RESEARCH

DIFFUSION OF INNOVATION IN SUSTAINABLE BUILDING PRACTICES AND THE ROLE OF STAKEHOLDERS

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ABSTRACT

The stakeholder network in a building project can influence the process of adopting sustainable building practice. Complexity of construction projects calls for integrated modes of collaboration, while the excess inertia among stakeholders resulted in sluggish adoption of sustainable design and technologies. This study examined buildings that both had and had not adopted Leadership in Energy and Environmental Design and/or ENERGY STAR in the New York metropolitan area, built, or went through major renovation between 1998 and 2013. Secondary datasets from multiple sources, including a private building database company, US Green Building Council, and the US Environmental Protection Agency, were combined based on building address and used for analysis. Stakeholders involved in those projects were retrospectively identified to understand the diffusion of innovation. The analysis included a total of 205 projects and 273 organizations. Findings suggest that having an architect who had worked on ENERGY STAR project(s) increased the likelihood of adopting ENERGY STAR. However, stakeholders' previous work collaboration was not associated with the adoption of sustainable programs. The method of utilizing multiple secondary datasets was tested to contribute to the methodology of building research by enabling the accumulation of knowledge.

KEYWORDS

sustainable building, adoption, stakeholder relationship, stakeholder's previous exposure

INTRODUCTION

According to the U.S. Energy Information Administration (EIA), commercial buildings consumed a total of 18 quadrillion BTUs in 2014, including delivered energy and electricity related losses. This is equivalent to 19 percent of total energy use in the U.S. Although sustainable building practices have been increasingly adopted over the past decade, the diffusion of sustainable practices is still sluggish and frequently debated (Hoffman & Henn, 2008; Lockwood,

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2007; Russell, 2007; Wilson & Yost, 2001). The complexity of building design and construction processes is likely to increase as energy-efficient design and technologies are adopted in building projects. The design and application of new technologies require active collaboration between stakeholders. Such collaboration is often considered one of the biggest challenges for adoption of sustainable practices in the building industry (Feige, Wallbaum, & Krank, 2011). Recently, non-technological aspects, such as social inertia, stakeholder engagement, and integration of project management, have been emphasized as drivers that may increase the adoption of sustainable building practices (Hoffman & Henn, 2008; Harty, 2008). The network of numerous stakeholders who are involved in building projects can influence the process of adopting sustainable building practices, as the increasing complexity of construction projects requires more integrated collaboration to adopt new practices.

This study examines how sustainable building practices spread throughout building projects and the factors that influence the diffusion process in stakeholder networks. Specifically, this study intends to provide evidence of the roles of stakeholders and their influence on building projects regarding the adoption of sustainable practices. It also examines how the stakeholders' roles in adopting sustainable practices and the levels of their impact differ with their cumulative exposure to sustainable practices. By analyzing stakeholders' relationships in a project, this study eventually seeks to identify a leverage point to intervene in the "circle of blame" in which major stakeholders, such as financial institutions, developers, contractors, and tenants, point their fingers at each other for not initiating sustainability (Cadman, 2007).

In this study, it is hypothesized that stakeholders' previous exposure to sustainable building practices increases the likelihood of adopting sustainable practices in the future, and that the impact of stakeholders' exposure to sustainable building practices can be different depending on their individual roles in the projects. The moderating effect of the role of stakeholders may depend on the stage of the project. Especially in the early design stage, which is most often the most influential to the outcome of the project, developers and owners often have the most power of decision-making. Architects and designers are also influential. Contractors may have relatively less power, but still directly influence the project (Newcombe, 2003). Lastly, it is hypothesized that having prior work collaboration between stakeholders has a positive impact on implementing green building practices.

LITERATURE REVIEW

LEED and ENERGY STAR

The Leadership in Energy and Environmental Design (LEED) program is a market driven rating system for sustainable buildings. LEED started in 1998 and was developed to both improve building performance and encourage the design and construction industries to share knowledge and skills used from project to project (US Green Building Council, 2003). Since the LEED program began, it has been adopted by public and non-profit organizations alike, as well as private owners/developers for different sizes and types of buildings. Many U.S. federal agencies, as well as state and local governments, currently require or remunerate LEED certification. Additionally, some private corporations, such as Ford, Sprint, Steelcase, PNC Bank, and Toyota have actively engaged in adopting LEED practices into their building process (Cidell, 2009).

