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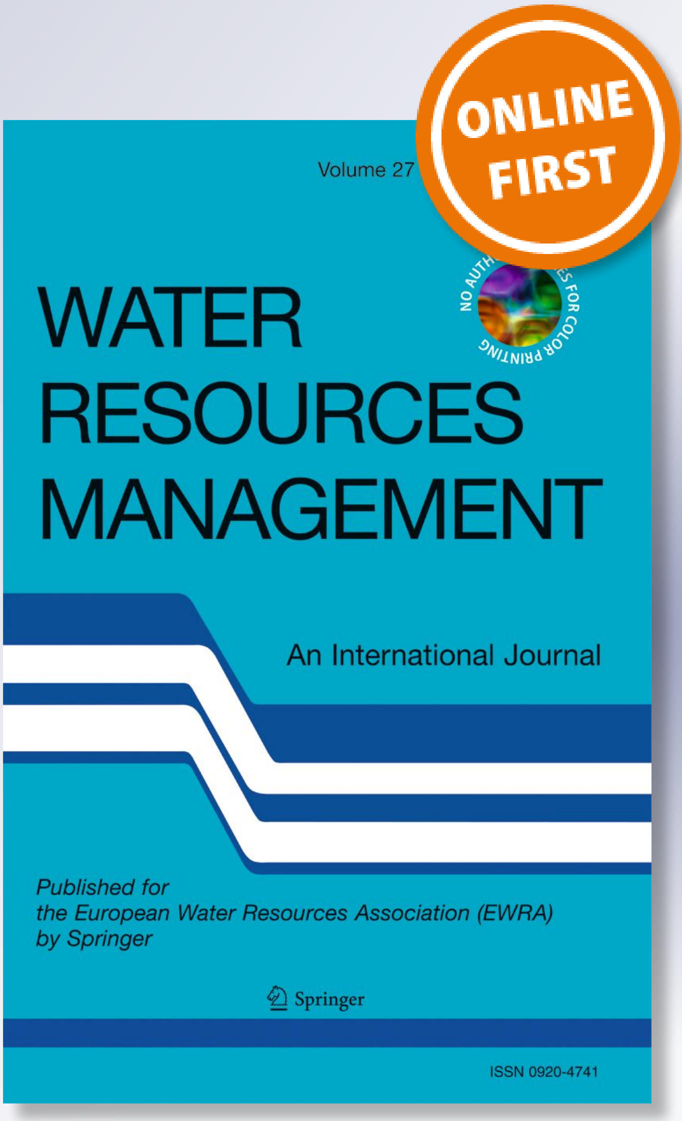

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Facilitators and Barriers of Applying Low Impact Development Practices in Urban Development

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Abstract To support sustainable long-term developments and minimize urban sprawl, Low Impact Development (LID) practices have been highlighted for a long time. They are useful, but understanding on LID practices and broadening the LID applications among practitioners is another important task. The main purpose of this study is to understand local professionals' perceptions on different LID techniques and awareness on their benefits, while also gathering opinions on barriers and incentives. An online survey was delivered to 91 recipients, a diverse pool of stakeholders involved in the Energy Corridor District (ECD) area in Houston, Texas. The majority of the respondents answered that they were familiar with LID. The techniques that have been applied to a larger extent are Detention Ponds and Bioswales. When asked about applying techniques in the future, Retention Ponds, Rain Gardens, Bioswales, and Detention Ponds are highly probable items. Decision-makers identified the major barriers as being the lack of incentives for their application, lack of knowledge of the client, and lack of knowledge of the development team. Education programs would be the most successful incentive, followed by financial incentives and innovations in policy systems. Urban planners have the most expertise in LID practices, followed by architects/landscape architects, while developers were found not to be very familiar with the concepts. This study understands the current and practical opinions about LID from the decision-makers. Different groups

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understand the importance of education and identified a major barrier as the lack of policy instruments. Some innovation in regulations may elevate proper LID practices.

Keywords Low impact development (LID) · Stormwater management · Best management practices · Survey · Urban development

1 Introduction

Over the past several decades, human impact has considerably altered the appearance and function of cities. Urbanization has caused urban and suburban areas to expand into many spaces that were once dedicated to rural activities (Benedict and McMahon 2006). The expansion of uncontrolled development, especially in U.S. cities, has led to urban sprawl and the fragmentation of natural resources. In recent years, this conventional development pattern has become the definition of less sustainable development (Saha and Paterson 2008). An increase in fast development rates has caused many environmental issues in urban areas, such as rapid expansion of impervious surfaces, an increase in surface stormwater runoff, a decrease in water and air quality, and an increased impact on soils, vegetation, and the hydrologic function of pavement (Dietz 2007; Sohn et al. 2014). Studies have linked these changes to an increase in natural disaster probabilities, such as flooding events (Kessler 2011; Price and Vojinovic 2008). As a part of ongoing efforts to limit urban sprawl and decrease the probability of flood damage at large, authorities have begun to apply development initiatives, such as smart growth (Benedict and McMahon 2006). In other words, many cities throughout the world emphasize the quality side of growth while attempting to limit expansion of their physical size. This is particularly important in managing environmental resources, especially those with direct links to improve environmental quality in urban areas.

