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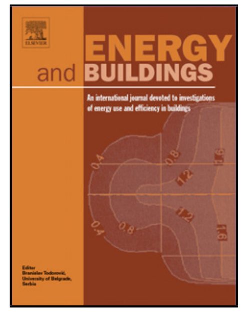

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Examining Issues Influencing Green Building Technologies Adoption: The United States Green Building Experts' Perspectives

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Abstract

Green building (GB) has been viewed as an effective means to implement environmental, economic, and social sustainability in the construction industry. For the adoption of GB technologies (GBTs) to continue to succeed and gain popularity, a better understanding of the key issues influencing its progress is crucial. While numerous studies have examined the issues influencing green innovations adoption in general, few have specifically done so in the context of GBTs. This study aims to investigate the underpinnings of GBTs adoption in the following areas: (1) the critical barriers inhibiting the adoption of GBTs, (2) major drivers for adopting GBTs, and (3) important strategies to promote GBTs adoption. To achieve these objectives, a questionnaire survey was carried out with 33 GB experts from the United States. Ranking analysis was used to identify the significant issues associated with GBTs adoption. Resistance to change, a lack of knowledge and awareness, and higher cost have been the most critical barriers. The major drivers for adopting GBTs are greater energy- and water-efficiency, and company image and reputation. The analysis results also indicate that the most important strategies to promote the adoption of GBTs are financial and further market-based incentives, availability of better information on cost and benefits of GBTs, and green labelling and information dissemination. The findings provide a valuable reference for industry practitioners and researchers to deepen their understanding of the major issues that influence GB decision-making, and for policy makers aiming at promoting the adoption of GBTs in the construction industry to develop suitable policies and incentives. This study

contributes to expanding the body of knowledge about the influences that hinder and those that foster GBTs implementation.

Keywords: Green building technologies; Barriers; Drivers; Promotion strategies; United States.

1. Introduction

The construction industry has a significant impact on the environment, economy, and public health. According to Yudelson (2007a), worldwide, buildings account for more than 40% of all global carbon dioxide (CO_2) emissions, particularly because they are a major contributor to energy consumption. In 2007, the World Business Council for Sustainable Development (WBCSD) reported that buildings account for 40% of total energy consumption (WBCSD, 2007). In addition, buildings in most developed countries, such as the United States (US), consume 68% of all electricity, 88% of portable water supplies, 12% of fresh water supplies, 40% of raw materials, and are responsible for 20% of solid waste streams (US Green Building Council (USGBC), 2003; Comstock, 2013). It is projected that the global carbon emissions of buildings will reach 42.4 billion tonnes by 2035, a 43% increase in the 2007 level (US Energy Information Administration (US EIA), 2010). With the implementation of sustainable/green innovations, negative environmental, social, and economic impacts of the construction industry can be reduced. Thus, adopting green innovations in construction activities will result in high performance and minimize their environmental impacts (Love et al., 2012). Typical examples of green innovations in the construction industry include green specifications (Lam et al., 2009), green building (GB) guidelines (Potbhare et al., 2009), and GB technologies (GBTs) (such as wind turbines and solar panels) (Love et al., 2012).

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World

Commission on Environment and Development (WCED), 1987). GB has emerged as a widely accepted phenomenon to implement sustainable development, which considers the triple bottom line of environmental, social, and economic performance of buildings, in the construction industry (Sev, 2009; Son et al., 2011). It is part of a global response to growing awareness of the huge role buildings play in causing CO_2 emissions that drive global climate change (Yudelson, 2007a, 2008). GBs are buildings that "use key resources like energy, water, materials, and land more efficiently than buildings that are just built to code" Kats (2003, p.2). They are designed, built, and operated to boost health, environmental, productivity, and economic performance over that of conventional (non-green) buildings (USGBC, 2003). GB is considered as a form of technological and process innovation in the construction industry, because it revamps the non-green way of building by integrating a variety of special building technologies, techniques, practices, and materials to achieve sustainability (Yudelson, 2007b; Love et al., 2012). Beyond environmental benefits, employing green innovations offers many social and economic benefits, such as reduced lifecycle cost, job creation, and poverty alleviation (Ahn et al., 2013; Comstock, 2013), that are increasingly important for sustainable development. As a result, green innovations adoption has experienced significant progress in many countries in recent years (Yudelson, 2008, 2009a).

GB technologies (GBTs) – an offshoot of green innovation – have evolved dramatically over the last decade. The promotion of green practices in building development has been the main impetus behind the development of various GBTs (Zhang et al., 2011a, b). Once rare, resource-efficient, environmentally friendly, and water- and energy-efficient technologies are now broadly recognized as mainstream. Innovative technologies, such as high efficient windows, green roof, solar shading devices, solar water heaters, gray water treatment plants, and high efficient HVAC systems, have all gained broad acceptance in the construction industry (USGBC, 2003; Koebel et al., 2015). "Technologies are the building blocks of increased performance" (Sanderford et al., 2014, p. 37), which explains why GBTs are central to address the need for sustainability in the construction industry. It has been highlighted that in countries like the US, stakeholders' use of GBTs is growing (Johnstone et al., 2010; Sanderford et al., 2014), suggesting that GBTs would displace many of the non-green technologies in the construction industry in the near future. However, for GBTs adoption to continue to succeed and become widespread and mature, a deeper understanding of the key issues influencing its progress is crucial (Love et al., 2012; Mao et al., 2015).

Despite the recognition of the importance of GBTs in achieving construction sustainability and the existence of many studies on issues associated with green innovations adoption in general, few have specifically examined barriers, drivers, and promotion strategies of GBTs adoption. As a result, with the intent to enhance GBTs promotion efforts, the primary objectives of this study are to investigate the: (1) critical barriers inhibiting the adoption of GBTs; (2) major drivers for deciding to use GBTs; and finally, (3) important strategies to promote the adoption of GBTs. In this research, the barriers, drivers, and promotion strategies of GBTs adoption are investigated through a questionnaire survey among GB experts from the US. The main reason for targeting the US GBTs market is that the US is one of the leading countries in GB development (Darko and Chan, 2016) and thus not only would this study pave a better way for further GBTs application and development in the US, but could also serve as a valuable reference for other underdeveloped markets (Chan et al., 2009).

