THE ADOPTION OF AN INNOVATION: BARRIERS TO USE OF GREEN ROOFS EXPERIENCED BY MIDWEST ARCHITECTS AND BUILDING OWNERS

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ABSTRACT

While green roof technologies are increasingly employed in Northern European countries, adoption is progressing at a much slower rate in the US. This manuscript discusses results of a survey that quantified knowledge, barriers, and perceived costs and benefits to use of green roof technology among a sample of architects and building owners in the Midwest. The survey also examined conditions that may encourage use of this technology among the respondents. Results show that many respondents do not fully recognize the economic or performance advantages offered by green roof technologies. The payback period for economic advantage is longer than owners are willing to consider. Both owners and architects possess a wide range of misconceptions about the performance advantages of green roofs. While green roof technology offers clear environmental advantages such as reduced stormwater runoff, increased habitat, and cooler temperatures that mitigate heat island effects, many building owner respondents either do not know about or value these advantages. This research quantified potential adopters' perceptions of an innovative technology and the survey results are interpreted and discussed within the conceptual framework of innovation diffusion literature. Strategies to hasten the adoption of green roof technology are suggested.

KEYWORDS

green roofs, innovation diffusion, building owners, architects, construction industry

1. INTRODUCTION AND BACKGROUND

Green roof technologies are gaining widespread use in some Northern European countries. Over the past twenty-five years, Germany has seen the installation of millions of square feet of green roofs with 14% of flat rooftops vegetated in 2001 (Herman 2003). Initially motivated by the replacement of green space, energy-efficiency, and cost-effectiveness, many municipalities in Germany now mandate green roofs in order to alleviate stormwater management issues.

Green roofs, as the term will be used here, refer to planted rooftops. They can be constructed with a thick substrate to support vegetation such as perennials, shrubs, and even trees and used as recreational spaces atop buildings, or with a thin planting horizon that supports hardy sedums, grasses and other low-growing perennial plants.

Green roofs are best known for their environmental benefits, though they offer economic and performance advantages as well. Green roofs retain and evapotranspirate stormwater, easing the burden on infrastructure and helping to mitigate erosion caused by runoff. They provide some habitat for wildlife such as birds and insects. Green roofs mitigate the urban heat island effect through much lower roof temperatures than standard asphalt roofs. It is also theorized that green roofs can help alleviate air pollution, though there is currently little research supporting this claim (Dunnett and Kingsbury 2004). Although first costs are higher, the economic and performance benefits include increased roof life, decreased heating and cooling costs, credits toward green building certification, and improved aesthetic and recreational opportunities (Dunnett and Kingsbury 2004).

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1.1 Related Research: Innovation Diffusion

Green roof technology can be considered an innovation in the roofing industry as it differs substantially from traditional roofing technologies. In *Diffusion of Innovations*, Rogers (1995) defines an innovation as "an idea, practice or object perceived as new by an individual or another unit of adoption". The literature on conditions that may hasten the adoption of innovations tends to fall into three areas: attributes and the adoption potential of innovation itself (Rogers 1995); characteristics of the adopter (NAHB 1990; Koebel et al. 2004); and communication channels of information about the innovation (Rogers and Shoemaker 1971; Rogers and Kincaid 1981; Rogers 1995).

The first area focuses on attributes of the innovation itself. Rogers (1995) posits that an innovation is more likely to be adopted if it is perceived to have relative advantage over the current technology. In the case of green roofs advantages could be economic, performance, aesthetic, or environmental. Trialability or ease of trial has also been found to enhance adoption of a new technology. Observability or the opportunity for potential adopters to observe the technology in use before committing to adoption is also important is the compatibility of the innovation with existing methods. The last condition that Rogers claims will hasten adoption is the perception of complexity by potential adopters.

Rogers (1995) defines categories of adopters as innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%). These percentages reflect a bell curve with increasing time corresponding to increasing adoption. Some literature on innovation diffusion maintains that characteristics of potential adopters vary widely by industry. In the building industry, a study of residential homebuilders by the Center for Housing Research (CHR) and the National Association of Home Builders Research Center (NAHB) studied the circumstances under which "residential homebuilding innovations become standard industry practices" (Koebel et al. 2004). The study found that adopters of building construction innovations rely heavily on tried and true technology and well established manufacturers because financial risk of building innovations can be substantial. It also found that early adopters are "critically important in demonstrating the benefits of products and materials to other builders." (Koebel et al.2004).

Literature on information awareness and communication channels about an innovation emphasize that the adoption of an innovation is a function of stages of information gathering and decision making (Rogers and Shoemaker 1971; Rogers 1995) and that a potential adopter's access to information on the innovation is critical to adoption (Rogers and Kincaid 1981). Rogers states that the communication channels that adopters use vary across adopter categories. This is confirmed by the Koebel et al. (2004) study which found that early adopter residential builders rely on technology transfer programs and universities more than middle or late stage adopters do. The study found sales and supplier representatives, subcontractors, and trade shows to be important information sources for all types of adopters. It also confirmed the importance of "technology advocates", a person promoting use of the innovation, for innovation adoption in the residential homebuilding industry. Two thirds of the respondents identified the firm's owner as the technology advocate. Architects and construction managers were also identified as technology advocates.

A 1989 study by the NAHB Research Center identified a wide variety of information barriers to "efficient and effective diffusion in residential construction as: lack of access to information about new products, inadequate education and training on products and materials, installation techniques, and methods of installation and maintenance, acceptance by finance and insurance industries, limited funding for research, . . ." (NAHB 1990). Other barriers to innovation within the construction industry and the green design industry identified in the literature include underdeveloped links between university research and the construction industry, minimal government support for construction technology development and adoption, and information flow problems between manufacturers and the building industry professionals (Oster and Quigley, 1977; Dibner and Lemer 1992; Jaffee and Stavins, 1995; Koebel, 1999; Cassidy 2003 and 2004; Yudelson 2003).

1.2 Related Research: Green Building Innovation and Green Roof Use

Despite the benefits, implementation of green roofs in the US is progressing at a slow rate. There is some

research relating to challenges encountered in the use of green roofs and green design practices. Recent surveys of design practitioners in the US have documented a growing interest in green design. However, they also revealed implementation challenges of some green technologies. Commonly cited obstacles are increased cost (both real and perceived), lack of performance data and information, and conflicting priorities of stakeholders and decision makers. An online subscriber survey of *Building Design and Construction*, a publication circulated to 76,000 architects, engineers, owners and contractors in the US and Canada, identified cost and lack of market acceptance as significant barriers to green design. Many of the respondents called for more studies independently validating cost benefits, case studies of successful projects, and training and education (Cassidy 2004). A similar online survey sent to all attendees of the first *Greenbuild* conference (sponsored by the US Green Building Council) in 2002 revealed comparable challenges of high first costs (78%), difficulty justifying costs and quantifying long term economic benefits (47%), discomfort with new technologies (39%), and lack of market interest (24%).

