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Green Infrastructure: The Case for Low Impact Development in Coastal North Carolina

Amelia Saul
Graduate Student, East Carolina University, Greenville, NC, USA
saula12@students.edu.edu

Jonathan Chase
Graduate Student, East Carolina University, Greenville, NC, USA
chasej90@ecualumni.ecu.edu

Dr. Syed Ahmed
Professor & Chair, Construction Management Dept, East Carolina University, Greenville, NC, USA
ahmeds@ecu.edu

Abstract
For more than 40 years, North Carolina (NC) has focused on maintaining and improving the state's water quality with conventional best management practices (BMPs) to control runoff. Despite the widespread application of BMPs, the desired results for water quality have fallen well short of expectations. NC has lost more than 100,000 acres of shellfish waters to contamination in the last 20 years and continues to lose these most sensitive waters (Low Impact Development for the NC Coast, 2008). Meanwhile, Low Impact Development (LID), within the broader construct of Green Infrastructure, has been gaining traction as a more economical and environmentally friendly alternative to conventional BMPs. In addition to improved water quality and healthier aquatic habitat, the use of LID techniques offers other benefits including lower infrastructure costs through reduced maintenance demands, greater lot yields, increased property values, and reduced incidences of costly flooding events. Despite this outreach and other educational efforts, the state has seen a small voluntary shift from conventional management techniques to LID. An online survey was distributed to 78 management professionals that work in coastal NC, investigating the awareness of LID. The survey's results indicate a common knowledge of LID regardless of years' experience or profession-type. Respondents have a favorable impression of LID and, of those who used one or more LID techniques in projects, there is a preference to LID versus conventional management techniques when future use is considered. While the state wields the most influence over the future deployment of LID, more significant outreach and education are seen as critical to a deeper understanding and acceptance of LID.

Keywords
Green Infrastructure, Low Impact Development, Coastal NC

1. Introduction

Historically, water quality and runoff quantity have been the primary targets of comprehensive and conventional storm water management programs. Conventional storm water management programs move storm water away from its built environment and states, such as NC, insist developers use storm water best management practices (BMPs) to obtain necessary permits. Site-specific management techniques do not consider impacts to the surrounding watershed that, as water quality assessments in Coastal NC have shown, result in the continued degradation of water quality and the natural environment. The continued growth of

Coastal NC will only exacerbate already troubling water quality statistics and the health of the state's aquatic habitats. According to the US Census Bureau's 2016 estimates from counties in Coastal NC, population growth rates are expected to continue to grow with the region's population approaching 1.2 million in 2030, a 43 percent increase from 2000 (Kulik et al., 2008).

Dias, Wilson, & Henn (2016) describe management practices as Green Infrastructure (GI), which outlines a network of LID practices with the combined purpose of reducing runoff and improving water quality. GI was first promoted by environmental organizations and tested on university campuses. Today the success of these LID techniques in controlling runoff is now being recognized by municipalities across the country (Dias et al., 2016).

1.1 Establishing Definitions of GI and LID

According to the Environmental Protection Agency (EPA), LID is considered a "management approach." In addition to improved water quality and healthier aquatic habitat, the use of LID techniques offers other benefits including lower infrastructure costs through reduced maintenance demands, greater lot yields, increased property values, and reduced incidences of costly flooding events.

Further, the EPA currently uses the term GI to refer to the management of wet weather flows using these processes, referring to the patchwork of natural areas that provide habitat, flood protection, cleaner air and cleaner water. At both the site and regional scale, GI/LID practices aim to preserve, restore and create green space using soils, vegetation, and rainwater harvest techniques. LID is an approach to land development (or re-development) that works with nature to manage as close to its source as possible.