To respond to these challenges, many cities are seeking for a more sustainable approach to bring a balanced development focusing on solutions in monitoring and controlling localized water cycle through the application of stormwater management practices (Barbosa et al. 2012; van Roon 2007). To support smart growth and sustainable long-term development, Low Impact Development (LID) practices, which help promote on-site infiltration and restore the integrity of the ecosystem, have been highlighted. LID practices can minimize the damage caused by impervious cover by filtering and recharging stormwater directly into the ground (Schwartz and Cody 2009). Proponents claim that LID is an effective tool for managing stormwater runoff and thus ensuring the environmental sustainability of society.

Ranging from civil engineering to urban and regional planning, various disciplines have emphasized the use of LID techniques to control both quantity and quality of stormwater (Dietz 2007; Dolowitz et al. 2012; Foster et al. 2011). However, it is still unclear what factors promote or hinder to implement LID techniques in real world practices. Moreover, previous studies have not fully investigated the current perception of applying LID techniques in various professionals. Many of ongoing discussions about LID focus mainly on the effectiveness of LID or the methodologies of LID implementation. They are useful indeed, but to expand understanding on LID practices and to broaden the LID applications among practitioners, it is important to acknowledge what barriers should be resolved and what questions need to be answered.

In this extent, the main purpose of this study is to understand local professionals' perceptions of different LID techniques and awareness of their benefits, while also gathering experts' opinions on LID practice barriers and incentives. The authors used an on-line survey to examine whether local developers have applied LID techniques in their real projects and identified the facilitators or barriers of applying LID in their current or future projects. The respondents of this study were chosen from the Energy Corridor District (ECD), located in the West Houston area, Texas. The research recruited representatives, including developers, architects/landscape architects, planners, and other professionals who are involved in the decision-making process of the current or future development efforts of the ECD, to assess their opinions and perceptions on LID practices. Understanding the current efforts made by different authorities that govern the West Houston area will fill in the gaps between experts' perceptions and the successful application of LID practices.

2 Low Impact Development

The United States Environmental Protection Agency (EPA) defines LID as an approach to land development that manages stormwater as close to its source as possible (United States Environmental Protection Agency 2016). The LID method combines land use planning, engineering, and design to create an infrastructural management process that is cost-effective, sustainable, and environment-friendly (Dolowitz et al. 2012). The LID approach brings more attention to local water control and utilizes stormwater as a resource rather than a constraint. Impacts from developments on water resources can be reduced with the application of stormwater management practices that allow infiltration from pervious concrete and collect and reuse the stormwater where it falls, thus reducing the introduction of pollutants into waterways (Ando and Netusil 2013).

Stormwater management practices are also called Green Infrastructure (GI), which outlines a network of LID practices with the combined purpose of reducing stormwater runoff and improving water quality (Kessler 2011). Earlier literature often refers to stormwater management practices as Best Management Practices (BMP). BMP include structural or non-structural controls that preserve the pre-development stormwater quality on-site. Not only do BMP include technologies, but they also refer to methods and practices for water pollution prevention as part of their scope. For research convenience, the term LID includes stormwater management practices in this study. LID practices are applied to broaden our understanding of urban issues and as an approach for improving urban sprawl and land fragmentation. Such practices should be implemented at a comprehensive level because they need to include economic, environmental, and social functions, values and benefits, which all work together to create a sustainable living environment.

LID practice controls stormwater at its source and applies tools and techniques that create a complex but efficient infrastructure throughout the site (Low Impact Development Center 2000). LID practices must be designed as a system in a city and linked to one another. This allows the framework to function as ecologically and sustainably as possible. LID plays a vital role in the urban setting and consists of three major functions that are to collect, convey and clean (Dietz 2007; Sohn et al. 2014). "Collect" functions by gathering rain water. A large amount of water washes off roofs and impervious surfaces when it rains. Eventually, the water may encounter polluted areas and gather sediment that is carried into city's groundwater, streams, or rivers. The "collect" function reduces stormwater runoff and improves the health of surrounding waterways. "Convey" connects stormwater runoff to other infrastructures. It directs stormwater runoff to on-site areas that can absorb, store and then transfer the water to ponds and process it through filtration systems. The use of LID systems on-site helps retain stormwater, which increases the local water supply and recharges groundwater aquifers. Finally, the "clean" function filters and purifies stormwater from excessive pollutants, sediments and evaporative runoff, providing a clean and healthy water supply (Low Impact Development Center 2000; United States Environmental Protection Agency 2016).