Anecdotal research on challenges specifically related to implementation of green roof technologies is abundant, but quantitative analyses are limited. Those that exist reveal challenges similar to the green design strategy use studies discussed above. The most commonly cited challenge to adoption of green roof technology is cost—both first and operating cost (Herman 2003; Cassidy 2004). First costs are higher and long-term payback studies showing economic advantage exist, but are not widely disseminated; operating costs are not well documented. Other challenges are lack of performance information, unknown maintenance issues, owner concerns about leaks and roof integrity (Scholz-Barth 2001), and low priorities of owners and their resistance to trying new technologies.

Two studies confirm low use of green roofs in the US, focusing primarily on cost issues. A comprehensive study of first-cost comparisons of 600 buildings, some built to the LEED™ standard and others not, concluded that few developers achieve the Heat Island LEED™ credit by using green roofs. Instead they employ other cool roof strategies. The authors postulate reasons of cost, but also owner concerns of additional weight, maintenance issues, aesthetic impact and added design effort (Mattiessen and Morris 2004). Another study assesses green building technology from a cost and economic feasibility perspective in the Seattle area. With regard to green roofs, the authors conclude that the cost horizon on green roof technology is still too far out. They say the technology is not yet cost effective in the short term, but has great environmental and long-term economic benefits. They suggest that the technology could be made more desirable to owners through incentive programs (Urban Environmental Institute 2002).

Quantitative studies of challenges to green roof implementation confirm the above assertions. A 2004 survey of US landscape architects documenting their frequency of green strategy use revealed that most respondents rarely use the technology. Even the 20% reporting highest use of green technologies implement green roofs rarely or sometimes. Forty-one percent of the respondents to the survey have never implemented a green roof. Their primary concern in use of the technology is unproven life-cycle cost benefits. The values of clients were also seen as a factor contributing to non-use of these technologies—respondents stated that their clients simply were not as concerned about sustainability and were not interested in trying this new technology (Calkins 2005).

A series of interviews with architects, engineers, roofers, developers, manufacturers, policy makers, and energy management consultants at a 1998 workshop on green roof technology in Toronto revealed many barriers to use of green roofs. The respondents lacked knowledge and awareness of green roof technology. They did not have enough information about costs and technical details and would have liked to be able to see more built examples first hand. Additionally, they had concerns about winter aesthetics, maintenance, liability, roof integrity, and the lack of industry standards (Peck and Callaghan 1999).

In Chicago, focus group discussions with real estate development professionals revealed a desire for existing examples of green roofs in Chicago that the respondents could see in person (confirming Roger's theory of observability). They also wanted data specific to the Chicago climate. Their concerns include diminishing property values, leaks, maintenance, pests, and mold (Sale and Berkshire 2004).

1.3 The Green Roof Perceptions and Barriers Study

The Green Roof Perceptions and Barriers Study (GRPBS), a survey of architects and building owners in Chicago and Indianapolis, was undertaken to quantify perceptions of green roofs and the barriers that challenge their implementation. The study's objectives were to 1) measure designers' and owners' knowledge level and experience with green roof technology, 2) understand their perceptions of costs, benefits, barriers, and challenges, and 3) elicit variables that might contribute to their use of green roof technology. The ability to understand conditions influencing adoption of green roofs is critical to strengthening information channels, performance research, information content, and public and market incentives to hasten the adoption of green roofs. It was hypothesized that the results of this study would support factors influencing adoption of innovations, and these factors could offer a conceptual framework for their interpretation.

The results of the GRPBS confirm and build on the green roof research discussed in the previous section, yet they differ in several important ways. The GRPBS quantitatively studies building owners and managers and draws comparisons with architects. Other studies examine only design practitioners (Peck and Callaghan 1999; Calkins 2005) or building owners (Davis and Kim 2003), and most are qualitative research using interview methods. Sale and Berkshire's 2004 study examined perceptions and barriers of building owners in Chicago; however, the GRPBS expands upon lessons learned by looking at architect and building owner perceptions quantitatively in both Chicago and Indianapolis. Understanding perceptions in Indianapolis is particularly pertinent because while the Chicago government aggressively supports green roofs, opinions of owners and designers in smaller cities without a pronounced green roof movement have not been studied.

It is anticipated that this research will be of use to a broad audience and the lessons revealed can be applied to other cities across the United States. The overall goal of this research is to facilitate the adoption of green roof technology. If this research quantifies perceptions, challenges, and obstacles, they can be better addressed by educators, researchers, and policy makers.

2. METHODS

The GRPBS employed a survey instrument to measure perceptions, challenges and use of green roofs by building owners and architects in Chicago and Indianapolis in the fall of 2004. These two cities were selected in order to understand a cross-section of urban populations in the Midwest. Chicago is a large city with a pronounced green building movement supported by influential members of the city government. Several high profile green roofs have been implemented there in the past five years, including the large, well publicized roof on top of City Hall. Indianapolis, by contrast, is a typical Midwestern city with less green building activity. It was anticipated that a study of these two types of cities might offer useful comparisons. Survey questions were designed to build on and quantify prior research and identify new issues in perceptions and challenges of green roof use.

2.1 Subjects

A total of two hundred and forty paper surveys were mailed to random samples of architects and building owners in Chicago and Indianapolis. The sixty architects in Chicago and sixty in Indianapolis receiving the questionnaire were located through ProFile Online (http://www.firstsourceONL.com). The sixty building owners in Chicago and sixty building owners in Indianapolis were gathered from local membership lists of BOMA (Building Owners and Managers Association) International. BOMA is a professional organization of more than 19,000 commercial real estate professionals including building owners, managers, developers, and leasing professionals. BOMA members tend to be developers or owners of large commercial, industrial, institutional and office properties. (BOMA International 2005)

Subjects were selected from populations of 451 architects in Chicago, 84 architects in Indianapolis, 239 BOMA members in Chicago and 93 BOMA members in Indianapolis. The sample was selected by assigning each member of the population a random number via a random number generator (Haahr 2002).

2.2 The Survey Administration

The survey was designed and administered according to the Total Design Method (TDM) for mail surveys (Dillman 1978). The major point of departure from

this method was the inclusion of an option to respond to the survey online. One full mailing (including cover letter, questionnaire, and return envelope) was mailed on August 30, 2004 to the entire sample. A follow-up postcard was mailed to the entire sample approximately one month later (October 7, 2004). A third and final mailing was sent to non-respondents on October 12, 2004. Respondents were assured that the survey was anonymous and voluntary. The online survey was intended to give respondents more options for response and it was hoped that it would increase the survey's total response rate. The online form was identical to paper surveys except that it was available on one page and in some cases it may have been slightly more difficult to write in answers that were not specifically listed as choices. All respondents, however, had the option to list comments at the end of each survey.