Since 1998, LEED has been the most recognized green building rating system in the U.S. and has evolved from versions 1 through 4 over the course of 15 years. LEED consists of six categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. These categories function as a checklist, which allows for achievement of a set number of credits under each grouping. LEED is sometimes criticized for its credit-based rating system because organizations may seek only to achieve the "lowest hanging fruit." However, LEED is a comprehensive approach that considers development, design, construction, and operation and maintenance.

Many professionals volunteered to help develop the rating system, and the fact that the rating system is easy to understand has helped to disseminate the new system in industry, which is evidenced by the growing number of accredited professionals. Scoring for the LEED program is weighted using the environmental impact categories of the United States Environmental Protection Agency's Tool for the Reduction and Assessment of Chemical and Other Environmental Impact (TRACI) and the environmental-impact weighting scheme developed by the National Institute of Standards and Technology (NIST) (USGBC, 2003).

LEED is a method that has been adopted to achieve three main factors of sustainability: environmental, economic, and social aspects. There have been efforts to provide evidence that LEED systems have an effect on these three factors. The positive impacts of LEED certified buildings have been analyzed from different perspectives, including reduced energy consumption, increased occupancy rates and rent, and higher occupant satisfaction. Even though the number and square footage of LEED certified buildings has increased since conception, the adoption rate has been sluggish because of the nature of building projects, which leads to a complex stakeholder network and an energy paradox of investment and benefits of energy efficiency.

ENERGY STAR, a voluntary labeling program for commercial buildings, started in 1999. The ENERGY STAR program is administered by the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE). A licensed Professional Engineer (PE) or Registered Architect (RA) must verify an application for ENERGY STAR certification before owners or managers submit the application to the EPA. Based on a scale of 1–100, the scores indicate a building's energy efficiency compared to that of similar buildings nationwide. A score of 75 or higher indicates top performance and a score of 50 represents median energy performance. In other words, an actual, measured energy use of a candidate building must be included in an application, and the energy consumption is compared to the national-level source of data from the Commercial Building Energy Consumption Survey (CBECS) with a number of adjustments—building usage, building size, number of personal computers, number of workers, hours of operation per week, and weather and climate (heating and cooling degree days). Since the first certification of an ENERGY STAR commercial building, more than 20,000 commercial buildings, a total of 3 billion square feet of commercial space, have been certified with an ENERGY STAR rating.

Both the LEED and ENERGY STAR programs started by targeting new buildings or existing buildings and were based on either self-affirmed or independent audits (Robinson, 2009). However, the LEED program requires more comprehensive approaches than ENERGY STAR, as LEED has six categories, one of which is energy performance (Kok, McGraw, & Quigley, 2012). Additionally, LEED advocates prescriptive, performance, or intent-based criteria, whereas ENERGY STAR favors measured performance data.

Diffusion of LEED and ENERGY STAR

One of the most important factors for diffusion of innovation is the availability of professionals or business agencies that can provide specific expertise when implementing innovation (Hall, 2004). Professionals or businesses are needed to bridge the gap between under-represented social needs and private needs to provide specific information about sustainable building practices. This important role of local human capital is shown in the diffusion of ENERGY STAR or LEED certified buildings between 1995 and 2010 in the metropolitan areas of New York, Los Angeles, Chicago, Washington, Dallas, and Phoenix (Kok et al., 2012). The number of LEED Accredited Professionals (LEED APs) is positively associated with geographic dispersion of LEED by area and year, while the number of LEED APs is negatively related to the dispersion of ENERGY STAR (Kok et al., 2012). The different impacts of the number of LEED APs by area and year may come from varying features of the two programs. The ENERGY STAR program is based on the achievement of specified efficiency levels of energy use, which are credited by a professional engineer. On the other hand, LEED requires a more complex approach, including six major categories to assess the sustainability of buildings, and its certification process is often guided by LEED APs. The positive relationship between the number of LEED APs registered in the selected metropolitan areas and the geographic dispersion of LEED certified office spaces by the area and year implies the importance of the availability of local human capital (Kok et al., 2012). However, the aggregated data are not sufficient to show direct relevance of having LEED APs and their actual role in building projects because some LEED APs do not work on building projects directly and different professionals (i.e., architects, engineers, urban planners) get LEED AP training/certification. Therefore, the number of LEED APs registered by area and year might not accurately capture the actual utilization of LEED APs. In this study, a construction project is the unit of analysis, where the focus of the investigation is whether stakeholders' have experiences with sustainable practices; their experiences have been operationalized into their previous exposure to sustainable building projects and whether their exposures are diffused and associated with the sustainability outcomes of building projects.