LID techniques improve the sustainability and integrity of the GIs. Although the practice increases the quality of the environment and health of waterways and decreases stormwater runoff management costs, there are still some challenges that developers, planners and architects/landscape architects encounter when preparing for a new project. LID techniques are not always easy to perform and there are often certain circumstances that influence the decision-making process. It is critical that in any project or application of LID systems, the design and installation of necessary features are properly considered (Dietz 2007). A good LID practice depends on the cost or availability of building materials or the complexity of the system of infrastructure and may incur additional expenses. Costs that affect the project are related to the construction costs of infrastructure. It is also possible to consider soft costs, such as design and engineering costs, as well as permitting costs for developments and controls. Another economic concern is the value of the land. In fact, developer's decisions are also determined by the expected sale or rent price and future market demand. Furthermore, the implementation of LID in a development requires the careful delineation of the construction phases and usually a much longer administration of their application. All of these concerns depend on the level of experience of the project development teams, which can be a constraint to proper LID design implementation (Ando and Netusil 2013; Dolowitz et al. 2012).

There are numerous benefits when LID is applied with careful instructions. Not only will the previously described environmental benefits be acquired, several researchers have also identified economic and social benefits of LID practices (Qin et al. 2013; Rossman 2010). There are, however, significant challenges that need to be resolved to enhance LID practices in the real world. LID is based on a complex process and involves a wide range of stakeholders. It means that many rights and understandings are interrelated and thus, requiring careful thought in implementation. Previous studies have emphasized the importance of LID and their concentration is geared toward broadening the application of LID. However, if LID practice could be a significant role player in green infrastructure and in BMP at large, it would be important to understand the obstacles and any associated hurdles that are placed ahead to practitioners. Therefore, an assessment of the current circumstances from real professionals and diagnosing the underlying problems can deliver a plausible solution to LID challenges.

3 Materials and Methods

3.1 The Energy Corridor District

The primary goals of the research are to understand the current efforts in the application of LIDs and to identify potential options for future developments to facilitate on-site implementation. To do so, a diverse pool of stakeholders involved in the development of the Energy Corridor District (ECD) area, the selected study site, was recruited.

The ECD is located within 1800 acres on the west side of Houston, Texas along the Interstate Highway 10 and the Eldridge Parkway. The district has a total population of approximately 21,000 people. More than 91,000 employees work within the district and occupy more than 2140,000m^2 of office space and more than 300,000m^2 of retail space (CDS Market Research 2013). The ECD is considered one of the nation's premier employment centers and is the home of the headquarters and regional offices of national and international energy service firms, including BP America, Shell Exploration and Production, ExxonMobil Chemical, ConocoPhillips, CITGO, Dow Chemical, PGS, Mustang/Wood Group, and so forth. The district also contains the headquarters of non-energy companies, such as Cardinal Health Care, Inc.; Sysco Corporation; Gulf States Toyota; Star Furniture; and others (The Energy Corridor 2016). Figure 1 shows the location of the ECD in the State of Texas.

In the ECD, there are open spaces surrounded by more than 105km^2 of urban park, including the Addicks and Barker Reservoirs, George Bush Park, and Bear Creek Pioneers Park. The parks and open spaces in the ECD provides more than 80 km of trails that include bike lanes and wide walkways for safe travel (Community Development Strategies 2011). The Board of Directors (BOD) of the ECD is actively looking for applying rigorous controls and monitoring their resources to improve, enhance and promote the built environment conditions within its boundaries (CDS Market Research 2013; Texas Legislative Council 2002). The ECD has a high potential working environment to implement the best management practices for a sustainable future. Few LID techniques have been implemented in the ECD, although it has been defined as an attractive site to apply due to the size of the district and demands of its future development. If the ECD could adopt LID techniques and create a living environment that is environmentally sound and ecologically resilient, the district could become a new hub for a more sustainable living and working place. This is the main reason for selecting the ECD for the study area to recruit experts as its representatives.