2.3 The Survey Instrument

The survey instrument was designed to gather information in four categories: demographic information, knowledge and experience, perceptions of costs and benefits, and future actions with green roofs. Demographic information was requested at the end of the questionnaire. The knowledge and experience section was designed to ascertain respondents' knowledge of and experience with green roof technologies. It also measured the barriers they may have encountered when attempting to use the technology, as well as how likely they were to implement a green roof in the future. The third section addressed respondents' perceptions of the costs and benefits of green roof technology. The two goals of this section were to determine beliefs, misconceptions, and awareness of the costs and benefits of the technology and to determine respondents' priorities in the building decision-making process. A few final questions were designed to determine what respondents believed would encourage green roof implementation, what steps they had taken to encourage implementation, and how they felt about legislation requiring green roofs. It was anticipated that these questions might offer some insight into the feasibility of market based or public incentives or regulations. Lastly, respondents were asked if they expected to design or install a green roof this year. This question enables characterization of qualities of those respondents who might be considered innovators or early adopters (Rogers 1995). The full survey questionnaire can be found on the Ball State University Building Futures Institute website at http://www.bsu.edu/web/capweb/bfi/.

2.4 Data Collection and Analysis

All responses to the survey were received between September and December 2004. The overall adjusted response rate for this survey was 39.7%. Surveys which were returned to the researcher due to a change in address or 'address unknown' were removed from the sample size, resulting in the adjusted response rate. Seven subjects responded online, out of 91 total responses.

Data were analyzed by question and by group using Microsoft Excel spreadsheets and statistical analysis functions. Results were analyzed to discern trends and contrasts among the four groups studied. Implications of the survey results were evaluated using the five conditions assisting adoption of innovations set forth by Rogers (1995).

3. RESULTS

Results of the GBPBS confirm that respondents experience both actual and perceptual barriers to use of green roofs and, overall, they do not recognize enough benefit to outweigh the perceived costs. These results offer a partial explanation for the low level of adoption of green roof technologies in the US. Results will be presented in three subsections: knowledge and experience, perceived costs and benefits, and barriers and incentives to use of green roof technology. Demographic characteristics of the respondents will be discussed in the first section. Where significant differences exist, distinctions will be made between groups in Chicago and Indianapolis.

3.1 Characteristics of the Respondent Populations

Respondent architects work with a wide range of building types and sizes. Chicago architect respondents reported that they typically work on fewer and smaller buildings than the Indianapolis architects. BOMA respondents in both cities tended to work with considerably larger buildings than the architects. Chicago BOMA respondents own or manage fewer but larger buildings than the BOMA respondents in Indianapolis. These results are shown in Ta-

bles 1 and 2. Architect respondents work with more residential and institutional buildings than BOMA respondents, who primarily specialize in commercial and office buildings. Much of the disparity in building size between architects and BOMA members surveyed can be attributed to the difference in building type, as residential buildings are generally smaller than the other building types.

In order to determine predisposition to or experience with green technologies, respondents' involvement with the LEED™ system was measured. As LEED™ is the current national standard for green building, experience with the system would indicate a predisposition to green building. The majority of respondents, both architects and building owners, have never been involved with a LEED™ building. None of the BOMA members reported involvement in a LEED™ project; most of the architects responded likewise, indicating a low predisposition to green technologies.

3.2 Experience and Knowledge

A primary goal of this survey research was to ascertain the architects' and building owners' level of experience and knowledge of green roof technology. Results show that architects have greater experience

TABLE 1. BOMA respondent characteristics.

	Indianapolis BOMA	Chicago BOMA
How many buildings do you own or manage?	25	15
On average, what square footage are the buildings you own or manage?	497,139 SF	898,406 SF
What percent of the properties you own or manage have less than a 45 degree roof pitch?	96%	89%
What kind of buildings do you own or manage? (check all that apply)		
Commercial	83%	88%
Industrial	22%	0%
Institutional	17%	12%
Residential	0%	6%
Are any of your properties LEED certified?		
Yes	0%	0%
No	67%	39%
"What's LEED Certification?"	53%	47%

TABLE 2. Architect respondent characteristics.

	Indianapolis Architects	Chicago Architects
How many buildings does your firm work on per year?	36	20
On average, what square footage are the buildings you design?	73,200 SF	64,760 SF
What percent of the buildings your firm has worked on in the past year have less than a 45 degree roof pitch?	60%	50%
What kind of buildings does your firm specialize in? (check all that apply)		
Commercial	50%	59%
Industrial	4%	17%
Institutional	71%	38%
Residential	13%	72%
Has your firm worked on a LEED certified building?		
Yes	25%	31%
No	75%	69%

with and knowledge of green roofs than building owners, and respondents from both Chicago groups have more knowledge than those in Indianapolis. Chicago architects reported a higher frequency of client inquiries about green roofs than Indianapolis architects. Building owners have more limited experience of green roofs with only one Chicago owner reporting installation. Over thirteen percent of building owners have inquired about green roofs, and nineteen percent have considered it, as can be seen in Tables 3 and 4.

Respondents from both groups in Chicago considered themselves to be more knowledgeable of green roof technology than those in Indianapolis with around 60% indicating that they are "somewhat familiar" with it. Fourteen percent of Chicago architects indicate that they are "very knowledgeable" of green roof technology. Aside from the "very knowledgeable" architect respondents, indications of familiarity do not greatly differ between architects and building owners, illustrated in Table 5. Both architect and building owner respondents indicated that they would use consultants to help design a green roof. Architects, as shown in Table 6, would use landscape architects as consultants while building owners were less in agreement about the type of consultants they would use.

3.3 Perceived Costs and Benefits

Respondents' perceptions about the costs and benefits of green roofs were surveyed in three categories: costs to the individual building owner, benefits to the individual building owner, and benefits to society (ie. environmental and social benefits). To better understand general priorities of architects and building owners, respondents were asked to rank how important they consider costs, direct benefits, and societal benefits when making decisions about their projects. When architects make design decisions, they reported that they place marginally more importance

TABLE 3. Building owners' level of experience with green roofs.

	Indianapolis BOMA	Chicago BOMA
Have you installed green roof technology on any of your buildings?		
Yes	0%	6%
No	100%	94%
Have you ever asked an architect about green roof technology?		
Yes	11%	17%
No	89%	83%
Have you ever considered the use of green roofs on your buildings?		
Yes	11%	28%
No	89%	72%

TABLE 4. Architects' level of experience with green roofs.

