger push of state mandates to fully diffuse LID practices among late and low-level adopters.

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