Additionally, the organizational complexity, as well as the fragmented nature of building projects, and the temporary social interactions among stakeholders make it difficult for stakeholders to adopt innovative sustainable practices, which often require more interaction and collaboration. This is because many stakeholders with different occupational specializations have different interests and concerns, and their activities tend to be decentralized rather centralized (Feige et al., 2011; Cleland, 1986). The result can be that the stakeholders blame each other for the slow adoption of sustainable practices rather than initiate them, especially among investors, developers, contractors, and occupants (Cadman, 2007; van Bueren & Priemus, 2002). The involvement of these multi-disciplinary players has discouraged behavioral changes to adopt sustainable solutions in construction projects. Therefore, this study suggests that stakeholders and their interests should be identified, and that their influences and relationships should be addressed. This would help to identify an opportunity for a stakeholder to play a role of an opinion leader and exert more influence than the other stakeholders (Rogers, 2003). It can ultimately help find out how to best intervene and interrupt any "circles of blame" (Cadman, 2007) and facilitate adoption of sustainable building practices.

Lastly, the strength of the relationship between stakeholders is another important factor for the adoption of sustainable building practices. Stronger ties can produce effective communication channels and an exchange of information that is not often shared with the people or organizations with whom one has only arm-length ties (Uzzi, 1997). The nature of construction projects includes fragmented relationships, a lack of central coordination, and temporary collaboration, which often makes it difficult to build strong relationships between organizations/stakeholders. In this study, it is assumed that stakeholders can build stronger relationships among the various other organizations as they work together on project(s). A trusted, strong relationship between stakeholders can positively influence the implementation of sustainable building practices (Khalfan, McDermott, & Swan, 2007; Egan, 1998; Latham, 1994). This might be related to power and influence, rather than a simple technical change (Bresnen, Goussevskaia, & Swan, 2005).

METHODS

This research applied a quantitative approach using secondary data, which included information from both traditional and sustainable office building projects that had been either newly constructed or renovated since the Leadership in Energy and Environmental Design (LEED) and ENERGY STAR programs started in 1998 and 1999 respectively. Secondary data were acquired from three sources: a private database (Emporis), a non-profit organization (U.S. Green Building Council), and a federal agency (U.S. Environmental Protection Agency). To reduce the regional variability in the data set, the sample was limited to newly constructed or renovated office buildings completed between 1998 and 2013 in the metropolitan area of New York City. In this research, the term ***renovation*** refers to situations when buildings have major, structure-wide physical changes and their usage is significantly reduced during these changes (Emporis, ESN91892). The LEED certification system takes into consideration new construction and major renovations, including major HVAC improvements, substantial envelope modifications, and major interior rehabilitation. ENERGY STAR scores reflect actual building energy consumption in quantiles compared with other similar buildings' energy performance.

Directories of traditional and sustainable office buildings in New York City and its metro area were obtained from the Emporis database in July 2013. There was a total of 454 buildings, including 196 new builds and 258 renovations. Of these, 205 buildings provided one or more of the involved companies' information in the New York metropolitan area. LEED certified building directories were obtained from the USGBC in April 2014. There was a total of 128 office buildings that were LEED certified with disclosed building addresses in the New York metro area. Among them, 26 office buildings were new construction, and 102 office buildings were certified as LEED for existing buildings. The registry of ENERGY STAR certified buildings provided by the EPA is available via an online database, which was obtained in November 2014. A total of 354 office buildings were ENERGY STAR certified, but the distinction between new construction and existing buildings (renovation projects) was not possible to discern.