1.2 Evolution of Conventional Storm water Management, LID, and GI in NC

For more than 40 years, the State of NC has focused on maintaining and improving the state's water quality with conventional storm water best management practices (BMPs) to control storm water runoff. In a presentation of the *2007 Stormwater Programs Annual Report* (Reeder, 2007) to the Environmental Management Commission (EMC), Reeder suggested rules need adjusting in response to statewide shellfish closure data, statewide development trends, and the effectiveness of rules in developing watersheds. Presently, 2016 Census estimates the population of this region at 1,046,000 (Census.gov, n.d.) Kulik, Doll, & Putnam (2008) estimated continued population growth in NC's coastal counties, with the coastal county population expected to approach 1.2 million in 2030, a 43 percent increase from 2000.

Despite the widespread application of BMPs, the desired results for water quality have fallen well short of expectations. NC has lost more than 100,000 acres of shellfish waters to storm water contamination in the last 20 years and continues to lose these most sensitive waters (Low Impact Development for the North Carolina Coast, 2008). Water quality is especially important to the state's coastal communities, where clean water and a robust shellfish population are vital to NC's coastal economy. This contributed over a $32 billion to the state's total gross domestic product in 2013 (North Carolina's Ocean Economy: A First Assessment and Transitioning to a Blue Economy, 2017). Meanwhile, Low Impact Development (LID), within the broader construct of Green Infrastructure (GI), has been gaining traction as a more economical and environmentally friendly alternative to conventional BMPs.

2. Purpose Statement

The purpose of this research is to make a case for the use of GI and LID for management in Coastal NC. Knowing the shortcomings of conventional practices, researchers examined why, despite the different efforts of the NCCF and others, more practitioners in Coastal NC are not voluntarily using LID techniques versus conventional management methods. Furthermore, researchers examined what these specialists feel

should be done to encourage more widespread application of LID techniques to work on improving water quality and the health of the state's shellfish population.

3. Methods

Despite the forty years that NC has mandated the application of conventional management techniques (BMPs) when developing sites, the sought-after resulting improvements in coastal water quality and the health of the coastal shellfish populations have fallen short of the desired expectations. With the arrival of GI/LID nearly 20 years ago and the push in NC, 10 years ago, many in NC hoped developers, engineers, planners, and academics would readily adopt these practices, which have proven to yield the results once sought from conventional techniques. The purpose of this study was to gauge the practitioners involved in management and design on an understanding of their knowledge and application of LID. Specifically, this study sought to identify the obstacles that exist that prevent more voluntary, routine, and consistent application of GI/LID techniques for managing coastal problems.

The Methodology section contains the following subsections: research method, participants, instrumentation, ethical considerations, procedures, and data analysis.

3.1 Research Design

The type of research method used in this study was quantitative research. The type of quantitative investigation pursued was non-experimental, descriptive design. This method was appropriate to the study since it aims to describe the present condition. The technique applied was a normative survey approach and evaluation. Given the period available to complete the research paper, a cross-sectional survey study was deployed.

One type of direct-data survey was included in this study – questionnaire survey. This format was preferred as it provided the researcher the ability to interact directly with each respondent. The question types varied to include multiple choice and open-ended to allow for meaningful commentary to gauge an individual's level of knowledge and involvement (or lack of) with GI/LID techniques, their perceived barriers to using GI/LID and whom they saw as having the most influence over design. The researcher used this type of research because this study focused on the perceived barriers to the more widespread application of GI/LID techniques. Thus, the descriptive method was most appropriate.

This survey research design was chosen for its cost-effectiveness, ease of administration, and access to information. Surveys using questionnaires are easier to administer and lend themselves to group administration. They also assure confidentiality and effective in providing information in a relatively brief time at a low cost to the researcher. They are widely used as a key tool for conducting management research and obtaining information about opinions, perceptions, and attitudes. The background characteristics collected from respondents enables answering the research questions on differences in practice and opinions on the future of advertising in the hospitality sector according to age, gender, and experience. (Writing Chapter 3: Methodology [for Quantitative Research]. n.d.).

Primary and secondary data were used in this study. The primary data resulted from the answers given by the respondents to an online survey developed by the researcher. The secondary data was through a review of literature that includes journals, reports, pamphlets and scientific conferences, presentations, and publications.