The remainder of the paper is structured into the following sections. The next section presents relevant theories and draws on the extant literature to examine the issues influencing green innovations implementation. The motivation for this research is then presented. The next two sections describe the research methodology and data analysis. The section that follows presents the findings and discussion. And the last section concludes the study. The research presented is expected to provide a valuable reference for industry practitioners and researchers to deepen their understanding of the major issues that influence GB decision-making as well as to help policy makers intending to launch policies and incentives to make GBTs adoption a mainstream practice in the construction industry.

2. Literature review

2.1. Green innovation

Innovation is “any idea, practice, or material artifact perceived to be new to the relevant adopting unit” (Czepiel, 1974, p. 173). In the adoption and diffusion of innovations theory, innovation is often viewed as a vital ingredient in the recipe for market differentiation and creating competitive advantage, and for creating new markets for products and processes (Christensen et al., 2004; Von Hippel, 2005; Chesbrough et al., 2006). GB is inextricably linked to innovation not only because it helps construction stakeholders (e.g., developers) gain competitive advantage through developing unique building products that have good market opportunities (Zhang et al., 2011b), but also because sustainability and in turn GB requires process changes, for instance, radical changes in the manner goods and services are produced, distributed and use (Fukasaku, 2000; Deering, 2000; Manley, 2008). For the purpose of this study, ‘green innovation’ is defined as “those products, practices, technologies, materials, and processes that either reduce the energy requirements of buildings and/or reduce the environmental impact of buildings” (Miozzo and Dewick 2004, p. 74). Thus, ‘GBTs’ is a branch of green innovation in the construction industry, whose adoption issues remain the main focus of this study. Ahmad et al. (2016) clustered GBTs into seven categories: indoor illumination technologies; control technologies; energy and water conservation technologies; renewable energy technologies; energy and water recovery technologies; technologies to ensure air quality; and technologies to maintain comfort zone temperatures.

To conduct this study, it is critical to examine previous GB-related studies. The following sections present literature reviews on GB barriers, drivers for GB, and strategies to promote GB.

2.2. GB barriers

While the merits of green innovations considerably comply with requirements of human health and environmentally sustainable development, green innovations still face challenges in their market penetration; there are several concerns about their implementation. What are the stumbling blocks that prevent the GB market from growing and expanding? There is a need to better understand the barriers to the implementation of green innovations to help find ways and means to overcome them. Several researchers and practitioners have investigated the barriers hindering the use of green innovations in construction. For instance, cost, implementation time, and the shortage of knowledge and awareness of GB are well documented in previous research.

A crucial barrier to the adoption of green innovations is cost (Lam et al., 2009; Chan et al., 2009; Zhang et al., 2011a, b; Shi et al., 2013; Ahn et al., 2013; Dwaikat and Ali, 2016). Ahn et al. (2013) generically presented cost as the biggest barrier to sustainable design and construction in the US. A questionnaire survey by Lam et al. (2009) in Hong Kong showed that cost was the most dominant barrier to integrating green specifications in construction. By adopting the same factors examined by Lam et al. (2009), Shi et al. (2013) repeated a similar study on the adoption of green construction in China and identified that cost was also the most critical barrier in that part of the world. The questionnaire survey study involving building designers in Singapore and Hong Kong showed that higher cost was an undeniable barrier holding back GB survival in the construction market (Chan et al., 2009). Potbhare et al. (2009) discovered that higher cost was the topmost barrier to adopting GB guidelines in India. As cost is widely recognized in the literature, it will be included as one of the potential barriers.

In construction, cost and time are closely related, as they are both essential in measuring project performance and success (Chan and Kumaraswamy, 2002). As a barrier to the adoption of green innovations, longer implementation time has been ranked second, just after cost in some studies. Lam et al. (2009) and Shi et al. (2013) showed that incremental time resulting from fulfilling green requirements was an inevitable barrier to the decision making of contractors, clients, consultants, and subcontractors, because it delays the project. A study by Hwang and Ng (2013) among project managers in Singapore revealed that longer time required during the pre-construction process ranked as the top challenge faced in GB projects execution. Another time-related issue is the lengthy approval process for new GBTs within a firm (Tagaza and Wilson, 2004).

The lack of knowledge and awareness of GB and its associated benefits is also pointed out by various researchers as a crucial barrier to the innovation adoption. In addition to cost, Ahn et al. (2013) highlighted the primary barriers to sustainable construction as long payback periods, tendency to maintain current practices and resist change, and limited knowledge and understanding. Other researchers (Williams and Dair, 2007; AlSanad, 2015) also found lack of knowledge and awareness of GB as a main barrier. This lack of knowledge and awareness can be linked to GB research and information gaps in the industry. The results of Rodriguez-Nikl et al. (2015) highlighted lack of information as the topmost barrier to adopting green innovations in general. Bin Esa et al. (2011) carried out a study to identify the obstacles to implementing GB projects in Malaysia. The major obstacles were found to be lack of awareness, education, and information on the benefits of GB. Researchers have also identified lack of reliable GB research as an important barrier (USGBC, 2003; Hwang and Tan, 2012).

Furthermore, there are social and psychological barriers, such as stakeholders' attitudes and behaviors, and purchase intention, that affect the acceptance and progress of GB (Hoffman and Henn, 2008; Zhao et al., 2015). The unwillingness to change the non-green way of building as identified by Meryman and Silman (2004) has become a major barrier to the adoption of green specifications. This coincided with the finding of one study conducted in China, which found that deep rooted non-green ideas were the key barrier to sustainable construction (Chen and Chambers, 1999). A recent study by Du et al. (2014) confirmed that the reluctance of stakeholders to change is the main barrier to the adoption of energy-saving technologies in the Chinese construction industry. Häkkinen and Belloni (2011) contended that the resistance to sustainable building occurs because of the need for process changes, which entails the perception of possible risks and unforeseen costs.