The procedure for compiling the secondary data from different sources started with the Emporis building directory, which included basic building information (year of completion, year of last renovation, address, the number of floors, gross square footage, and information about the companies that were involved in the project). All of the three different data sets were matched based on building's address. After matching the data sources, the companies' work relationships and previous exposure to sustainable practices were explored by looking at the relational data among stakeholders throughout shared projects. The companies' work relations and history indicated whether they had worked together on a previous project before the completion of, or before working on, a current project.

The combined data included a total of 205 building projects for 273 organizations. Some of these organizations were involved in more than one project. Of the 205 building projects, 102 projects were new construction and 103 projects were renovation of existing buildings (Table 1). Fifty-five projects were in New York City and 150 projects were in the surrounding metro area. There were 68 buildings with 10 or fewer floors, 30 buildings with 11–13 floors, and 107 buildings with 14 or more floors. Seven of the new buildings were completed between 1998 and 1999. Many of new buildings were built in the early to mid-2000s: six buildings in 2000, 14 buildings in 2001, 13 buildings in 2002, nine buildings in 2003, eight buildings in 2004, eight buildings in 2005, eight buildings in 2006, and 12 buildings in 2007. The number of buildings completed decreased to three projects on average each year since 2008. More renovation projects were completed between 1998 and 2006 than after 2006. The average size of the buildings was approximately 420,000 square feet (gross floor area), and the median was 250,000 square feet.

RESULTS

The analysis procedure of the compiled secondary data set was designed to 1) create indicators for stakeholders' previous exposure with sustainable building practices, and 2) perform contingency analysis and logistic analysis with binary response variables to investigate the distribution of variables and test the hypotheses.

Exploratory variables indicated whether a combination of two stakeholders among four (developer, owner, architect, and general contractor) had worked together on previous projects, whether each stakeholder had worked on a similar sustainable building program, and the number of stakeholders with previous exposure to LEED, ENERGY STAR, and either one of them. Three response variables were 1) whether the project was LEED certified or not, 2) whether the project was ENERGY STAR certified or not, and 3) whether the project was either certified as green building (LEED or ENERGY STAR) or not. The different combinations have varying sample sizes, since all of the available cases depending on the exploratory variables were included. The summary (Table 2) shows the sample size, likelihood ratio, Fisher's exact test statistics, and odds ratios. These response variables were interpreted as dichotomous (i.e., LEED or non-LEED, ENERGY STAR or non-ENERGY STAR, green building certified or not) rather than ordinal (i.e., non-LEED, LEED certified, Silver, Gold, or Platinum) or continuous (i.e., the number of credits achieved depending on the version of LEED or ENERGY STAR) due to the limited number of project cases.

For a dichotomous response, multiple logistic regressions were used with several explanatory variables. An estimate of parameter refers to the effect of the explanatory variable on the log odds that the response variable equals 1, controlling the other explanatory variables. The exponential of an estimate of parameter indicates the multiplicative effect of the odds of a one-unit

TABLE 1. Compiled building data

Characteristics	Categories & The number of buildings
Types of projects	New construction (102), Renovation (103)
Year built (new construction)	1998–9 (7), 2000–1 (20), 2002–3 (22), 2004–5 (16), 2006–7 (20), 2008–9 (9), 2010–11 (6), 2012–13 (2)
Year renovated (renovation)	1998–9 (19), 2000–1 (30), 2002–3 (20), 2004–5 (18), 2006–7 (14), 2008 (2)
Location	NYC (55), NYC metro (150)
Number of floors	10 or fewer (68), 11–13 (30), 14 or more (107)

TABLE 2. Contingency analysis of LEED certified buildings by stakeholders' previous experience.