	Indianapolis Architects	Chicago Architects
Have you ever specified green roof technology?		
Yes	8%	31%
No	92%	69%
Have your clients ever asked about green roof technology?		
Yes	17%	50%
No	83%	46%
Don't know	0%	4%
Have you ever recommended or suggested the use of green roofs to clients?		
Yes	38%	48%
No	63%	52%

TABLE 5. Familiarity with green roofs.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
How familiar are you with green roofs?				
Very knowledgeable	0%	0%	4%	14%
Somewhat familiar	42%	61%	42%	59%
Have heard of them	47%	33%	37%	24%
Not familiar at all	11%	6%	17%	3%

TABLE 6. Green roof consultant use.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
Would you/your firm consult a landscape architect or horticulturalist when designing/installing a green roof?				
We would consult with a landscape architect	41%	47%	57%	86%
A landscape architecture firm would design the roof	29%	40%	22%	36%
We have landscape architects on staff	NA	NA	22%	0%
We would consult with a horticulturalist	18%	40%	17%	11%
The design would be completed by architects/our firm	53%	47%	4%	11%

on that benefits to the building owner than they do for costs to the building owner. BOMA members were not asked this question as it was assumed that they would consider costs and benefits to themselves of primary importance. Architects ranked benefits to society as less important than benefits to their clients when they make design decisions, but they still considered benefits to society more important than the BOMA respondents.

To gather information on specific factors important to respondents when making decisions about buildings, BOMA members and architects were asked to rate the level of importance of several issues on a scale of one to five. All respondents were in agreement that initial costs are "very important" (median of 5) to their design decisions. As shown in Table 7, city building codes, maintenance, and heating/cooling costs were also important to respondents. All groups considered tried and true, traditional technology to be more important when making decisions about buildings than cutting-edge technology. Views, landscaping, stormwater runoff, environmental concerns, and wildlife habitat were more important to architects than to building owners, while taxes and insurance costs were more of a priority to building owners than to architects. There was little difference between responses from Indianapolis and Chicago respondents.

In questions specific to green roof technology, respondents are intensely concerned about the monetary costs associated with building and maintaining green roofs. Ninety percent of building owners believed green roofs would result in higher maintenance costs than the prevailing, traditional roofing technologies. The majority of both building owners and architects believed initial costs to be higher as well. Many building owners believed green roofs to have higher irrigation costs, risks of roof failure, and replacement costs than traditional roofing technologies, shown in Table 8. To a lesser degree, architects also believed these costs to be higher than traditional technologies.

While both BOMA and Architect respondents recognize some benefits of green roof technology,

TABLE 7. Decision making priorities.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
Initial cost	5.0*	5.0	5.0	5.0
Heating/cooling costs	4.5	4.0	4.0	4.0
Maintenance costs	5.0	4.0	4.0	4.0
Insurance costs	4.0	4.0	3.0	3.0
Taxes	5.0	4.0	3.0	3.0
Public relations	3.5	3.0	3.5	3.0
Cutting-edge technology	3.0	3.0	3.0	4.0
Traditional / 'tried-and-true'	3.5	4.0	4.0	4.0
City building codes	5.0	5.0	5.0	4.0
Views	3.0	3.0	4.0	4.0
Recreation possibilities	3.0	2.0	3.0	3.0
Roof materials	4.0	3.0	3.0	4.0
Landscaping	3.0	3.0	4.0	4.0
Stormwater runoff	3.0	3.0	4.0	3.0
Environmental concerns	3.0	4.0	4.0	4.0
Wildlife habitat	2.0	2.5	3.0	3.0
LEED Certification	3.0	2.5	3.0	3.0

* 1=not important, 5=very important

TABLE 8. Perceived green roof costs to building owner.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
What do you believe the costs to the individual building owner are when using green roof technology versus traditional roofing technologies?				
Higher initial cost	79%	89%	91%	90%
Higher maintenance costs	89%	94%	43%	72%
Irrigation costs	42%	78%	43%	48%
Looks funny	11%	28%	9%	0%
Higher risk of roof failure	37%	83%	39%	34%
Higher replacement costs	32%	72%	52%	31%

both groups still believe that the costs to the building owner outweigh the benefits, as seen in Table 9. Increased recreational opportunity was considered a benefit by most of the architects; the benefit indicated most often by building owners and more than half of the architects was public relations. Little more than one half of building owners considered reduced heating and cooling costs a benefit and most architects recognized this benefit. One-third of architects believed green roof technology would result in reduced stormwater fees and longer roof life. A small percentage of BOMA members did not think that green roofs provided any benefits to the individual. Despite their familiarity with the technology, Chicago BOMA members did not recognize as many benefits to the technology as Indianapolis BOMA members.

Architect respondents recognized more environmental and social benefits of green roofs than did building owners (Table 10). Most architects believed that green roofs reduced the heat island effect, improved air quality, improved views and reduced

TABLE 9. Perceived green roof benefits to building owner.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
What do you believe the benefits to the individual building owner are when using green roof technologies versus standard roofing technologies?				
Public relations	68%	69%	48%	55%
Reduced stormwater fees	16%	6%	35%	24%
Increased roof life	5%	13%	17%	41%
Recreation	5%	19%	17%	41%
Reduced heating and cooling costs	63%	50%	70%	86%
Improved views from inside the building	26%	13%	43%	28%
There are no benefits	5%	6%	0%	0%

TABLE 10. Perceived green roof benefits to society

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
What do you believe the benefits to society are when using green roof technologies versus standard roofing technologies?				
Heat island mitigation	32%	41%	61%	86%
Improved air quality	58%	71%	61%	79%
Global warming mitigation	32%	12%	39%	59%
Increased wildlife habitat	26%	24%	43%	45%
Improved views from other buildings	53%	35%	61%	66%
Improved views from the ground	21%	35%	22%	28%
Improved stormwater quality	32%	24%	57%	34%
Reduced stormwater quantity	32%	18%	48%	62%
There are no benefits	0%	0%	4%	0%

stormwater quantity. Half thought that the technology could help to mitigate global warming and forty-four percent considered green roofs a way to provide wildlife habitat. While over sixty percent of the BOMA members surveyed thought there would be benefits in air quality and some believed there to be improved views and heat island mitigation, few believed there to be other social or environmental benefits.

3.4 Perceived Barriers and Incentives

In order to determine barriers to green roof use, respondents who have not installed green roofs were asked why they have not used the technology and what they perceive to have prevented their implementation. The results are shown in Table 11. Performance aspects of green roofs were the predominant barrier cited by building owners, namely concerns about possible roof failure, leaks, and weight. These performance concerns were indicated by twenty percent more building owners than any category relating to cost. Some BOMA members also listed maintenance, short-term and long-term costs, and "No one suggested it" as barriers. Chicago building owners cited more barriers to implementation and more knowledge of green roof technology than building owners in Indianapolis, who claimed to know little about the technology

Architects' perceived barriers were lack of knowledge and information, risk of leaks or roof failure, and

TABLE 11. Perceived barriers to green roof use.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
If you have never installed/specified a green roof what obstacles or barriers have you encountered?				
No one suggested it	42%	27%	47%	18%
Client/architect did not want it	0%	0%	47%	36%
Long-term costs	11%	47%	13%	5%
Short-term costs	16%	53%	53%	23%
Liability	5%	13%	13%	14%
Insurance	5%	13%	0%	5%
Building codes	5%	13%	0%	5%
Maintenance	32%	40%	20%	32%
Fire risk	0%	0%	0%	0%
Possible roof failure/leaks	47%	80%	53%	32%
Weight	47%	67%	33%	32%
Not appropriate	32%	13%	0%	14%
Don't know enough	42%	40%	67%	36%

resistance to the technology by their clients. Indianapolis architects reported higher experience with barriers, particularly related to knowledge and lack of client interest, than those in Chicago. Fifty percent of Chicago architects say their clients have asked them about green roof technology, but a smaller percentage of these clients have followed through to use it.