Successful innovation adoption requires effective cooperation and working relations amongst different stakeholders within a specific project (Kumaraswamy et al., 2004). Therefore, a lack of interest and communication among project team members may affect the adoption of green innovations (Williams and Dair, 2007; Hwan and Tan, 2012; Hwang and Ng, 2013). Other barriers cited by researchers include:

- lack of interest and market demand (Hwang and Tan, 2012; Samari et al., 2013; Djotoko et al., 2014);
- lack of government incentives and regulations (Love et al., 2012; Zhang et al., 2012; Gan et al., 2015);
- distrust about GB products (Williams and Dair, 2007; Winston, 2010);
- unfamiliarity with green technologies (Eisenberg et al., 2002; Tagaza and Wilson, 2004);

- lack of training and education (Djokoto et al., 2014; Luthra et al., 2015; Gan et al., 2015);
- unavailability of approved green materials and technologies (Potbhare et al., 2009; Aktas and Ozorhon, 2015);
- lack of GB expertise/skilled labor (Eisenberg et al., 2002; Tagaza and Wilson, 2004);
- lack of importance attached to GB by leaders (Du et al., 2014);
- lack of promotion (Zhang et al., 2012; Djokoto et al., 2014);
- lack of financing schemes (Potbhare et al., 2009; Elmualim et al., 2012; Gan et al., 2015);
- lack of availability of demonstration projects (Potbhare et al., 2009); and
- lack of available and reliable green suppliers (Lam et al., 2009; Gou et al., 2013; Shi et al., 2013).

After a careful examination of the existing literature relating to GB barriers, a variety of factors that have the potential to hamper the adoption of GBTs were identified. Table 1 provides a list of 26 factors that are well documented and, hence, more applicable. Rowlinson (1988) suggests that for a research study, well-known factors are more applicable, because respondents could be able to respond easily. As they are more applicable, examining them would be more useful for gaining a deeper understanding of the real barriers that inhibit GBTs adoption (Cheng and Li, 2002). In this paper, these underlying factors will be examined in terms of their criticality in preventing wider adoption of GBTs, as seen from the perspectives of US GB experts.

Table 1
Potential barriers to GBTs adoption.

Code	Barrier factors
b01	Higher costs of GBTs
b02	Lack of GBTs databases and information
b03	Lack of GB expertise/skilled labor
b04	Lack of knowledge and awareness of GBTs and their benefits
b05	Lack of government incentives/supports for implementing GBTs
b06	Lack of reliable GBTs research and education

b07	Fewer GB codes and regulations available
b08	Insufficient GB rating systems and labelling programs available
b09	Unfamiliarity with GBTs
b10	High degree of distrust about GBTs
b11	Conflicts of interests among various stakeholders in adopting GBTs
b12	Lack of interest and market demand
b13	Implementation of GBTs is time consuming and causes project delays
b14	Resistance to change from the use of traditional technologies
b15	Complexity and rigid requirements involved in adopting GBTs
b16	Lack of promotion
b17	Lack of importance attached to GBTs by leaders
b18	Risks and uncertainties involved in implementing new technologies
b19	Difficulties in providing GB technological training for project staff
b20	Lack of technical standard procedures for green construction
b21	Lack of available and reliable GBTs suppliers
b22	Lack of financing schemes (e.g. bank loans)
b23	High market prices, rental charges, and long pay-back periods of GBs
b24	Lack of availability of demonstration projects
b25	Limited experience with the use of non-traditional procurement methods
b26	Lack of tested and reliable GBTs

2.3. Drivers for GB

A better understanding of GB drivers is necessary to encourage or lead potential adopters to accept and continue to use green innovations. This section presents a review of GB drivers addressed by previous studies. For example, Love et al. (2012) identified six key drivers or reasons why the client of the Western Australia's first six-star Green Star energy-rated commercial office building decided to use innovative green technologies. These were improved occupant's health and well-being; marketing strategies; reduce the environmental impact of the building; reduction in whole-life cycle costs; marketing and landmark development; and attract premium clients and high rental returns.

Gou et al. (2013) assessed Hong Kong's developers' readiness to adopt GB and found that the following issues motivated the developers to voluntarily adopt GB: low operation energy cost; environmentally friendly; reduced greenhouse gases; ability to differentiate in the market; lower vacancy rates; ease in re-sale; higher rents and/or sales prices; and improved comfort, health, and productivity. Low et al. (2014) examined the success factors and drivers for greening new and existing buildings in Singapore. The important drivers discovered included return on investments; local and overseas competitions; rising energy bills; corporate social responsibility; and marketing/branding motive.

Aktas and Ozorhon (2015) investigated the GB certification process of existing buildings in Turkey. Their findings highlighted the main drivers to include improved occupants' satisfaction and comfort; recycle materials; electricity, energy, and water savings; and commitment to environmental sustainability. Andelin et al. (2015) explored the GB drivers for investors and tenants in Nordic countries. Different sets of drivers were identified for investors and tenants, however, company image and reputation; and lower lifecycle costs were identified as the most remarkable mutual drivers.

Windapo and Goulding (2015) carried out another recent study in South Africa, which revealed that the drivers for adopting GB include good public image; competitive advantage; cost savings; and improved productivity. One of the widely cited studies on sustainable construction drivers in Greece is by Manoliadis et al. (2006), who found energy conservation; resource conservation; and waste reduction to be the most important drivers of change. Ahn et al. (2013) also identified that energy conservation; improved indoor environmental quality; environmental/resource conservation; waste reduction; and water conservation were the top six drivers for sustainable design and construction.

Chan et al. (2009) showed that the most important business reasons driving the GB market were lower operation costs, higher building value, lower lifetime cost, enhanced marketability, and higher return on investment. The literature further discusses that there is a job creation opportunity associated with GB adoption (Comstock, 2013). Chan et al. (2009) argued that investing in GB not only provide benefits for customers or buyers, but almost every stakeholder in the industry also benefits, because it provides many business opportunities. Furthermore, they opined that due to the increased marketability of new green products, new job opportunities may arise. Mondor et al.'s (2013) study demonstrated that: (1) investment in green systems can yield direct savings and improved sustainability operations and maintenance practices; (2) GB projects can accelerate broader organizational sustainability efforts; (3) GBs can create major benefits for a region, including additional commerce; and (4) GB projects can affect their industry standards by setting a standard for future design and construction, and also by facilitating a culture of best practice sharing, benchmarking, and peer comparison.

Serpell et al.'s (2013) study revealed that the main drivers for GB included company image; cost reduction; and market differentiation. Vanegas and Pearce (2000) argued that the sustainable construction drivers should focus on the impacts of the built environment on human health, resource depletion, and environmental degradation. Augenbroe and Pearce (2009) proposed 15 drivers for sustainable construction, e.g., indoor environmental quality; waste reduction; re-engineering the design process; energy conservation; resource conservation; adoption of performance-based standards; better ways to measure and account for costs; and product innovation. Yudelson (2008) identified 14 benefits that build a business case for GB, e.g., reduced operating and maintenance costs, marketing benefits, productivity benefits, and increased building value. There are several other published studies addressing the issue of GB drivers (Sayce et al., 2006, 2007; Falkenbach et al., 2010; Qi et al., 2010).