	Contingency Analysis					
			Likelihood ratio			
	Sample size (N)	DF	Chi Square	Prob > ChiSq	Odds ratio (95% CI)	Fisher's exact test two-sided prob ≤ P
Green bldg. programs x number of stakeholders with exposure to Green bldg. standards	28	2	3.365	0.1859	.	0.2668
Green bldg. programs x developer's previous exposure to Green bldg. standards	84	1	1.479	0.2239	6.4546 (0.3757, 110.8765)	0.2668
Green bldg. programs x owners with previous exposure to Green bldg. standards	133	1	0.193	0.6605	0.6335 (0.0743, 5.4040)	1.0000
Green bldg. programs x architects with previous exposure to Green bldg. standards	160	1	1.849	0.1739	2.9319 (0.6824, 12.5963)	0.1490
Green bldg. standards x general contractors with previous exposure to Green bldg. standards	60	1	2.346	0.1256	3.28 (0.7426, 14.4873)	0.1928
LEED x number of stakeholders with exposure to LEED	28	2	1.542	0.4624	.	1.0000
LEED x developers with previous exposure to LEED	84	1	0.098	0.7540	0	1.0000
LEED x owners with previous exposure to LEED	133	1	0.125	0.7241	0	1.0000
LEED x architects with previous exposure to LEED	160	1	0.588	0.4430	0	1.0000
LEED x general contractors with previous exposure to LEED	60	1	0.746	0.3877	3.1875 (0.2845, 35.7064)	0.3630
ENERGY STAR x number of stakeholders with exposure to ENERGY STAR	28	2	9.051	0.0108	.	0.0319*
ENERGY STAR x developers with previous exposure to ENERGY STAR	84	1	1.634	0.2012	7.2 (0.4166, 124.4266)	0.2461
ENERGY STAR x owners with previous exposure to ENERGY STAR	133	1	0.049	0.8249	0.7879 (0.0903, 6.8756)	1.0000
ENERGY STAR x architects with previous exposure to ENERGY STAR	160	1	2.792	0.0947	3.96 (0.8778, 17.8657)	0.0898*
ENERGY STAR x general contractors with previous exposure to ENERGY STAR	60	1	0.780	0.3772	2.05 (0.4357, 9.6463)	0.3916

increase in the explanatory variable keeping all other explanatory variables fixed (Agresti, 1996). In other words, the parameter estimate of an architect's previous exposure to sustainable building projects refers to the effects of the architect's previous exposure on the log odds that the project will be LEED certified, controlling the other explanatory variables. JMP statistical software was used for analysis, and the hypotheses were tested in this compiled data set.

The data set started with a total of 205 building project cases for both new construction and renovation. New construction was combined with renovation for the following reasons: 1) similarity in new construction and major renovation projects in terms of the scale of projects, the project process, and the challenges for adopting sustainable practices, 2) non-distinguished ENERGY STAR certification for new or existing buildings, and 3) the limited number of cases. Among them, 28 cases had information for all the involved stakeholders: developer, owner, architect and general contractor, and 3 of the 28 cases were LEED certified. All projects had at least one or more stakeholder(s) who had not had previous LEED experience. Each observation was independent since each indicated an independent single building project. However, this 3x2 contingency table did not meet the other assumption for using chi-square because more than 20 percent of the expected cell counted less than 5 and two cells counted 0 (Yates, Moore, & McCabe, 1999). Therefore, the result of Fisher's Exact Test was not significant, which indicates that there was no significant difference in the likelihood of achieving LEED certification for projects with LEED experienced stakeholders and achieving certification with non-LEED experienced stakeholders.

For the level of ENERGY STAR experience, 28 cases out of the 205 projects had information for all involved stakeholders, and 5 projects out of the 28 cases were ENERGY STAR certified. The number of stakeholders with exposure to ENERGY STAR and architects' previous experience on ENERGY STAR were significant factors influencing the project outcome regarding ENERGY STAR certification ($p = 0.0319$ and 0.0898) at the 10 percent significance level. ENERGY STAR and an architect's exposure to ENERGY STAR was significant—the likelihood of achieving ENERGY STAR was greater for projects with architects who had had previous exposure to ENERGY STAR than it was for those with architects who had had no such exposure ($p = 0.0898$).

The likelihood of achieving LEED increased for projects when an involved general contractor had had previous exposure to LEED versus when the general contractor had not, however, this relation was not significant ($p = 0.3630$). Additionally, even though there was a greater probability of acquiring sustainable building certification when a developer, an architect, or a general contractor had previously worked on sustainable building standards than when they had not, this previous experience was not statistically significant ($p = 0.2668$, 0.1490, 0.1928 respectively).