Architects from both cities indicated a higher likelihood than building owners to specify green roof technology on one of their projects in the future. Nearly 80% of Chicago architect respondents and 52% of Indianapolis architects said they are "somewhat" or "very likely" to design a green roof in the next five years, while far fewer building owners indicate they will install one. Thirty-eight percent of Chicago architects and four percent of Indianapolis architects responded that they were likely to install a green roof this year; none of the building owners believed they would do so. Table 12 shows that twenty-four percent of BOMA members believed that they would never install a green roof.

While some respondents plan to use green roof technologies, the majority are opposed to legislation requiring it. Half of all architects and over three-quarters of BOMA members are against this type of legislation. In Table 13, Chicago architects were the only group not ardently opposed to green roof legislation, with almost two-thirds stating that they would support a law requiring green roofs on a percentage of flat-roofed commercial buildings. Sixty-

TABLE 12. Likelihood of installing a green roof.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
How likely are you to install/specify a green roof in the next five years?				
Very likely	0%	6%	22%	31%
Somewhat likely	5%	13%	30%	49%
Not likely	84%	69%	48%	20%
Will never specify a green roof	11%	13%	0%	0%

TABLE 13. Support for green roof legislation.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
Would you support legislation requiring green roofs on commercial buildings?				
Over 20% of flat roof area	6%	6%	13%	33%
Over 50% of flat roof area	11%	24%	22%	19%
Over 80% of roof area	0%	0%	0%	7%
Over 100% of flat roof area	0%	0%	0%	4%
I would not support this type of legislation	72%	71%	65%	37%

five percent of Chicago architects would support some green roof legislation.

Both building owners and architects indicated that various incentives would increase their likelihood of implementing green roofs, seen in Table 14. More than sixty percent of BOMA members responded positively to cost-based incentives such as tax credits and grants assisting first costs. Some were also interested in guaranteed long-term cost benefits. Architects are primarily swayed by environmental benefits, long-term cost benefits, and tax incentives, although grants to help with financing were also considered somewhat important. Ten percent of respondents stated that only code requirements would make them specify or install green roofs and a small number of building owners said nothing could make them install a green roof. Chicago owners indicated less likelihood of incentives convincing them to install green roofs.

3.5 The Early Adopter Respondents

Based on respondents' indication of their likelihood of installing/specifying a green roof in the next five years, characteristics and results of a subgroup of respondents were examined. Respondents, specifically 26% of Architects and 6% of BOMA respondents, who said they were very likely to install/specify a green roof in the next five years were analyzed with respect to their perceptions of benefits and barriers, knowledge, and values of green roofs. The results can be seen in Table 15. Based on concepts used in Roger's (1995) innovation diffusion literature to describe innovation adopter groups, the term early adopters was assigned to this group and will be used to describe this group of respondents in the remainder of the paper.

These early adopters are primarily architects, with slightly more in Chicago than in Indianapolis. None of the Indianapolis BOMA respondents are in this

TABLE 14. Incentives for green roof use.

	Indianapolis BOMA	Chicago BOMA	Indianapolis Architects	Chicago Architects
Would any of the following incentives make you more likely to install/specify green roof technology in the future?				
Grants to help with financing	75%	67%	55%	58%
Tax incentives	81%	67%	45%	73%
Stormwater management benefits	44%	27%	55%	42%
Environmental Benefits	38%	53%	55%	69%
Long-term cost benefits	69%	53%	64%	62%
Recreational possibilities	0%	7%	18%	31%
Others in my area installing them	6%	13%	50%	15%
Nothing could make me install/specify one	0%	13%	0%	0%
Only codes requiring it would make me install/specify one	0%	20%	0%	19%

TABLE 15. Early adopter respondents compared to overall respondent group.

	Early Adopter Respondent Group	Overall Respondent Group
'Very likely' to install a green roof in the next five years	100%	17%
Have worked on a LEED™ certified building	47%	17%
Have installed/specified a green roof	60%	13%
'Very knowledgeable' about green roof technology	27%	6%
Value cutting edge technology (1-5)	4.0	3.0
Value 'tried and true' technology (1-5)	3.0	4.0
Value environmental concerns	4.0	4.0
Perceive higher maintenance costs of green roofs	47%	73%
Perceive higher risk of roof failure with green roofs	27%	46%
Perceive increased roof life	53%	22%
Perceive reduced heating and cooling costs	67%	70%
Perceive heat island mitigation benefits	93%	59%
Perceive stormwater mitigation benefits	93%	43%
Perceive wildlife habitat benefits	73%	36%
Support some legislation of green roofs	50%	40%

group as none indicated that they are very likely to install a green roof in the next five years. The early adopters indicated greater familiarity and experience with green roof technologies than the general respondent pool. They held fewer misconceptions about the costs and benefits of green roofs. Most of the respondents who have already specified/installed a green roof are in this group and many have worked on a LEED™ project. This group of respondents value environmental concerns and emphasize tried-and-true technologies less than the overall group.

The early adopter respondents perceived performance benefits of increased roof life, while they perceived less risk of roof failure than other respondents. The early adopters recognize greater environmental benefits to green roofs in areas of wildlife habitat, heat island and stormwater mitigation.

4. DISCUSSION

Acceptance and adoption of an innovation ultimately comes down to the innovation meeting the needs of the potential adopters better than the current technology. In the case of green roofs, survey results show that they may not yet meet the needs of many potential adopters queried in this research. However, the early adopter respondent group recognizes and values their benefits, and plans to adopt the technology.

Results of this research and findings of other studies on innovation diffusion will be discussed below in the categories of attributes of green roofs affecting adoption potential (Section 4.1), characteristics of potential adopters (Section 4.2), and information flows and communication channels (Section 4.3). Results of this research confirm some findings of previously discussed studies of innovation diffusion in general and in the building industry, and of green roofs.

4.1 Attributes of Green Roofs Affecting Adoption Potential

Rogers posits that an innovation is more likely to be adopted if it is perceived to have relative advantage, is easily tried, can be observed somewhere else, is compatible with existing methods, or is perceived to be relatively simple (Rogers 1995). Survey results show that most potential adopters do not recognize the relative advantages as they perceive great costs and limited benefits to use of the technology. They have limited opportunity to observe green roofs in place, and they perceive the technology to be quite different from and far more complex than existing roofing technologies.