Following a detailed review of the literature, a large number of drivers for adopting green innovations were identified and clustered, from which a list of 21 drivers found to have received relatively considerable attention in the literature was compiled for this study (Table 2).

Table 2
Potential drivers for adopting GBTs.

Code	Driver factors
d01	Reduced whole lifecycle costs
d02	Greater energy-efficiency
d03	Greater water-efficiency
d04	Improved occupants' health, comfort, and satisfaction
d05	Improved productivity
d06	Reduced environmental impact
d07	Better indoor environmental quality
d08	Company image and reputation/marketing strategy
d09	Better workplace environment
d10	Thermal comfort (better indoor temperature)
d11	High rental returns and increased lettable space
d12	Attract premium clients/increased building value

d13	Reduced construction and demolishing wastes
d14	Preservation of natural resources and non-renewable fuels/energy sources
d15	Set standards for future design and construction
d16	Reduced use of construction materials
d17	Attract quality employees and reduce employee turnover
d18	Commitment to social responsibility
d19	Facilitate a culture of best practice sharing
d20	Efficiency in construction processes and management practices
d21	Improved performance of the national economy and job creation

2.4. Strategies to promote GB

There are a number of strategies to promote the adoption of green innovations. For example, a wide range of rating systems and labelling programs, such as the UK's Building Research Establishment Environmental Assessment Method (BREEAM), the US's Leadership in Energy and Environmental Design (LEED), Australia's Green Star, and Singapore's Green Mark Scheme, have been developed to improve GB development and evaluation. These rating systems and labelling programs provide useful information and guidance on GB to the general public and industry practitioners, and there are several studies showing that they are essential for GB promotion (Qian and Chan, 2010; Windapo, 2014; Murtagh et al., 2016).

It is also widely recognized in the literature that government's involvement is one of the most crucial and effective ways to promote GB (Varone and Aebischer, 2001; Chan et al., 2009). Research suggests that the most cost-effective means to promote the adoption of green innovations are to impose mandatory regulations on market parties and introduce practical financial and regulatory incentives (Qian et al., 2016; Olubunmi et al., 2016; Shazmin et al., 2016) to increase the attractiveness of GB to stakeholders. Although regulations and policies are helpful in promoting GB, it should be noted that their effectiveness is closely related not only to their content, but also to their enforcement (Gan et al., 2015). Therefore, to effectively promote GB, there is a need to ensure that GB policies and regulations are sufficiently enforced following their launching (Qian and Chan, 2007; Zhang et al., 2011a, b).

Qian and Chan (2007) conducted a comparative study on government measures for promoting building energy efficiency in the US, UK, and Canada, and proposed a framework on these measures. Their framework contains several measures, such as implementation of further market-based incentives, product rating and labelling, subsidy, better enforcement of existing standards, investment incentives, and low-cost loans. Potbhare et al. (2009) developed a green implementation strategy to accelerate the adoption of GB guidelines in developing countries. Their study identified a number of crucial strategies to promote the adoption of GB guidelines, such as availability of better information on cost and benefits of GB guidelines, availability of institutional framework for effective implementation of GB guidelines, educational programs for developers, contractors, and policy makers related to GB guidelines, and the creation of environmental awareness by workshops, seminars, and conferences.

Häkkinen and Belloni (2011) argued that developing the awareness of clients about the benefits of GB is one of the most important actions to promote GB. As the attitudes and behaviors of consumers have a significant influence on GB promotion, strengthening publicity and education may be an efficient and effective way to enhance public awareness of environmental sustainability as well as customers' willingness to pay for GBs (Zhang, 2015). In their study on GB promotion in China, Li et al. (2014a) proposed the following strategies to promote GB: to enhance the awareness of the stakeholders, to strengthen technology research and communication, and codes and regulations.

Table 3 lists a total of 12 potential strategies to promote the adoption of GBTs. Although several studies were considered, these strategies were identified based mainly on the works of Qian and Chan (2007), Potbhare et al. (2009), and Li et al. (2014a), as they highlighted strategies that were relatively more important for the purpose of this study. Successful implementation of these strategies could help overcome most of the barriers summarized in

Table 1 to further promote GBTs adoption. Hence, this study will examine them to help understand the most important strategies to promote the adoption of GBTs in construction.

Table 3
Potential strategies to promote the adoption of GBTs.

Code	Promotion strategies
p01	Financial incentives and further market-based incentives
p02	Mandatory GB codes and regulations
p03	Green labelling and information dissemination
p04	Better enforcement of GB policies
p05	Low-interest loans and GB subsidies
p06	Public environmental awareness creation through workshops, seminars, and conferences
p07	More publicity through media (e.g., print media, internet, and radio and television programs)
p08	Educational programs for developers, contractors, and policy makers related to GBTs
p09	Availability of better information on cost and benefits of GBTs
p10	Competent, active, and proactive GBTs promotion teams/local authorities
p11	Availability of institutional framework for effective implementation of GBTs
p12	A strengthened GB technology research and education, and communication of new technologies

The literature reviews above summarize past studies about the implementation of green innovations in the construction markets of different countries worldwide. Most of the previous studies focused more on the barriers to, drivers for, and strategies to promote the adoption of green innovations in general (e.g., Chan et al., 2009; Häkkinen and Belloni, 2011; Shi et al., 2013; Ahn et al., 2013; Li et al., 2014a; AlSanad, 2015). As such, most of the findings and suggestions from these studies are generic for GB, requiring validation regarding their applicability to the adoption of GBTs. Therefore, conducting a research that is specifically focused on the adoption of GBTs, in order to validate the findings of the literature review in this context is worthwhile.

3. Motivation for this research

Implementation of GBTs is very promising. GBTs have the potential to positively impact environmental issues and help local governments achieve sustainable development goals (Robichaud and Anantatmula, 2011). Hence, many countries have either already made the promotion of GBTs adoption high on government agenda or have plans to do so in the near future. Identification of the key issues associated with the adoption activity is essential for effective promotion of GBTs. However, is it recognized that research on GBTs adoption issues needs further efforts. Too general issues in previous studies present some limitations when applied to the adoption of GBTs in practice. Therefore, the issues that are specific to GBTs adoption need to be identified to be more applicable. As such, the most critical/important issues also need to be identified and prioritized. When this initiative is accomplished and fully documented, these issues can be focused on in GBTs promotion. Thus, this paper identifies the major issues that influence GBTs adoption to help promote GBTs adoption in the future.