3.2 Participants

The target population of interest to this study was practitioners or others familiar with management in Coastal NC. The research sampling method used was non-probability purposive sampling. In purposive

sampling, the researcher uses their expert judgment to select participants that are representative of the population (Conducting Education Research – Step 6: Select Sampling Technique, n.d.). The sample was developed based on the researcher's professional relationships (list of contacts) with developers, engineers, planners and others who work in Coastal NC. Regarding restrictions on the participant pool, the sample respondent had to either influence or be responsible for determining whether to use conventional or GI/LID techniques in coastal management design. Limitations were not provided in the sample. It was requested of the participants that the survey be forwarded to other colleagues that were involved or had an influence on decision making for practices in Coastal NC.

3.3 Data Collection

Two data collection tools were used for this study: 1) questionnaire and 2) secondary research – review of literature that includes journals, reports, pamphlets and scientific conferences, presentations, and publications.

The self-report questionnaire had 21 questions. The questions were a combination of structured questions (i.e. multiple choice (1), "yes" or "no" (2) and unstructured questions.

3.3.1 Recruiting the Sample

Initially, the researcher contacted perspective participants to let them know that they would be receiving an online survey from the researcher via Survey Monkey. Further, the researcher explained that he was a graduate student pursuing a Master of Construction Management from East Carolina University. The researcher told the sample that the survey was an essential part of completing his research paper - a requirement for graduation.

The consent of potential respondents was not obtained before distributing the online survey. Participants took an online survey by themselves, which they read to themselves and provided their answers. Participants were surveyed once and the average amount of time spent completing the survey was seven minutes.

4. Results

The online survey included a total of 21 questions. The questions were divided into the five following sections: 1) Socio-demographic information, 2) Knowledge of GI/LID, 3) Importance of LID practices, 4) Barriers to GI and LID, and 5) Facilitators for LID applications.

4.1 Socio-demographic information

The first section addressed socio-demographic information that include gender, education, profession, years of experience in the profession, years' experience in coastal design, implementation, regulation, and construction, professional licenses and certifications, and contact information for follow up questions if necessary. Of the 74 respondents, 74% of the participants were male and 26% were female. Ninety-five percent of respondents held a bachelor's degree or greater.

In order to understand the thoughts of those influencing the implication of LID practices, an online survey was delivered to 78 recipients, with further requests to share with other colleagues to include land developers, architects/landscape architects, engineers, planners, and regulators of management practices in Coastal NC. A variety of professions were well represented in the survey. Of the 74 participants, 25 identified as planners (34%), followed by 20 engineers (27%) and 14 who identified as being a regulator "Other" (19%) (Table 1). The largest portion of the respondents had 11-20 years' experience (38%) followed by those with 21-30 years' experience (32%).

Table 1: Type of Profession

Profession	*Number*	*Percentage*
Planning	25	34%
Other	4	19%
Landscape Arch	3	4%
Gov't Not Planning	14	19%
Engineer	20	27%
Developer	5	7%
Biologist	2	3%
Attorney	1	1%
Academic	2	3%

Years of experience in coastal management slightly differed from overall years in their respective professions. Thirty-three percent of the respondents had 11-20 years' experience in direct coastal management followed by those with 1-5 years' experience (28%). Eight of the respondents cited having zero experience in coastal management, which could correlate with lack of knowledge being a key impediment to LID implementation.

Several respondents had one or more certifications. Most respondents were either certified planning professionals (AICP's – 13) and Professional Engineers (PE's – 13). In NC, there is a LID certification process, whereas eight respondents were NCLID. Other certifications included (five – BMP certifications and six LEED professionals).

4.2 Knowledge of GI/LID

The second section of the questionnaire survey requested information regarding the participant's knowledge of GI/LID. Based on the data collected, 42% of respondents said they had common knowledge about the concept of GI/LID. Forty-six percent thought they had deep knowledge, and 13% called themselves an expert.