4.1.1 Relative Advantage. If an innovation is more advantageous than the idea it supersedes, it is more likely to be adopted quickly (Rogers 1995). This survey revealed that potential adopters of green roof technology do not yet perceive strong advantages to

its use. Most respondents do not currently use the technology and while some recognize advantages, they do not perceive them as strong enough to adopt the technology. While some architect respondents are ready to adopt the technology, final design decisions are made by building owners; architects are thus limited to promoting use of the technology then specifying what the owner wants. Respondents' values play a large role in their recognition of advantages. Some respondents, particularly building owners, place little value on the benefits to the environment when making decisions about building technologies. Therefore all of the environmental advantages that green roofs offer mean little to them. The relative advantages of green roof technology can be examined in categories of economic advantages, performance advantages, and environmental/social advantages.

4.1.1a Relative Advantage: Cost. Survey results reveal that respondents are concerned about the financial risks of green roofs perceiving higher first costs and high maintenance costs, while not recognizing the potential paybacks. This confirms similar results of the Koebel et al. study (2004) and their assertion that the financial risk of building innovations can be substantial and slow their adoption. With the exception of the early adopter respondents, the cost advantages offered through reduced heating and cooling costs, extended roof life and reduced stormwater fees were not recognized.

As cost plays a major role in respondents' decision-making priorities, respondents are not likely to adopt the technology until they recognize the economic advantages of green roofs. The market has shown that the first and short-term costs are higher than traditional roofing technologies, yet a limited number of studies show that the technology will pay back over the long term in reduced heating and cooling costs (Matteison and Morris 2003) and where applicable, stormwater fees (Urban Environmental Institute 2002). Respondents to this and other studies do not recognize this value because their cost horizon is shorter. One building owner reported that a "three year payback on an operating system is about all that would be supported by our industry." Because traditional cost-benefit analysis does not take into account the real costs of externalities such as environmental impacts, the time horizon for payback on green roofs is very long, well over 20 years by some accounts (Urban Environmental Institute 2002). Market segments that focus on short-term costs such as commercial developers will be unlikely to make the investment without some added motivation.

First and short-term costs must be reduced in order for green roof technology to be widely adopted. Ultimately widespread use of the technology will lower the price. In Germany, where green roofs are often required, these systems on flat rooftops are now comparable in price to traditional roofing systems (Urban Environmental Institute 2002). However, until that point, financial incentives must be employed to short term costs in order to spur adoption.

Public agencies can play a key role in enhancing the economic advantages of green roof technologies. Green roofs can offer municipalities a solution to address federal mandates for stormwater runoff, non-point source pollution, and urban heat island reductions. If the municipalities offer owners financial incentives to use green roofs, the municipalities may realize an economic advantage by using the technology to solve their environmental problems and meet federal mandates.

Grants, tax credits, and development bonuses can provide financial incentives to increase the economic advantage of green roof technology because they can bring the cost of green roofs in line with standard roofing technologies. Both respondent groups indicated that incentives such as tax credits, development bonuses, and grants would increase their likelihood of installing green roofs. Currently, the US Environmental Protection agency offers limited grants for use of green roofs. Another successful incentive offers developers bonus floor-area-ratios resulting in an overall increase in square footage for installation of green roofs. This strategy is being used successfully in Portland, Oregon and Chicago, Illinois. Chicago also offered small grants for small-scale installations in 2005.

While respondents oppose direct legislation mandating green roofs, stormwater fees can be another type of financial incentive for green roof use. Stormwater fees, well used in Germany, are charges to building owners for their properties' contributions to municipal stormwater systems. Studies show that green roofs can absorb water during heavy rainfall

and release it over a longer period of time than a conventional roof, taking pressure off municipal stormwater systems during critical peaks (Dunnett and Kingsbury 2004). If municipalities institute substantial stormwater fees (these fees are currently in effect in Portland, Oregon and a few other cities across the US), the payback of green roofs may have a shorter horizon. High stormwater fees and regulations requiring reduced runoff at sites in Germany have been one of the primary motivators for adoption of green roof technology in that country. Currently, these regulations are not widespread in the US and where fees do exist, they are usually not expensive enough to encourage investment in technologies to reduce stormwater runoff.

4.1.1b Performance Advantage. Building owner respondents express concern about performance factors and do not yet recognize that green roofs hold some performance advantages over standard roofing technology. Though the first priority of building owner respondents is cost, most report that physical barriers such as potential of roof leaks and roof weight prevent their use of green roof technology. This confirms the assertion that leaks are a major barrier to green roof implementation (Scholz-Barth 2001), and "Costing Green's" contention that the problem is likely less from cost, and more related to concerns of weight and maintenance (Mattiesen and Morris 2004). The early adopter respondents did recognize increased roof life as a benefit to green roof technology and few perceived a higher risk of roof failure.

Well disseminated research and information proving the performance effectiveness of green roofs, as well as their safety and reliability is critical to convince owners to adopt the technology. However, like economic advantages, performance advantages of green roofs are not well documented. The studies that do exist have not been widely distributed to potential adopters.

4.1.1c Environmental Advantage. While the environmental advantages of green roofs are well-documented, many respondents do not recognize or value them. This, coupled with respondents' overall low experience with the LEED™ system, suggests that respondents in this survey hold no striking predisposition for or commitment to green or sustainable technologies. The architects in the study possessed more knowledge of the environmental and social benefits of green roof technology, had more experience with LEED™, and placed a higher value on the environmental performance advantages of green roofs. The early adopters more often recognized the greater environmental advantages to green roofs in areas of increased wildlife habitat, and stormwater and heat island mitigation and they value environmental benefits as important to their design decisions most likely contributing to their intent to adopt the innovation.

Building owner respondents do not hold environmental and social benefits as important to their design decisions. While the environmental advantages of green roofs are increasingly documented, gaining more knowledge of environmental benefits will likely not be enough to persuade owners to adopt the technology. Documentation of environmental advantages, however, may be enough to convince policy makers to mandate the technology or provide incentives for owners to adopt green roof technology. Additionally, intensive education efforts aimed at building owners that document environmental problems resulting from current roofing technology may slowly change the owners' overall values related to environmental issues.

The early adopter respondents' greater recognition of green roof technology's economic, performance, and environmental advantages demonstrates the connection between Rogers' theory of relative advantage contributing to adoption of an innovation and their increased interest in adopting this innovation.

4.1.2 Trialability. An innovation's adoption potential can be increased with an ability to experiment with use of the innovation in a limited fashion (Rogers 1995). In building construction, partial trial of materials, products or technologies is not easily accomplished because this trial would require a significant capital commitment (NAHB 1990; Koebel et al. 2004). This is true of green roof technology as it is expensive and requires specific structural conditions on the building. Owners are not likely to try out green roof technology then remove it to return to familiar methods as this would be expensive and time consuming. Therefore, potential adopters of the

technology will want to be confident of its efficacy before committing to its use.