4. Research methodology

This study adopts literature review and a questionnaire survey as its main method of data collection. The research approach is presented in Fig. 1. In order to achieve the research objectives, this study also conducts ranking, *t*-test, and concordance analyses using the SPSS 20.0 statistical package.

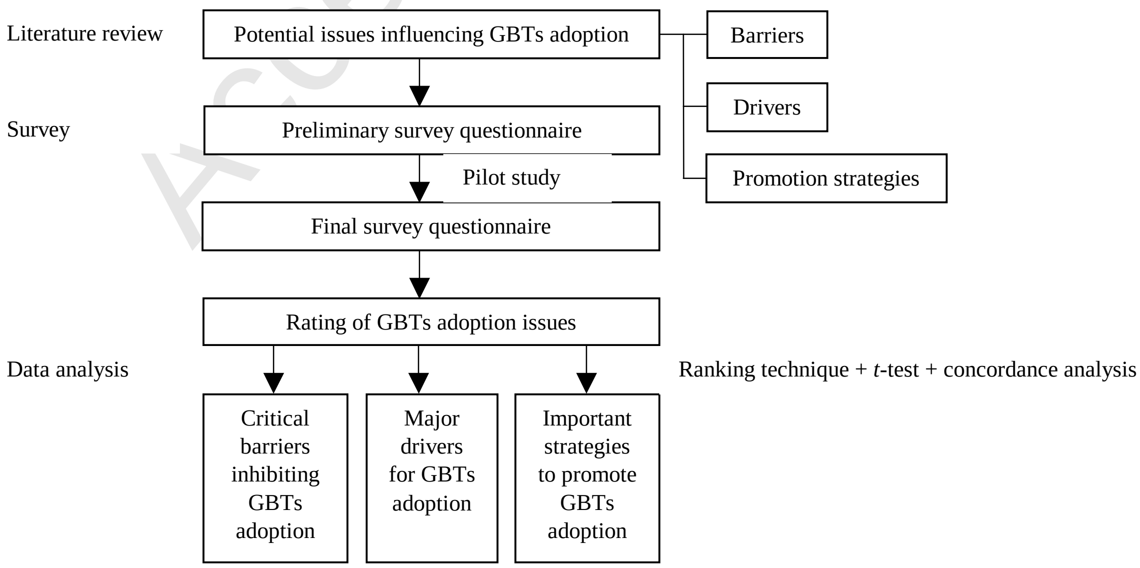

Fig. 1. Research framework

4.1. Questionnaire design

As a systematic technique of data collection, the questionnaire survey method has been widely used to solicit professional opinions on the issues influencing the adoption of various innovations in construction management research (Rahman, 2014; Mao et al., 2015). Specifically, in the GB literature also, questionnaire survey has been a popular method to examine the issues influencing the adoption of green innovations (Lam et al., 2009; Andelin et al., 2015). Thus, to examine the issues influencing the adoption of GBTs in the construction industry, a questionnaire survey was carried out. Based on the literature review discussed above, a questionnaire was designed to solicit professional opinions from international GB experts. The questionnaire was composed of three parts. The first part explained the research objectives and presented contact details. The second part was designed to collect background information regarding the experts' position, profession, years of experience, nature of experience, country of origin, and whether they had been involved in activities related to the adoption of GBTs. The third part consisted of a list of potential barriers to the adoption of GBTs (see Table 1), a list of potential drivers for adopting GBTs (see Table 2), and a list of potential strategies to promote the adoption of GBTs (see Table 3). The experts were requested to evaluate the degree to which each factor was a critical barrier to GBTs application using a five-point scale (1 = not critical and 5 = very critical). In terms of the main drivers for implementing GBTs, the experts were asked to express their professional opinions using a five-point scale (1 = strongly disagree and 5 = strongly agree). Finally, the experts were asked to rate the importance of various strategies according to their roles in promoting the adoption of GBTs using a five-point scale (1= not important and 5 = very important). The five-point Likert scale was selected, because it gives unambiguous results that are easy to interpret (Ekanayake and Ofori, 2004). Prior to the questionnaire survey, a pilot study was conducted to test the comprehensiveness and relevance of the questionnaire (Li et al., 2011). The pilot study involved three professors, a senior lecturer, and a postgraduate researcher who were experienced in this research area. The questionnaire was finalized based on feedbacks from the pilot study.

4.2. Data collection

The questionnaire was distributed by email to carefully selected international GB experts (both practitioners and academics), who were identified mainly through research publications and databases (member directories) of worldwide GB councils. This study adopts Cabaniss's (2002, p. 42) definition of an expert: "an expert is someone with special skills or knowledge evidenced by his/her leadership in professional organizations, holding office in professional organizations, presenter at national conventions, published in recognized journals, etc." Therefore, the suitability of the initially identified experts was determined based on their basic knowledge and understanding of use of green innovations in the construction industry, evidenced by their relevant GB research publications (to respect the anonymity of the experts, examples of the publications are not given) and/or registration as accredited green professionals with recognized GB councils (such as USGBC, Green Building Council Australia, U.K. Green Building Council, Canada Green Building Council, and World Green Building Council). All questionnaires were sent out to the experts, attaching a Microsoft Word file and a web link (to allow online responses), and a request for them to forward the questionnaire to their colleagues or to other experts that they know also have basic knowledge of the issues to be assessed. Due to this approach to sample data collection (similar to Rahman, 2014), the exact number of distribution is unknown; however, more than 500 questionnaires were sent out. In order to encourage participation, the experts were informed in the survey questionnaire that the outcomes can be shared with them (Li et al., 2011). Due to resource constraints, it was difficult to produce different language versions of the questionnaire, so only an English version of the questionnaire was used for the survey based on the assumption that most of the selected experts could read, write, and understand English.

The survey collected 104 valid responses concerning GBTs application from GB experts around the world. Of these 104 responses, the majority (i.e., 33 responses) was received from the US. The current study is based on only the 33 responses from the US. These 33 responses were adequate compared with previous GB-related studies (e.g., 30 in Hwang and Ng (2013) and Zhoa et al. (2016), and 31 in Hwang and Tan (2012)). In the general construction management literature, with 25 experts, Mostaan and Ashuri (2016) determined and analyzed the major challenges and enablers for highway PPPs in the US. Moreover, as the central limit theorem holds true with a sample size higher than 30, statistical analysis could still be conducted (Ott and Longnecker, 2001; Ling et al., 2009).