3.2 Study Sample and Survey Measurement

To understand the perception of decision-makers regarding the implication of LID practices, an online survey was delivered to 91 recipients, which includes land developers, architects, urban planners, landscape architects, engineers, property managers, and property owners. The authors obtained the final approval to conduct this human subject research from the Institutional Review Board (IRB) of Texas A&M University. After the data cleaning process, four responses were excluded from the data analysis. The excluded data belonged to participants who expressed a lack of experience and therefore failed to deliver complete responses. The unit of analysis selected is 40, which includes respondents that were actively engaged in the decision-making process of the development of the ECD. Quantitative and qualitative results

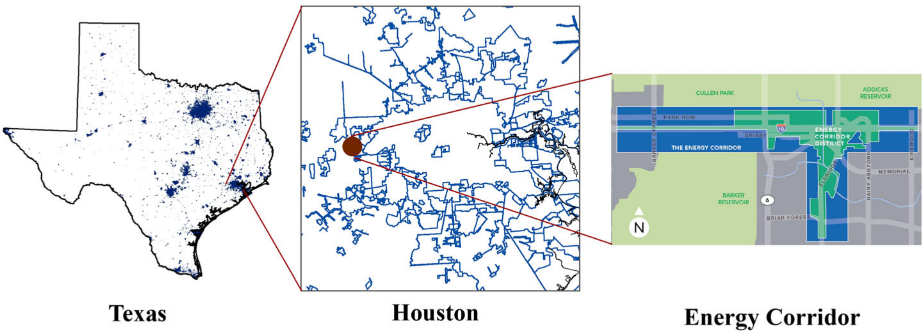

Fig. 1 Location of the Energy Corridor District

were derived based on the answers given by the different professionals and decision-makers. The results documented the participants' understanding of LID concepts and benefits, identified obstacles to the implementation of LID practices, and suggested opportunities for a solution to the challenges identified in the ECD and the West Houston areas.

To assess the perceptions and opinions concerning the LID environment, the on-line survey addressed 5 major sections (Fig. 2). The first section addressed the general knowledge of LID practices, assessing the methods of education received on the topic. Based on the LID manual (University of Arkansas Community Design Center 2010), the questions evaluated the application of specific practices in current or ongoing projects or the willingness to apply them in the future. The survey then measured the participating professionals' perceptions and their attempts to apply LID practices and addressed the issues related to the knowledge of the functions and benefits of LID practices. The results of the survey generated both quantitative and qualitative data to assess the appropriate methods and motivations for the successful application of LID. In addition, the survey provided information on the types of practices applied in real-world projects as well as the willingness of the professionals to apply the LID practices in their future projects. As mentioned, several factors determine a respondent's decision to include LID practices in their projects, and a few questions quantify the survey participant's opinion on the barriers and incentives that could be a part of the implementation of LID techniques. Table 1 explains the research construct for the survey questions.

3.3 Data Analysis

Data analysis focuses on understanding professionals' opinions towards the application of LID practices during the decision-making process. A descriptive analysis regarding the basic understanding of the LID concept, application of LID practices in previous projects, and likelihood of applying LIDs in the future are the three basic areas addressed by the survey. Subsequently, the opinions of participants concerning the constraints in LID practices and their suggestions for possible incentives for the decision-makers are analyzed.

4 Results and Discussions

Of the 40 respondents, the majority of the participants were Planners (16, 40.0%), 9 were Developers (29.0%) and 15 were Architects or Landscape Architects (37.5%). Approximately 60% of the respondents held a Bachelor's Degree as their highest level of education, while 42.5% earned a Master's Degree as well. Several respondents had one or more certifications: the majority of which (10) had an AICP Certification, 9 had received a LEED Certification, 9 held an ASLA/RLA Certification, 5 had an AIA Certification and 1 held a PE Certification.