The difficulties of limited trial of the technology point to a need for a green roof product that can be installed in a simple and inexpensive application. Modular green roof products that can be installed piece by piece are becoming more common, but they are still not considered an easily tried option. Municipal, state or federal grants funding a green roof trial at no cost to the owner may hasten adoption by easing the financial risks to the owner.

4.1.3 Observability. The opportunity for potential adopters to observe an innovation in use elsewhere can hasten its adoption (Rogers 1995). In green design, the strongest opportunities for observing innovations occur with actual built projects in which green strategies can be observed in photos or site visits. Survey results showed greater familiarity with green roofs by both groups in Chicago. This can be attributed to the fact that Chicago has a pronounced green roof movement with well-publicized installations on City Hall, the Peggy Notebaert Nature Museum and the Chicago Center for Green Technology, among others. Respondents have likely had an opportunity to observe a green roof installation. Indianapolis has no high-profile installations of green roofs, so those respondents and other potential adopters have fewer opportunities to observe green roof technology in person.

Green roofs have been documented in print publications dedicated to green design and to a lesser degree in some national design trade publications. This may explain the greater familiarity that Indianapolis architects have over Indianapolis building owners. However, green roof demonstration projects can allow potential adopters to see the technology in place over a variety of seasons. If municipalities, environmental organizations or groups concerned about environmental issues can install demonstration green roofs, then this will increase opportunities for potential adopters to observe green roofs and may hasten their adoption.

4.1.4 Compatibility with Existing Methods. Innovation diffusion theories maintain that an innovation will be more readily adopted if it is perceived as being consistent with existing values, past experiences and needs of the potential adopters (Rogers 1995). Green roof technology has a low compatibility with existing roofing methods. It is a significant departure from traditional roofing technologies in aesthetics, maintenance, cost, design, and specification. Traditional roofing technology requires routine and well understood maintenance; design and specification issues are usually well understood by architects and structural engineers. In contrast, green roofs require a different kind of maintenance to ensure that the plants and soil are functioning, designers must familiarize themselves with a new technology, and roofing subcontractors need specialized expertise for installation. Green roofs may also necessitate changes to other elements of the building design such as roof lines or structural elements.

Like other studies of innovation in building construction (Yudelson 2003; Koebel et al. 2004; Calkins 2005), results of this survey show that respondents, particularly building owners, value tried and true technologies. The incompatibility of green roofs with traditional roofing technologies could offer an explanation for their overall low use.

Efforts by green roof product manufacturers to develop products that can be installed by any roofer will also increase compatibility with existing methods. While one could argue that the aesthetics of green roof technology are better than the traditional alternatives, the look of green roofs is a departure from the norm and respondents generally did not recognize the aesthetic benefits. Perhaps most importantly, traditional technology is designed to shed water as quickly as possible, while green roofs are designed to absorb rainwater, allowing for a portion of it to evaporate. Respondents clearly are uncomfortable with this idea as one of their primary concerns is roof leakage. Education on proper installation and efforts by green roof product manufacturers to develop products that can be installed by any roofer will increase compatibility with existing methods.

Innovations that are incompatible with existing methods commonly require a prior adoption of a new value system (Rogers 1995). This can be a slow process. For instance, strategies with higher costs and no obvious economic payback will probably not be widely adopted on commercial projects unless there is a value shift in business toward accounting of environmental costs along with economic costs. In the

past few years, a shift has been occurring in the values of many public agencies at the local, state, and federal level, with some requiring or providing incentives for green design strategies (Calkins 2002). While some sustainable strategies are currently in conflict with codes and regulations, public support for green design is increasing. Some public agencies are offering strong support and facilitation of green design strategies (USGBC 2003; Cassidy 2003); others are leading with implementation of ground breaking public projects such as the City of Atlanta and Chicago City Hall's green roofs. As respondents currently value monetary costs so highly, they perceive an incompatibility of green roofs with existing methods that have lower first costs. A shift in accounting to include external environmental costs, bringing the cost of green roofs in line with traditional technologies, is unlikely to occur. Therefore other incentives are necessary to make green roofs more compatible with existing methods. Again, grants and other financial incentives can bring costs of green roofs more in line with existing roofing methods, hastening adoption.

4.1.5 Complexity. Perception of difficulty and complexity can slow the adoption of an innovation because the adopter must develop new skills and obtain information for use (Rogers 1995). Respondents perceive green roof technology to be relatively complex. Their lack of knowledge of the technology indicates that extensive information gathering would be needed if they were to adopt the technology. The respondents' overall lack of experience and low reported knowledge of the technology means that they will need to engage in extensive analysis and changes to their standard specifications. Some of the perceived complexity of green roof technologies is due to the newness of the technology and incompatibility with existing methods. However, widely disseminated standardized information on green roofs targeted to architects and building owners may lessen perceptions of complexity. Respondents strong indication that they would need to hire special consultants such as landscape architects and horticulturalists (who are not normally called in to consult on roofing decisions) supports their perceptions of the complexity of green roofs. Also the common perception that maintenance costs would be higher may mean that they are worried about their level of familiarity with techniques for maintaining green roofs.

The early adopters placed less emphasis value on tried-and-true technologies when making decisions about buildings and this, coupled with greater knowledge and experience likely reduced their perceptions of complexity and contributed to their planned adoption of green roofs.

4.2 Characteristics of the Adopters

Koebel et al. (2004) state "innovation is inherently disruptive" and potential adopters who value tried-and-true technologies will be less likely to adopt an innovation. Results of the GRPBS confirm this discussion. However, the early adopter group emphasizes cutting-edge technology and values environmental concerns which when coupled together likely contributes to their planned adoption of green roof technology. Other studies have also found that potential adopters who are oriented to cost and profit are less likely to adopt an innovation (Koebel et al. 2004; NAHB 1990). While all respondents valued first costs when making decisions about a building, and they recognized the higher first costs of green roofs, the early adopters were able to recognize the long-term financial benefits to green roofs likely balancing their perceptions of overall costs.

In the building industry, the decision to adopt an innovation must often be made by several groups or individuals. For green roofs, owners, architects, project managers, general contractors, code officials and many consultants (structural engineers, mechanical engineers, and landscape architects) must all be willing to adopt the technology. And in the commercial building industry, owners are often not one individual, instead they can be a group of individuals in an organization. While the wide variety of potential adopters do not have equal decision making powers, they all must be willing to adopt the technology enough to approve, design, specify or install it.

Koebel et al's (2004) finding that owners, architects and construction managers act as technology advocates for innovation adoption confirms the decision to study BOMA members and architects in this research. If these parties choose to adopt green roof technology, then they can act as advocates with the numerous other groups listed above. As this survey

did not query perceptions of construction managers, this is an area for further research.