The experts' profiles indicated that 13 (39.4%) of the experts were senior managers, 10 (30.3%) were directors/CEOs, and the remaining 10 (30.3%) held other positions, such as professor, project manager, sustainability advisor, and senior technologist, in their organizations. With the professional background of the experts, those who identified themselves as architects (12, 36.4%) and engineers (12, 36.4%) formed the majority, followed by town planners (3, 9.1%). Of the total number of 33 experts, 13 (39.4%) had more than 15 years of experience in GB, 7 (21.2%) had 11 to 15 years of experience, another 7 (21.2%) had 6 to 10 years of experience, and only 6 (18.2%) had 1 to 5 years of experience. Furthermore, all of the experts had been involved in activities related to adoption of GBTs before, with 25 (75.8%) of them having direct experience in GB projects.

In order to measure internal consistency among the various factors to assess the reliability of the five-point scales, Cronbach's alpha coefficient was used. The values of this study's tests were 0.912 (for barriers), 0.878 (for drivers), and 0.844 (for promotion strategies), which were all greater than the threshold of 0.7, indicating that the measurements using the five-point scales were reliable at the 5% significance level (Nunnally, 1978). Hence, the collected sample can be treated as a whole, and suitable for further ranking, *t*-test, and concordance analyses (Mao et al., 2015) in the following sections.

4.3. Data analysis

The mean score ranking technique has been widely used in previous GB-related studies to rank and determine the key factors among several individual factors (Manoliadis et al., 2006; Chan et al., 2009). It is a suitable method for testing the criticality and importance/significance of factors (Cheng and Li, 2002; Chan et al., 2003). There are papers that expound specific details about the method and its mathematical background (Holt, 1997; Ekanayake and Ofori, 2004). In this study, the mean score method is used to prioritize barriers, drivers, and promotion strategies of GBTs adoption, as perceived by the experts. Where two or more factors happen to have the same mean score, the factor with the lowest standard deviation (SD) was assigned the higher rank (Mao et al., 2015). The one-sample *t*-test was used to ascertain whether the mean score of each factor was significant or not (Zhao et al., 2016; Rahman, 2014).

The nonparametric test, Kendall's coefficient of concordance (also known as Kendall's *W*) is a coefficient index for ascertaining the overall agreement amongst sets of rankings (Chan et al., 2009). Before the statistical analyses, Kendall's concordance analysis was performed to check whether the experts were consistent or not in ranking the various factors in the survey questionnaire (Siegel and Castellan, 1988). The value of Kendall's *W* ranges from 0 to +1, where a value of 0 indicates "no agreement" within the group on the ranking of a particular set of factors, and +1 indicates "complete agreement". In this study, Kendall's *W*, W_{barriers}, W_{drivers}, and $W_{\text{promotion strategies}}$, were 0.269, 0.232, and 0.130, respectively (see Tables 4 to 6). It is recommended that, since the number of factors ranked in all cases were more than

7 (N > 7) and with large sample size (> 20), the significance of an observed W should be determined by referring to the approximate distribution of Chi-Square (X^2) with N-1 degrees of freedom (df) (Siegel and Castellan, 1988). In the present study, $X^2_{\text{barriers}} = 221.641$, df = 25; $X^2_{\text{drivers}} = 152.940$, df = 20; and $X^2_{\text{promotion strategies}} = 47.260$, df = 11, all of which have probability of occurrence under $p < 0.001$, indicating that there exists a good agreement among the experts regarding the rankings of the barriers to, drivers for, and strategies for promoting the adoption of GBTs.

5. Survey results

5.1. Ranking of barriers inhibiting the adoption of GBTs

The experts were requested to rate the criticality of 26 factors in hindering the adoption of GBTs. The results of the experts' perceptions are shown in Table 4. The t-test of the means indicates that 15 out of the 26 factors were considered significant or critical in GBTs implementation. The first, as ranked by the experts, is "resistance to change from the use of traditional technologies" (mean = 4.24), which is thus deemed as the most critical barrier inhibiting the adoption of GBTs in the US construction market. It is also noted that this is the only barrier with mean score above 4.00. "Lack of knowledge and awareness of GBTs and their benefits" and "higher costs of GBTs" have the same mean scores. However, the SD of "lack of knowledge and awareness of GBTs and their benefits" is 0.740, which is lower than that of "higher costs of GBTs," which is 1.166. Therefore, "lack of knowledge and awareness of GBTs and their benefits" (mean = 3.88, SD = 0.740) is ranked second, and "higher costs of GBTs" (mean = 3.88, SD = 1.166) is ranked as the third most critical barrier. The fourth- and fifth-ranked barriers are "lack of GB expertise/skilled labor" (mean = 3.73) and "lack of government incentives/supports for implementing GBTs" (mean = 3.67), respectively. It is interesting to note that "implementation of GBTs is time consuming and causes project delays" (mean = 2.55, rank 24) was ranked very low as a barrier to applying GBTs. This is in contrast with what has been previously reported by other researchers (Lam et al., 2009; Hwang and Ng, 2013; Shi et al., 2013), that time is a crucial barrier to the adoption of green innovations.

Table 4
Ranking of barriers inhibiting the adoption of GBTs, *t*-test, and test of concordance.