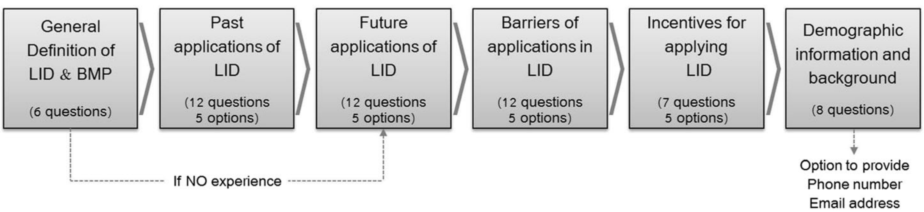

Fig. 2 Survey structure

Table 1 Research construct

Construct	Variables		Measurement
General Information			
Current Knowledge on LID	Low Impact Development Familiarity		Nominal
	Best Management Practices Familiarity		Nominal
	Discussion of LID concept with design team		Nominal
	Media of distribution of Information		Nominal
Application of LID Techniques			
Application of LID in The ECD	Application of LID in The ECD		Nominal
	Application of LID in projects		Nominal
	ECD Importance of LID practices in past/on-going projects:		Likert Scale
	Collect	Clean	Convey
	Underground Detention	Rain Garden	Bioswale
	Detention Pond	Greenway	Vegetated Roof
	Rainwater Harvesting	Tree Box Filter	Vegetated Wall
	Retention Pond		Pervious Paving
			Solar Panel
	Likelihood of application of LID Practices in future projects		Likert Scale
	Collect	Clean	Convey
	Underground Detention	Rain Garden	Bioswale
	Detention Pond	Greenway	Vegetated Roof
	Rainwater Harvesting	Tree Box Filter	Vegetated Wall
	Retention Pond		Pervious Paving
			Solar Panel
	Existence of barriers in the application of LID Practices		Likert Scale
	• Cost related factors		
	• Site Related Factors		
	• Knowledge and Experience		
	Relevance of incentives for the application of LID Practices		Likert Scale
	• Education Programs		
	• Financial Innovations		
	• Policy Innovations		
Confounding variables			
Socio-demographic Information	Gender		Nominal
	Education		Ordinal
	Years of Experience in Profession		Ordinal
	Years of Experience in The ECD		Ordinal
	Profession		Nominal
	Certifications		Nominal
	Location/Email Address/ Phone Number		Nominal

The largest portion of the respondents (52.5%) had more than 20 years of experience in their current profession, followed by 11 ~ 20 years of experience (20.0%). The majority of the respondents (82.5%) answered that they were familiar with the concept of LID. Among all of the participants, most of planners were familiar with the LID concept, while 13.3% of architects/landscape architects and 55.6% of developers answered that they were not familiar with it.

The survey delves into more details regarding the discussion and application of LID practices in the implementation of past projects. Table 2 shows that 40 participants responded to the following questions. Missing responses refer to participants who were not familiar with the concepts of LID. Only two (5.0%) decision-makers had never discussed LID techniques

Table 2 Knowledge of LID

	Yes (%)	No (%)	Missing (%)
Q: Have you ever discussed LID concepts with your team/office?			
Planners	15 (93.8%)	0 (0.0%)	1 (6.3%)
Architects/Landscape Architects	10 (66.7%)	0 (0.0%)	5 (33.3%)
Developers	3 (33.3%)	2 (22.2%)	4 (44.4%)
Total	28 (70.0%)	2 (5.0%)	10 (25.0%)
Q: Have you ever applied LID concepts in your previous or on-going projects?			
Planners	14 (87.5%)	1 (6.3%)	1 (6.3%)
Architects/Landscape Architects	9 (60.0%)	1 (6.7%)	5 (33.3%)
Developers	4 (44.4%)	1 (11.1%)	4 (44.4%)
Total	27 (67.5%)	3 (7.5%)	10 (25.0%)

with the rest of their team, and three had never applied LID practices to past projects; there were a total of 27 (67.5%) individuals who had applied LID practices in the past. About 60% of the architects/landscape architects had discussed and included LID techniques in their projects. Of the developers, only four developers included LID concepts in their past projects.

Table 3 shows which LID practices have been applied, and then, respondents were asked to evaluate the importance of their decision to include the technique in past or on-going projects by providing a value between 1 (low importance) and 5 (high importance). The techniques for LID that have been applied to a larger extent, apart from those that have already been mentioned, are Detention Ponds (60.0% of applications) and Bioswales (57.5%), which also received the highest value of importance after their application to past or on-going projects, respectively 4.32 and 4.53 out of a total of 5.00. The practices that were applied less in the past are Vegetated Walls (15.0%), Tree Box Filters (17.5%) and Vegetated Roofs (27.5%). The importance of those applications was determined to be the lowest. Tree Box Filters received an average value of importance of 3.30 out of 5.00, while the Vegetated Wall received an average value of 2.54. Although other practices were applied by a larger number of decision-makers, they received low values of importance once the project was completed: these techniques

Table 3 Importance of LID practices

	Applied (Freq.)	Applied (%)	Total	Mean	Standard Deviation
Q: Have you applied any of these LID practices in past or on-going projects, and how important are those LID practices to your projects?					
Underground detention	19	47.5	40	4.09	1.23
Detention Pond	24	60.0	40	4.32	0.87
Rainwater Harvesting	23	57.5	40	3.75	0.91
Retention Pond	21	52.5	40	4.15	1.14
Rain Garden	21	52.5	40	4.42	0.73
Tree Box Filter	7	17.5	40	3.30	1.34
Greenway	19	47.5	40	4.23	0.80
Bioswale	23	57.5	40	4.53	0.82
Vegetated Roof	11	27.5	40	3.85	0.73
Vegetated Wall	6	15.0	40	2.54	1.36
Pervious Paving	25	62.5	40	3.81	1.08
Solar Panel	14	35.0	40	3.58	1.08

included Solar Panels (3.58), Pervious Paving (3.81), and Rainwater Harvesting techniques (3.75), which respectively received 14, 25 and 23 applications.