Table 2: Depth of Knowledge Regarding GI/LID

Answer Choices (with example)	*Response*	*Participants (#)*
No Knowledge (This is new to me)	0%	0
Common knowledge (Know about concept but have not seen it applied)	42%	30
Deep knowledge (Recommended strategy for storm water controls, etc.)	45%	33
Expert (Designed, installed, implemented, reviewed)	13%	9

The level of knowledge based on the profession was analyzed. The results indicated that 60% of planners said they had deep knowledge of GI/LID design among practitioners surveyed while only 40% of engineers felt this way. Respondents that identified as regulator-other, developer, or landscape architect described themselves as having common knowledge of GI/LID. Generally, engineers were most likely to describe themselves as having expert knowledge of GI/LID.

Respondents were asked if they discussed GI, specifically LID, with their team. Of the participants surveyed, 75% answered yes, 23% had never discussed (i.e., answered "no"). Researchers found that

planners (34%) were more likely than other professions to have discussed GI/LID with their team followed by engineers (27%).

The respondents were also asked if they had applied LID concepts in their line of work. Of the individuals surveyed, 65% of respondents answered "yes", while 31% said "no." When looking at answers based off profession, researchers found that every biologist and academic professional that responded to the survey had applied or is applying LID techniques to their projects. Developers were the lowest where only 33% of respondents had used or are using LID. An average of 70 percent of planners, engineers, regulator – other, and landscape architects had applied or is applying LID to their projects.

Table 3: Practical Application of LID Concepts

Profession	*Applied LID*	*Have not applied LID*	*Participants (#)*
Planners	65%	35%	25
Engineers	75%	25%	20
Regulator- other	71%	29%	14
Landscape Architects	67%	33%	3
Developers	33%	37%	3
Biologists	100%	0%	2
Academia	100%	0%	2
Professional- other	60%	40%	5

4.3 Importance of LID Practices

The number one choice for the LID practice used in the past or in on-going projects was permeable paving, cited 49 times. When importance of LID practices was evaluated by the type of profession, 64% of planners believed LID practices to be important to projects, followed by 45% of engineers, and 35% of regulator-other. Although few developers responded to the survey, 67% thought LID practices were important to their projects.

As a follow up to the importance of LID to past or on-going projects, respondents were asked what percentage of their projects have incorporated GI/LID practices. The responses could be open-ended and varied greatly. Planners and regulator-other experienced projects that ranged from not incorporating LID at all to some that always incorporated LID. Engineers response differed slightly differed ranging from less than 5 percent to 75 percent. One developer noted that LID was used in 95 percent of their most recent projects and 100 percent in the retrofit of older properties.

Next, respondents were given a list of six LID practices and asked if they would apply any of these LID practices in the future; they could choose all practices that applied. The majority of respondents chose permeable paving, rain gardens, bioswale, cistern, and rain barrels. Vegetated roof was the least chosen option.

Respondents were then asked to rate their satisfaction with the use of GI/LID in their respective projects. More than half (52%) of the respondents said the use of GI/LID in their projects had satisfied/met expectations, while 6% of respondents noted their dissatisfaction with LID, and 20% were somewhat satisfied. Looking at responses based on profession, with the exception of developers, more than half of the respondents said that LID practices had impressed/met expectations.

Table 4: Impression of LID Practices by Profession

Profession	*Indicated "Impressed/Met Expectations"*	*Participants (#)*
Planners	52%	25
Engineers	50%	20

Regulator- other	57%	14
Landscape Architects	100%	3
Developers	33%	3
Biologists	0%	2
Academia	100%	2
Professional- other	60%	5

Respondents were also surveyed to determine the most common storm water practices. Among the choices given, wet pond, reduced impervious cover, infiltration system, and permeable pavement were chosen most often. Respondents did indicate experience with all the LID choices provided with vegetated roof being chosen the least often.