Code	Frequency of responses					Mean	SD	Rank	Significance[a]
	1	2	3	4	5				
b14	0	1	2	18	12	4.24	0.708	1	0.000
b04	0	2	5	21	5	3.88	0.740	2	0.000
b01	1	4	6	9	13	3.88	1.166	3	0.004
b03	0	3	6	21	3	3.73	0.761	4	0.000
b05	2	4	5	14	8	3.67	1.164	5	0.007
b22	2	3	6	17	5	3.61	1.059	6	0.002
b02	1	5	8	11	8	3.61	1.116	7	0.000
b18	0	6	10	12	5	3.48	0.972	8	0.002
b09	1	3	13	13	3	3.42	0.902	9	0.011
b12	1	5	13	8	6	3.39	1.059	10	0.040
b06	1	3	15	12	2	3.33	0.854	11	0.501*
b07	1	4	16	10	2	3.24	0.867	12	0.338*
b23	2	6	13	8	4	3.18	1.074	13	0.118*
b21	0	10	12	8	3	3.12	0.960	14	0.032
b11	2	8	8	14	1	3.12	1.023	15	0.474*
b25	3	7	9	11	3	3.12	1.139	16	0.545*
b15	2	11	6	9	5	3.12	1.219	17	0.609*
b17	1	9	12	8	3	3.09	1.011	18	0.572*
b10	4	6	12	7	4	3.03	1.185	19	0.521*
b19	1	8	18	5	1	2.91	0.805	20	0.013
b16	2	10	15	3	3	2.85	1.004	21	0.884*
b20	2	15	10	6	0	2.61	0.864	22	0.392*
b26	8	8	8	7	2	2.61	1.248	23	0.079*
b13	5	12	11	3	2	2.55	1.063	24	0.020
b24	8	8	12	4	1	2.45	1.092	25	0.007
b08	10	14	6	2	1	2.09	1.011	26	0.000
Kendall's *W*[b]						0.269			
Chi-Square						221.641			
df						25			
Level of significance						0.000			

Note: [a] '*' Data with insignificant results of one-sample t-test ($p > 0.05$) (2-tailed); [b] Kendall's Coefficient of Concordance test on the barriers among the experts.

5.2. Ranking of drivers for adopting GBTs

The experts were also asked to rank the major drivers for implementing GBTs. The results are summarized in Table 5. The significance levels from *t*-test analysis show that only one out of the 21 factors rated by the experts is insignificant. Moreover, the mean scores of all the factors are above 3.00 (the average of the rating scale). These results suggest that, overall, the factors considered in this study play important roles in driving the adoption of

GBTs in the construction industry. As shown in Table 5, “greater energy-efficiency” (mean = 4.64) is ranked first, suggesting that energy saving, along with reduced CO_2 emissions, was perceived as the prime reason for deciding to apply GBTs. The experts agreed that the second major driver is “greater water-efficiency” (mean = 4.33), followed by “company image and reputation/marketing strategy” (mean = 4.18), “improved occupants’ health, comfort, and satisfaction” (mean = 4.15), “reduced environmental impact” (mean = 4.12), “reduced whole lifecycle costs” (mean = 4.09), “attract premium clients/increased building value” (mean = 4.06), “better indoor environmental quality” (mean = 4.03), and “high rental returns and increased lettable space” (mean = 4.00). The least ranked driver is “efficiency in construction processes and management practices” (mean = 3.09).

Table 5
Ranking of drivers for adopting GBTs, *t*-test, and test of concordance.

Code	Frequency of responses					Mean	SD	Rank	Significance[a]
	1	2	3	4	5				
d02	0	0	0	12	21	4.64	0.489	1	0.000
d03	0	0	3	16	14	4.33	0.646	2	0.000
d08	0	0	5	17	11	4.18	0.683	3	0.000
d04	0	0	4	20	9	4.15	0.619	4	0.000
d06	0	1	7	12	13	4.12	0.857	5	0.000
d01	1	2	3	14	13	4.09	1.011	6	0.000
d12	0	0	7	17	9	4.06	0.704	7	0.000
d07	0	0	10	12	11	4.03	0.810	8	0.000
d11	0	0	9	15	9	4.00	0.750	9	0.000
d09	0	1	7	17	8	3.97	0.770	10	0.000
d05	0	4	8	10	11	3.85	1.034	11	0.000
d14	0	4	7	19	3	3.64	0.822	12	0.000
d17	0	3	11	14	5	3.64	0.859	13	0.000
d10	0	2	12	16	3	3.61	0.747	14	0.000
d18	0	6	5	19	3	3.58	0.902	15	0.001
d15	0	7	7	13	6	3.55	1.034	16	0.005
d19	0	6	10	11	6	3.52	1.004	17	0.006
d21	0	9	8	9	7	3.42	1.119	18	0.037
d13	0	6	11	13	3	3.39	0.899	19	0.017
d16	0	8	7	18	0	3.30	0.847	20	0.048
d20	0	8	14	11	0	3.09	0.765	21	0.501*
Kendall’s *W*[b]						0.232			
Chi-Square						152.940			
df						20			
Level of significance						0.000			

5.3. Ranking of strategies to promote GBTs adoption

Table 6 summarizes the results on the relative importance of strategies to promote the adoption of GBTs among construction stakeholders. First, a total of 12 promotion strategies were examined in the survey, and the *t*-test of the means indicates that all of the strategies had significant importance. The experts believed that the six most important strategies are "financial incentives and further market-based incentives" (mean = 4.30), "availability of better information on cost and benefits of GBTs" (mean = 4.21), "green labelling and information dissemination" (mean = 4.00), "mandatory GB codes and regulations" (mean = 3.97), "a strengthened GB technology research and education, and communication of new technologies" (mean = 3.88), and "educational programs for developers, contractors, and policy makers related to GBTs" (mean = 3.88).

Table 6
Ranking of strategies to promote GBTs adoption, *t*-test, and test of concordance.

	Frequency of responses								
Code	1	2	3	4	5	Mean	SD	Rank	Significance[a]
p01	0	1	1	18	13	4.30	0.684	1	0.000
p09	0	2	5	10	16	4.21	0.927	2	0.000
p03	0	2	7	13	11	4.00	0.901	3	0.000
p02	0	3	4	17	9	3.97	0.883	4	0.000
p12	0	1	7	20	5	3.88	0.696	5	0.000
p08	0	2	6	19	6	3.88	0.781	6	0.000
p05	0	5	9	9	10	3.73	1.069	7	0.000
p10	0	2	13	14	4	3.61	0.788	8	0.000
p07	0	5	8	15	5	3.61	0.933	9	0.001
p04	0	6	7	17	3	3.52	0.906	10	0.003
p11	0	4	13	11	5	3.52	0.906	10	0.003
p06	0	9	8	11	5	3.36	1.055	12	0.036
Kendall's W[b]						0.130			
Chi-Square						47.260			
df						11			
Level of significance						0.000			

6. Findings and discussion

GB represents a comprehensive mission in the construction industry that incorporates the accomplishment of environmental stewardship, social responsibility, and economic prosperity. To help accelerate the adoption of GBTs, this study identifies and examines the major barriers, drivers, and promotion strategies of GBTs adoption by analyzing the professional views of GB experts from the US. The ranking of these issues would enable stakeholders, especially policy makers, to understand key areas wherein future GB/policy initiatives are necessary to encourage wider uptake of GBTs. The following sections discuss the findings of the study. In this study, the promotion strategies work alongside the drivers to overcome the barriers. This study uses a pathway to examine the adoption activity, starting with the barriers and finally arriving at the promotion strategies, which is a more useful way to better understand the variety of issues influencing GBTs adoption than analyzing the issues individually (Aktas and Ozorhon, 2015). Due to the space/word limitation, the following discussions give priority to the top-ranked factors in the results highlighted in the previous sections. The findings are also compared with the findings reported in the broad literature concerning the adoption of green innovations.