The results of the study provide empirical evidence for the following statement: involvement of stakeholders who had previous experience on a similar practice would result in more desirable project outcome. However, dissociation between previous collaborative work experience and the desirable project outcome may infer different messages from the literature supporting that trust built among stakeholders through collaboration can yield more desirable project outcomes. The first hypothesis was that the adoption of sustainable building practices in construction projects is influenced by stakeholders' previous exposure to sustainable building projects. The hypothesis was supported as the number of stakeholders that had experience working on green building programs (LEED and ENERGY STAR) was positively related to achieving certification in these programs on later building projects. There was a higher chance of achieving ENERGY STAR certification when any two stakeholders had previous experience working on ENERGY STAR certified buildings. However, having only one stakeholder that had previous experience with the ENERGY STAR program did not increase the likelihood of adopting the program compared to when none of the stakeholders had previous experience with the program.

This led to further analysis for the second hypothesis, which explores whether the role of stakeholders made a difference on the relationship between having only one stakeholder with previous experience and adopting green practices. It was also hypothesized that developers, owners, and architects who had had previous exposure to sustainable building projects were more influential than general contractors in the adoption of sustainable building practices. Further analysis of each stakeholder's exposure to LEED or ENERGY STAR indicated that having an architect and a general contractor who had previously worked on green building standards was more likely to result in adopting green building standards. More specifically, a project with an architect who had previously worked for ENERGY STAR certification was more likely to adopt the ENERGY STAR program.

Lastly, stakeholders' work collaboration was not positively associated with the adoption of sustainable building practices; the third hypothesis was not supported. There was no significant relationship between stakeholders, such as developers, owners, architects, and general contractors, who had collaborated previously and the adoption of green building programs.

DISCUSSION

The results of this study indicated that the more stakeholders had had exposure to sustainable practices, the higher the chances of their adopting these practices in projects. The outcome of this study suggests that there is different magnitude of impact associated with the roles of certain stakeholders to achieve sustainability in building projects. Specifically, architects with previous experiences with ENERGY STAR projects increased the likelihood of getting projects certified.

The findings imply the importance of cumulative knowledge and previous experience of stakeholders to implement sustainable practices in sub-sequential projects. The positive relationship between stakeholders' previous exposure to sustainable building practices and the adoption of them in sub-sequential projects reflects that experiential knowledge, or know-how, may accumulate within an organization. Specifically, certain stakeholders, such as an architect, can influence the implementation of sustainable building practices by initiating the practices, using persuasive power, or providing reliable knowledge and resources. An organization with experiences in sustainable building programs increased the likelihood of a project to be certified with sustainable practices in this study.

Experiential knowledge and know-how may be accumulated within an organization and carried over to future projects. An organization with experience in sustainable building programs increased the likelihood of a project to be certified with sustainable practices, such as LEED and ENERGY STAR. On the other hand, collaborative work history did not necessarily increase a chance of adopting sustainable practices. This implies sustainable practices may not be affected by previous collaboration or stakeholders' weak or strong relationships, or previous collaboration does not necessarily yield a stronger relationship between stakeholders.

Working on a project together may not necessarily improve the quality of coordination or collaboration or the building of trust that can be transferred from one project to another in an interdependent, multi-organizational setting in complicated contractual and managerial relationships (Bresnen & Marshall, 2001; Cherns & Bryant, 1984). In the diffusion of innovation theory, the communication channel is an important component for the diffusing, or adopting, of new practices (Rogers, 2003). Also, a trusted, strong relationship can enhance effective communication and the exchange of complex information (Uzzi, 1997). This is closely related to challenges for fostering project-based stakeholder relationships because of the discontinuity of working relationships from one project to another, lack of effective coordination and communication, and fragmentation among stakeholders across the project timeline (Feige et al., 2011; Bresnen et al., 2005; Priemus, 2005). This perspective also aligns with the idea that implementing new practices is a social accomplishment or change, rather than a simple technical change, because it is related to the power and influence of stakeholders (Bresnen et al., 2005).

There could be several reasons that working together does not strengthen the relationship. One reason could be a lack of central coordination or vertical fragmentation among stakeholders on a project. Even if stakeholders had worked together, they might not have ever had a chance to exchange tacit information or know-how or solve a problem together during that project, which are the key components in trust building (Khalfan et al., 2005).