Table 4 separates the importance by profession. Planners largely applied Rainwater Harvesting (14) and Pervious Paving techniques (13), as well as Bioswales (12). However, their experience shows that the practices that are seen as more important are Detention Ponds (4.36) and Bioswales (4.38). The practice applied least often was Vegetated Walls (3.00), which was also regarded as the least important technique (2.83), together with Vegetated Roof (3.50) and Tree Box Filters (3.60). Architects/landscape architects gave the highest importance to Detention Pond techniques (4.60 out of 5), followed by Greenways (4.50), Bioswales and Vegetated Roofs (4.20). Vegetated Walls (2.80) were deemed as the least effective practice and was also the technique that had the lowest application (only 2). Developers valued the importance of Rain Gardens and Bioswales. The practice that was least important for them was Vegetated Walls (2 out of 5).

When the respondents were asked about applying LID techniques in the future, planners were highly likely to apply Retention Ponds (4.31), Rain Gardens (4.75), Bioswales and Detention Ponds (4.63). The 16 planners were less likely to apply Vegetated Walls (3.13) or Vegetated Roofs (3.50) in the future. The architects and landscape architects had a slightly different opinion; Bioswales (4.63) were ranked as the most likely technique to be applied to future projects; Detention Ponds, Rainwater Harvesting techniques, Retention Ponds, and Rain

Table 4 Importance of LID practices by profession

Q: Which LID practice have you applied before?	Planners (Tot. = 16)		Architects/Landscape Architects (Tot. = 15)		Developers (Tot. = 9)	
	Applied (Freq.)	Applied (%)	Applied (Freq.)	Applied (%)	Applied (Freq.)	Applied (%)
Underground detention	9	47.4	7	36.8	3	15.8
Detention Pond	10	41.7	10	41.7	4	16.7
Rainwater Harvesting	14	60.9	8	34.8	1	4.3
Retention Pond	10	47.6	8	38.1	3	14.3
Rain Garden	11	52.4	9	42.9	1	4.8
Tree Box Filter	4	57.1	3	42.9	0	0.0
Greenway	10	52.6	7	36.8	2	10.5
Bioswale	12	52.2	10	43.5	1	4.3
Vegetated Roof	7	63.6	4	36.4	0	0.0
Vegetated Wall	3	50.0	2	33.3	1	16.7
Pervious Paving	13	52.0	9	36.0	3	12.0
Solar Panel	9	64.3	5	35.7	0	0.0
Q: If applied, how important was this practice in your past/on-going project?						
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Underground detention	3.82	1.25	4.13	1.46	4.33	0.58
Detention Pond	4.36	1.03	4.60	0.70	4.00	0.82
Rainwater Harvesting	3.64	0.74	3.60	1.17	4.00	n/a
Retention Pond	4.00	0.95	4.11	1.54	4.33	0.58
Rain Garden	4.25	0.62	4.00	0.87	5.00	n/a
Tree Box Filter	3.60	0.55	3.00	1.87	n/a	n/a
Greenway	4.20	0.92	4.50	0.76	4.00	0.00
Bioswale	4.38	0.77	4.20	0.92	5.00	n/a
Vegetated Roof	3.50	0.53	4.20	0.84	n/a	n/a
Vegetated Wall	2.83	0.75	2.80	2.05	2.00	n/a
Pervious Paving	4.00	0.95	3.78	1.20	3.67	1.53
Solar Panel	3.83	0.94	3.33	1.37	n/a	n/a

Gardens were next with a value of 4.53 out of 5. Architects/landscape architects agreed with developers that Solar Panels were the technique with the lowest likelihood of being applied to future projects (3.47) together with Vegetated Walls (3.80) and Tree Box Filters (3.93). Developers had a contrary opinion and identified Bioswales (2.78) as the technique that was least likely to be applied in the future, together with Vegetated Roofs (2.67) and Vegetated Walls (2.78) on a lower scale. The developers were mostly interested in applying Pervious Paving techniques (4.22) as well as Detention Ponds (4.00). Table 5 summarizes the results.