With the questions to follow, the focus shifted from GI/LID to conventional systems. The survey asked respondents to evaluate their satisfaction with conventional management (non-GI/LID) systems. Only 38% of respondents said the use of conventional systems in their projects satisfied/met expectations. The same number (38%) said they were somewhat satisfied with conventional systems while 8% said they were not satisfied at all/did not meet expectations. Only 5% said conventional systems impressed/exceeded expectations. Further comparison of satisfaction of LID versus conventional system based on respondents' professions determined that overall, most respondents were not as satisfied with conventional practices as compared to LID methods. When compared with their future use in projects the results are similar. Based on the responses, there is support for future projects for LID practices.

4.4 Barriers to GI and LID

The fourth section asked contributors their thoughts on barriers and obstacles to GI and LID. There were two questions in this section. The first question asked respondents to identify which barriers/obstacles they had found in implementing, reviewing, suggesting, and/or recommending LID practices. According to the survey results, respondents cited the following 4 barriers 1) construction costs of LID practices were too expensive, 2) geology/hydrology factors were not appropriate, 3) political (ex. community not in support of, fear of costs to developer), and 4) lack of incentives for the application. Of note, "lack of knowledge of the client" was cited 28 times as contributing to barriers to implementation of LID. Overall, the results indicate that a general lack of knowledge exists.

As a follow up to obstacles and barriers to LID, respondents were asked, based on their experience, which group they felt wielded the most influence over design. Thirty-five percent of respondents believe that the NC government wielded the most influence over design, followed by local government at 25%. Based on profession, overall, most planners, engineers, and regulator-other believed the state wields the most influence on design.

Table 5: Group Cited as Wielding the Most Influence on Stormwater Design by Profession

Group	*Planners*	*Engineers*	*Regulator-Other*	*Landscape Architect*	*Developers*	*All others*
Design Team	24%	10%	29%	0%	33%	22%
Developers	8%	10%	0%	33%	33%	11%
Clients	0%	5%	0%	0%	0%	11%
Local Government	20%	30%	14%	67%	0%	22%
State Government	28%	40%	50%	0%	33%	11%

4.5 Facilitators for LID applications

The last section of the survey included facilitators for LID implementation. Survey respondents were asked to choose programs and/or incentives that could be recommended to increase GI/LID application in Coastal NC. The results found that many respondents believe regulatory changes at the state level for LID versus conventional systems would increase GI/LID. Of the professions surveyed, planners held the most in-depth knowledge of LID practices, while engineers have the most expertise in LID design. Planners, engineers, biologists, academics, and professionals described as others discussed LID practices in the past when preparing for projects.

Table 6: Program Change and/or Incentive Necessary for LID Implementation

Program and/or Incentive	Number of Times Chosen
Regulatory changes at State level for LID versus conventional (grey) systems	43
Financial Incentive	36
Regulatory requirements at local level for LID versus conventional (grey) systems	35
Policy innovation	29
Education Programs	25
Design team education programs	24
Development team education programs	24
Workshops/Conferences	21
Marketing	15

5. Discussion

The purpose of this research was to examine the use of GI and LID for management in Coastal NC. Furthermore, researchers examined why management practitioners are not voluntarily shifting away from the use of conventional management techniques to GI and LID methods.

The survey was distributed to enlisted representatives including developers, architects/landscape architects, planners, engineers and other professionals who are involved in the decision-making process of the current or future development efforts within Coastal NC, to assess their opinions and perceptions on LID practices.

The findings from the survey show those involved in management decisions within coastal NC share a common knowledge of GI and LID techniques. Overall, planners held a deeper knowledge than their counterparts did whereas engineers had more expertise in LID design, installation, and use. Although common knowledge of LID was prevalent among the respondents, the instance of subsequent discussion of this topic and did not correlate with the knowledge; in fact, it dropped off. Ultimately, the actual application of LID methods because of common knowledge was even lower.

Survey participants were asked to assess the importance of LID practices to past or on-going projects. Most noted that LID was necessary for reasons such as meeting state requirements, fulfilling a local desire, meeting certifications (as in LEED or Green Building Council) and supporting environmental causes. Respondents were also asked to rate their satisfaction with the use of GI/LID for their projects. Most were satisfied with GI/LID and stated that it met their expectations. Only a few were dissatisfied with the results. When asked to compare satisfaction with LID versus conventional practices, respondents were not as enthusiastic. Overall, most respondents were more satisfied with LID in comparison with conventional methods.