4.3 Information Flows and Communication Channels

Innovation diffusion theories assume that innovations are not always readily understood to be superior, so potential adopters must collect enough information to determine whether they want to adopt the innovation. Rogers (1995) characterizes two kinds of information to facilitate innovation adoption. The first, software information, is information about how to use a new technology/innovation. For green roofs, this is information on how the roof would be designed, detailed, specified, constructed, and maintained. The second type of information needed for adoption of an innovation is evaluation information. Information about how an innovation is expected to perform will "reduce the uncertainty about an innovation's expected consequences" (Rogers 1995). Results of the GRPBS and other studies reveal that economic, environmental, functional, and aesthetic performance information on green roofs is of major concern to owners, managers, and designers. This type of information is critical to adoption of green roof technology.

Survey results revealed that Architect and BOMA respondents possess both misconceptions and a lack of knowledge about evaluative aspects of green roof technology that is likely inhibiting their planned adoption of the technology. They report frustration with the lack of available performance research and information on the technology, and some of the knowledge they possess is incorrect. Their misconceptions of green roof technology have led to their perception of greater costs and less benefits than actually exist. They perceive a higher roof failure rate and higher replacement costs, when neither perception is accurate (Peck and Callahan 1999). They do not recognize proven benefits such as increased roof life, reduced heating and cooling costs, and long-term payback (Dunnett and Kingsbury 2004). While the majority of roof surfaces owned or managed by BOMA respondents are less than a 45 degree pitch, one in four claimed they have no appropriate roof surfaces, which reveals a lack of understanding of the technology.

These findings are consistent with results of the studies discussed above (NAHB 1990; Peck and Callaghan 1999; USGBC Roundtable 2002; Yudelson 2003; Davis and Kim 2003; Sale and Berkshire 2004). They highlight the necessity of reliable, readily available, standardized information—both software and evaluative—to hasten adoption of this innovation. Greater availability of performance data, tailored to individual markets and climates would help reduce these misconceptions about green roofs. If ample research on costs and benefits were available to potential users of green roofs, those users would be far more likely to make well-informed decisions about implementing the technology. Cost-benefit analyses would make long-term savings more transparent to architects and building owners. Building owners with long-term interests in their buildings may adopt the technology, while developers concerned with the short term would have the information to decide if the payoff is appropriate to their financial goals.

Comprehensive and well-disseminated studies of the costs and benefits of green roof technology might convince municipalities to promote use of green roof technology. While perceptions of policy makers were not part of this study, the increasing number of municipalities offering incentives for use of green roofs indicates interest. Federal legislation requiring municipalities to deal with environmental problems may help policy makers recognize that green roofs are often more cost-effective than traditional engineering strategies for resolving certain environmental problems at the city scale.

Strengthening dissemination methods and outlets is critical. Two applicable information communication models are offered by Rogers. Research has shown that many adopters gather information from their peers through communication within interpersonal networks. This method, perhaps the most common in the design fields, is a convergence model where participants create and share information to reach a mutual understanding of the benefits of an innovation (Rogers and Kincaid 1981). This may be the best model for information communication between architects and designers of green roofs. Already there are many professional groups exchanging information on design and specification of green roofs such as Green Roofs for Healthy Cities, which holds an annual conference on the subject, and the United States Green Building Council (USGBC). These

groups have recently focused their efforts on the generation and dissemination of evaluative performance information for designers to use in educating and convincing their clients. As this information becomes more readily available, general professional groups such as the AIA (American Institute of Architects) or ASLA (American Society of Landscape Architects) can distribute it to designers who are not part of the green design networks. Exchange of case studies and experiences of use of the technology will likely occur at professional conferences and local chapters of the AIA and USGBC. The convergence model can also offer a way for building owners to exchange information and case studies on green roof technologies, although there is currently less discussion in their professional group as evidenced by this survey. Therefore, information is more likely to be provided to the building owners from an outside source or change agent, though BOMA International may begin to make information more accessible to its members.

In the change agent diffusion model, a person or group provides information about an innovation to a potential adopter. With green roof technology, the change agent might be government, professional organizations, non-profit organizations, product manufacturers, or the project's technology advocate (owner, architect, or construction manager). Government agencies have the potential to be key change agents in adoption of the technology as they are in a position to facilitate information exchange on green roof technologies and encourage adoption through incentives, grants, and regulations (Dibner and Lemer 1992; Calkins 2002). In addition to providing incentives, they can provide information to designers and owners on topics such as local climate, suitability, and resource information. Already Chicago's city government, with strong support from the Mayor, is acting as a change agent by promoting a green roof on top of City Hall and providing financial incentives and extensive information to commercial building developers in the city. The City's advocacy is affecting this survey's respondents as those from Chicago indicate more familiarity with the technology. Therefore, green roof advocacy groups should focus their efforts on municipal government agencies. Research to determine perceptions and opinions held by policy makers as well as their motivating factors would better inform the advocacy groups.

Both municipal agencies and green roof advocacy groups need to aim performance or evaluative information dissemination efforts at both building owners and their tenants. Information should be tailored to the values and priorities of each of these groups, with economic information provided to owners and health and worker productivity information provided to tenants. If building tenants are willing to pay more for green features, the costs of green roofs may become more in line with traditional technologies.

5. CONCLUSION

This study was undertaken in an attempt to understand the perceptions and values of architects and building owners with the belief that if advocates can recognize the needs and opinions of these decision-makers as well as the way they make the decisions that could shape this industry, they will be able to make more informed and effective choices. Understanding these groups' perceptions is an essential step in moving green roof technology solidly into the mainstream, and these conclusions may also be valuable more generally in the field of green building. Results of this study confirm ideas presented in innovation diffusion literature about conditions that will hasten adoption of an innovation, characteristics of potential adopters, and the importance of information flow to the adoption of green roofs.

While the survey found that many respondents lack information and possess misconceptions about the costs and benefits of green roofs and don't highly value environmental issues, the early adopter respondents value the benefits and have greater knowledge of the technology. This study found that there is a very real need for education and information efforts aimed at a wide variety of potential adopters if green roofs are to become more widespread in the United States.

With targeted education and more research these barriers can be overcome. Many avenues for future research have resulted from this and related studies. Understanding the values and beliefs of policy makers and legislators can help to gauge the likelihood of incentive programs. It could also quantify municipalities' efforts at education and information dissemina-

tion. Continuing analysis of existing incentive programs as well as other programs that are designed to increase implementation will be valuable to advocates and policy makers around the world. Understanding perceptions of construction managers toward green roof will provide information on another potential technology advocate. More research on information flow and communication channels of those who are adopting green roof technology would also be helpful. Finally, research continuing to quantify the economic, environmental, and performance benefits of green roofs will eventually convince potential adopters of this innovation's value.

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