According to the survey results, decision-makers identified the major barriers to the application of LID practice as being the lack of incentives for their application, lack of knowledge of the client, and lack of knowledge of the development team. The responses show that the barriers that had little impact on the application of LID were the availability of material for the construction of the technique, lack of knowledge of the design team, and length of the phases of the construction.

Based on the results sorted by different professional fields, planners agreed that the knowledge of the client (3.94), the development team (3.63) and the construction team (3.56) were the most important barriers to implementing LID. As minor barriers, they identified the lack of availability of construction materials (2.31) and the regional climate (2.64). Architects/landscape architects ranked the lack of knowledge of the development team and client as the highest barriers (3.93) and also highlighted the construction costs of LID practices and lack of incentives for the application of LID (3.80). They agree with planners that a minor barrier is the unavailability of construction materials for LID techniques (2.29) and valued the construction phases as well as the size and shape of the site (2.67) as small constraints. On the contrary, developers ranked the lack of incentives (4.00) and the existing conditions of the site (3.88) as high constraints. The lowest values were for the unavailability of materials (2.00), lack of knowledge of the design team (2.67), and length of the phases during construction (2.56). Table 6 illustrates the results.

Respondents then evaluated possible incentives that could facilitate the application of LID techniques. The decision-makers suggested that education programs for the development teams would be the most successful incentive, followed by financial incentives and

Table 5 Likelihood to apply LID techniques in the future

	Planners (Tot. = 16)		Architects/Landscape Architects (Tot. = 15)		Developers (Tot. = 9)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Q: Would you apply these LID practices in the future?						
Underground detention	4.31	0.87	4.00	1.07	3.56	1.59
Detention Pond	4.63	0.89	4.53	1.06	4.00	1.00
Rainwater Harvesting	4.56	0.81	4.53	0.64	3.56	1.24
Retention Pond	4.31	1.08	4.53	0.92	3.78	1.20
Rain Garden	4.75	0.77	4.53	0.83	3.56	1.51
Tree Box Filter	4.27	1.03	3.93	0.92	3.11	1.45
Greenway	4.63	0.89	4.53	0.74	3.22	1.56
Bioswale	4.63	0.89	4.67	0.62	2.78	1.30
Vegetated Roof	3.50	1.21	4.20	0.94	2.67	1.41
Vegetated Wall	3.13	1.06	3.80	0.86	2.78	1.48
Pervious Paving	4.44	0.96	4.47	0.64	4.22	0.67
Solar Panel	4.20	1.26	3.47	0.92	3.33	1.66

Table 6 Barriers in LID applications

	Planners (Tot. = 16)		Architects/ Landscape Architects (Tot. = 15)		Developers (Tot. = 9)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Q: Which barriers have you found in implementing LID practices?						
Construction costs of LID practices were too expensive	2.75	0.77	3.80	0.86	3.78	0.97
Cost of LID application was too expensive in the site	2.81	0.98	3.40	0.91	3.44	0.88
Phases of construction were too long	2.81	0.66	2.67	0.72	2.56	0.53
Geology/Hydrology factors were not appropriate	3.19	0.91	3.13	0.99	3.38	1.06
Regional Climate was not appropriate	2.69	0.70	2.33	0.98	3.11	1.17
Size and Shape of the site were not appropriate	2.88	0.89	2.67	1.05	3.67	0.71
Existing conditions or infrastructures did not allow the application	3.25	0.77	3.07	0.88	3.88	1.13
Materials for construction were not available	2.31	0.60	2.29	0.91	2.00	0.87
Lack of incentives for the application	3.67	1.11	3.80	0.68	4.00	0.71
Lack of knowledge of the design team	2.81	1.11	2.93	1.22	2.67	1.12
Lack of knowledge of the development team	3.63	1.02	3.93	0.80	3.11	0.93
Lack of knowledge of the construction team	3.56	0.89	3.60	0.99	2.89	0.93
Lack of knowledge of the client	3.94	1.06	4.07	0.80	3.38	0.92

innovations in policy systems. Specifically, planners highly value the importance of policy innovations, as well as workshops, conferences, and education programs for the development team (4.38). There was not a factor that had been identified at a particularly low value, but economic incentives, such as marketing, were ranked the lowest (4.13). Architects and landscape architects ranked policy innovations as the first factor as well (4.33), but financial incentives (4.27) and education programs for development team (4.13) were also highly recommended as incentives. Education programs for the design team (3.60) and marketing (3.80) were the factors of less importance. Developers found that financial incentives (4.22) and education programs for the development team (4.11) were of high value. On the contrary, policy innovations had the lowest value (3.11), together with marketing (3.63) (Table 7).