Overall, the survey results demonstrated a general lack of knowledge on behalf of regulators, clients, and/or the design team. Beyond greater government involvement at the state level, planners also valued financial incentives followed by general policy innovation as ways to increase the use of LID techniques. Engineers answering the same question provided the same response noting change should occur at the state level. They also felt financial incentives would be a motivator. In contrast, those identifying as regulator-other, ranked greater education as the best incentive. Landscape architects were the only community of professionals to choose unanimously that change at the local level was the best form of incentive. Developers identified financial incentives, workshops/conferences, and education programs as tools that would increase the rate of LID implementation. Other professionals surveyed believe change should occur at both state and local levels equally, followed by marketing and education team programs.

6. Limitations

One of the limitations of this research study was the constitution of the sample. First, respondents were not randomly selected from a larger population to participate in the study. The researcher's professional relationships with most of the sample may have biased the sample or, at a minimum, favorably influenced the response rate. The sample was also not structured such that a pre-determined equal number of management practitioners were solicited based on their profession. Therefore, the response rate by profession could not be measured and, further, the results might have reflected a bias in that the perceptions of one or two professions stood out more than another profession only because the researcher, for example, knew more planners and engineers than developers.

Further, by allowing respondents to forward the survey link to a colleague, the researcher was not in control of the study's ultimate sample size. Another limitation was the structure of some of the survey's questions. For example, some of the questions could have been set up using the Likert Scale format but were not. Lastly, several questions also allowed respondents to "choose as many answers as applied" which prevented the researcher's from quantifying the importance (rank) of one answer over another.

7. Conclusion

After extensive efforts over the last few years, particularly the work of the NCCF and others, GI and LID have limped into the day to day fabric of practice in Coastal NC. Despite the efforts of the NCCF and the state's formal recognition that attempts to regulate and manage GI and LID has fallen short of expectations, resulting in shellfish closures and continued degradation of water quality, LID still struggles to be recognized as the preferred method for control.

To understand why such reluctance has occurred by applying LID over conventional methods, a survey was sent to those involved in practice in Coastal NC, to ascertain their opinions and perceptions over barriers and strategies surrounding LID. The overarching theme amongst those designing, regulating and managing LID was a lack of knowledge exists whether on behalf of regulators, clients and/or the design team. As a result, misconceptions over cost and usage in various climates and soils continue to plague LID's acceptance. Trinkaus & Clar (2015) stated that if there is no prior knowledge about LID, the implementation will never succeed.

A more troubling barrier to LID's implementation is the regulatory fragmentation around LID. Most recently with state legislative changes, the state is in charge of management. Affirming the state's role in management, survey respondents believed the state wields the most influence over management and is a catalyst for making the change to LID.

Experts tend to agree there are strategies in place that make a case for LID. First, the benefits of LID are understated. Further, LID can be applied in a variety of climates and soil types. Eight case studies found that LID projects cost 19 percent less on an average capital construction cost basis and could provide up to 20 additional benefits beyond water quality than traditional designs (Forasté, et al., 2011).

In making a case for LID, Trinkaus & Clar (2015) stated that with any document, the information needs to be well-defined for users. The information needs to include specifics as to why the changes are being made (Trinkaus & Clar, 2015). However, change sometimes needs a nudge. A widely accepted practice among many is providing incentives for modifying management behavior. The results from a most recent survey conducted by the NAHB shared that home builders would be much more likely to adopt low-impact or more sustainable management practices if local jurisdictions offered fast-track permitting or other incentives for installing them (Birk, 2017). Partnering with the idea of incentives, Nattress (2017) ended with good advice and believes communication is important for green efforts. Many believe that in order to have effective water resource management, local governments, businesses, community organizations, and residents need to work together and adopt integrated approaches to impacts (UNHSC, 2011).

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