The method using secondary data in this study shows the possibility of using secondary data in building research, especially when having both successful and non-successful (or sustainable or non-sustainable) buildings in the study to avoid selection bias upon the response variable, and when looking at the relationships over a longer period of time. Green certified buildings have been more recognized and have more data available to study, and as a result, many studies on the topic of building sustainability have included only cases of sustainable building. The method used in this study allowed the inclusion of cases having both positive and negative responses.

This study has limitations in the conclusions it can draw regarding the causality of the relations. First, it is a retrospective study that captures the trajectory of the adoption of sustainable practices by relying on the records of the projects, which led to missing data. The matching and compiling procedure in this study started with the Emporis dataset, which may not cover all buildings in the New York metropolitan area. Only nine out of the 128 LEED certified projects that were obtained from USGBC were found in the Emporis dataset. Only 22 out of the 354 ENERGY STAR certified projects were found in the Emporis dataset. This reflects that the Emporis dataset may not cover all of the buildings in the region.

Second, one assumption in the study is that stakeholders' previous exposure to sustainable building practices and stakeholders' previous collaborative work relationships are captured in the data set based on the projects in the New York metropolitan area. This data might not capture stakeholders' previous involvement in construction projects with sustainable or energy efficient features before 1998. Any earlier exposure to sustainable practices might be related to some of the credits in LEED certification or the features of ENERGY STAR certification. This produces a conservative estimate of the impact stakeholders' previous exposure on the adoption of sustainable building practices. However, it also could be argued that it may cause a type II error.

Third, recently built high-rise buildings may have more detailed data than low-rise buildings built ten or more years ago. Of 205 total projects, 134 building projects (new construction or renovation) were completed in 2004 or earlier, and at least 155 of these projects had a size of less than 1,000,000 square feet of gross floor area.

There is also a limitation regarding the generalizability of the results of this study. First, the data were collected only in the New York metropolitan area. Therefore, it is inevitable that the external validity of the results will be limited. The New York metro area is one of the most active real estate markets in the U.S.; therefore, local resources and human capital may be more accessible than in suburban or rural areas. For this reason, the results of the study might not be comparable to the building industries in these smaller markets. However, the results may be analogous to sub-urban areas neighboring other big cities because of shared resources and human capital or the spillover effects of phenomenon in neighboring large cities. Additionally, the study is limited to office buildings. Different types of buildings, such as hospitals, schools, and residential buildings, might have different mechanisms to propel the adoption of sustainability.

CONCLUSION

The building industry faces the mounting challenge of integrating many stakeholders and activities throughout a building's life cycle in order to minimize the environmental impact of the building itself. To achieve this goal, stakeholders must be engaged and agree to achieve a cohesive structure by working together for the benefit of the project.

By compiling data from various sources, these research findings suggest that an architect's and a general contractor's previous experience with sustainable building practices can have an impact on implementing sustainable building practices on future projects. This background experience can indicate knowledge management/accumulation within an organization. However, stakeholders' previous work collaboration does not appear to be significant in the adoption of those practices, pointing to possible difficulties that project-based organizations may have in developing or maintaining strong ties with other stakeholders in the short term. Unlike knowledge management and accumulation, transferring or exchanging knowledge and know-how seem difficult between project-based stakeholders. Considering a diverse pool of primary concerns and motives for implementing sustainable practices, understanding various stakeholders' primary concerns regarding the adoption of sustainable practices can help stakeholders know which supporting information or evidence to present to be more persuasive in the adoption process. The ultimate goals of this study are to 1) enhance the understanding of factors that influence the adoption of sustainable building practices, 2) investigate the relationships between these factors and the adoption of the practices, and 3) suggest leverage point(s) to break the "circle of blame" among stakeholders to initiate the adoption of sustainability.

From a methodology point of view, the study shows the possibility of using secondary open source data in building research, which can often pose a challenge to researches attempting to obtain such a large dataset. The method of using secondary data and combining them in this study also suggests the need for using unified building identification numbers to increase interoperability among different data sources. This will allow stakeholders, researchers, users, potential buyers and tenants to look up building information more easily. The dataset studied in this research was limited to commercial buildings in the New York metropolitan area, and contained fragmented information from different sources, which resulted in missing data. Therefore, for future studies, having a larger dataset with less missing data by reaching out to building owners in different geographic regions would enhance the exploration of the impact of stakeholders' previous experience and cumulative knowledge on adopting sustainable building practices.

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