Table 7 Facilitators for LID applications

	Planners (Tot. = 16)		Architects/Landscape Architects (Tot. = 15)		Developers (Tot. = 9)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Q: Which incentives would you recommend?						
Financial incentives	4.25	0.86	4.27	0.59	4.22	0.97
Policy innovation	4.38	0.50	4.33	0.72	3.11	1.17
Design Team education programs	4.25	0.68	3.80	0.56	3.89	0.60
Development Team education programs	4.38	0.62	4.13	0.35	4.11	0.60
Construction Team education programs	4.19	0.66	4.07	0.59	3.89	0.60
Workshop/Conference	4.38	0.62	3.93	0.46	3.67	0.50
Marketing	4.13	0.92	3.80	0.77	3.63	0.92

Overall, the results showed that urban planners have the most expertise in LID practices (100% of positive answers), followed by architects/landscape architects (70%), while developers were found not to be very familiar with the concepts. Both the planner and architect/landscape architect groups have discussed LID practices in the past when preparing for projects. Planners participated in conferences and workshops that cover the issues in LID and had been properly informed by media sources and books on their benefits and challenges. Only a few of the developers were actually able to collect information and education on the topic. These results shows that planners and architects/landscape architects are facilitated by the presence of national or state chapter conferences providing informative sessions on the topics of LID, while developers have somewhat restricted access or are less interested in the same resources.

By analyzing the survey respondents by profession, the authors used these trends and different experiences to determine opinions on LID techniques. Planners ranked only one practice with the "Collect" function and preferred more "Cleaning" practices. Meanwhile, architects/landscape architects and developers ranked all of the top three practices from "Collecting" techniques, whereas all of the groups gave lower importance to the practices with the "Convey" function. When considering all of the responses comprehensively, "Collect" and "Clean" practices were ranked as the most important techniques and were implemented in past LID applications.

When looking at the trend change between the existing project experience and anticipated future implications, the importance of Bioswale becomes a less dominant feature, whereas Rainwater Harvesting and Pervious Cover receive more attention than before. This is an interesting result as the most of past studies emphasize the effectiveness of bioswale in LID practices (Davis et al. 2006; Hunt et al. 2008; Roseen et al. 2006; Sun and Davis 2007). Many of the past studies illustrating the effectiveness of LID have gauged bioswale and for that reason the numerical evidence has been suggested to audience that bioswale could be a role player in current LID implementations. Techniques, such as Detention Ponds, Rain Gardens, and Retention Ponds were shown to be a consistent choice from the professionals for past projects (Chapman and Horner 2010; Glass and Bissouma 2005). It is interesting that among many other techniques, the functions in "Convey" received less attention in the past (DeNardo et al. 2005; Gregoire and Clausen 2011; Roehr and Kong 2010) and were still nominated as the least favorable features for the future. Many reasons could account for this, but the cost and construction difficulties maybe one of the reasons.

There are limitations of this research. First, the study area was strictly limited in the ECD in Houston, thus the study findings may not generalizable to other cities or regions. Second, the sample size of this study is relatively small. However, the research has recruited well-experienced and high-ranked professionals in various fields who can influence decision-making process of the current or future projects in West Houston areas. Thus, their opinions would represent the perception of applying LID practices in the real world projects and share professional voices to promote implementing more LID applications to maximize benefits for future development. Finally, some newly developed LID applications may not be included in the on-line survey.

5 Conclusions

The purpose of providing this survey to major decision-makers is to help understand experts' opinion on the application of LID practices and to identify the major barriers in its implementation. This study allows us to understand the current and actual opinions of the decision-makers and provides specific results on their perceptions. The analysis of the results helps fill in the gap between the numbers collected representing decision-maker's perceptions and the existing efforts of policies and regulations. Different groups of decision-makers understand the importance of education when discussing about LID practices. Conferences and workshops are valuable resources for education and training on the topic. However, planners have been able to gather the most information; thus, more education programs should be provided for development and construction teams, as well as for the client delivering the project ideas.

In addition, the implementation of the results allows future policy-makers to understand the perceptions of their users in depth and provides specific guidelines for the best management of the site. Professionals participated in this study have identified a major barrier as the lack of policy instruments. Innovation in regulations and strategies will guide all of the groups to implement proper LID practices. Different groups have expressed the likelihood of applying extensive practices that might function as infrastructure. The results revealed that there are clear and strong interests from experts to apply LID techniques. With proper policy assistance and educational support, LID could play a vital role in stormwater management for a city. It could also help monitor application costs and maintain the implemented technologies. The results of this research can support different authorities to understand the issues of LID implementation by filling in the gap between decision-makers' perceptions and policy-makers' actions.

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