6.1. Barriers

There remain barriers to the successful and widespread adoption of GBTs in the US. The survey results indicate that ‘resistance to change from the use of traditional technologies’ (ranked first) was perceived to be the most critical barrier. This finding is consistent with the previous study by Du et al. (2014) concerning the adoption of energy-saving technologies in the Chinese construction industry. Resistance from stakeholders can be detrimental to the ultimate success of GBTs implementation. By nature, human beings are resistant to change, and this can be particularly true in the construction industry wherein liability is a serious issue (DuBose et al., 2007). The US construction industry is often known to be an innovation laggard. Due to its size, fragmentation, diversity, and low investments in research and demonstration, the construction industry is characterized by relatively slow rates of innovation (USGBC, 2003). Whether due to exogenous or endogenous risks, construction firms in the US have traditionally resisted innovation (Sanderford et al., 2014). These issues may explain why resistance to change is considered the most critical barrier inhibiting the adoption of GBTs in the US. Besides, it is true that it is difficult to persuade stakeholders who are accustomed to traditional technologies to change their mindsets, attitudes, and behaviors to use GBTs.

As a critical barrier to implementing GBTs in the US, 'lack of knowledge and awareness of GBTs and their benefits' occupied the second position. The high rank of this barrier supports the findings of previous research that lack of knowledge and understanding from stakeholders, such as contractors, subcontractors, clients, and structural engineers, is a major barrier to the adoption of green innovations in the US (Ahn et al., 2013; Rodriguez-Nikl et al., 2015). Bayraktar and Arif (2013) observed that there were no efforts in the US to create awareness programs that specifically target GBTs market opportunities among stakeholders. In practice, non-green thinking still prevails. While GBTs are increasingly capturing the attention of the construction industry, many stakeholders remain unaware of the wide-ranging benefits associated with them. The accumulation and sharing of knowledge is crucial to drive the sustainability agenda in the construction industry (Chong et al., 2009; Love et al., 2012). Therefore, a lack of knowledge and awareness of GBTs cannot provide sufficient confidence to encourage most construction stakeholders to adopt GBTs.

As expected, 'higher costs of GBTs' was ranked high amongst the barriers to implementing GBTs in the US; it was ranked as the third most critical barrier by the experts. The high criticality of cost in inhibiting the widespread adoption of GBTs is supported by the literature (Zhang et al., 2011a, b). Although many GBs can be built at comparable or even lower cost than non-GBs (Kats, 2003), GB demands the use and integration of new and innovative green technologies that usually cost more than their non-green counterparts, making stakeholders hesitant to implement them. The use of GBTs can increase project cost by 2-7% (USGBC, 2003). In the construction industry, almost every stakeholder shows concern about cost in the first instance when considering the application of new technologies and new norms (Shi et al., 2013), which is a very obvious barrier in the field of green technology. The lack of knowledge and understanding of the real costs and benefits of GBTs might be one of the key issues exaggerating the concern about cost.

Another critical barrier is the 'lack of GB expertise/skilled labor' (ranked fourth), resulting from a shortage of GB education and training efforts in the construction sector. On the basis of this finding, it can be stated that the number of stakeholders who have expertise in GBTs in the US is limited. The finding agrees with the literature that lack of technical knowhow is a barrier to the implementation of green innovations (Tagaza and Wilson, 2004; Williams and Dair, 2007). Because of the complex nature of most GBTs, insufficient technical knowledge and expertise in them would greatly hinder their successful implementation and development. Li et al. (2014b) pointed out that GB knowledge and experience is the most important organizational factor to implement GBTs on construction projects. Hence, more technically competent stakeholders who are experienced and well versed with currently available GBTs are needed to move forward with the application of GBTs in the US.

The fifth ranked barrier was 'lack of government incentives/supports for implementing GBTs', which provides evidence that this barrier was emphasized by the experts, as they see insufficient support for the development of GBTs in the US. Lack of government incentives is reported as a major barrier to the implementation of green innovations in other studies as well (Love et al., 2012; Zhang et al., 2012). Stakeholders would like to see policy makers' and advocates' direct intervention in the GBTs market in the form of more effective incentives to support their implementation of GBTs. Reasonable incentives can motivate market stakeholders to pursue GBTs. In the US, some states and local governments provide incentives, such as tax credit, expedited permits, and density bonus, to encourage the adoption of GBTs among construction stakeholders. These states and local governments have tried to prove that even modest incentives can stimulate market interest in GBTs by offsetting the higher cost (USGBC, 2003). However, if stakeholders cannot receive sufficient government support, then it would be difficult for them to bear the higher costs of GBTs. Without sufficient government support, the expected economies of scale in GBTs are difficult to achieve in the current market mechanism.

An interesting finding is that the experts did not perceive 'implementation of GBTs is time consuming and causes project delays' (rank 24) as a highly critical barrier to implementing GBTs, which did not concur with previous studies, as indicated earlier. It was expected that time would receive higher criticality amongst the GBTs adoption barriers, because, for example, it is known that since most current GBTs have yet to be perfected, their implementation usually causes problems that lead to project delays (Hwang and Ng, 2013). Moreover, the consideration of GBTs could cause project delays, as more time is often needed to effectively incorporate all necessary technologies into the green design. This usually means more involvement, communication, and interactions between different groups of stakeholders with the requisite knowledge and experience, which could also delay the project. However, one possible reason why the time-related barrier was ranked very low may be that integrated design process which allows enough time for feedbacks and revisions on GB projects (Yudelson, 2009b) helps ensure that sufficient time is allocated for the green project so that GBTs could be implemented within project schedule, thus making the schedule delay or time overrun problem decrease in criticality.

6.2. Drivers

Despite the existence of barriers in the implementation of GBTs, stakeholders have several reasons for deciding to use GBTs. 'Greater energy-efficiency' was the highest ranked driver for applying GBTs. This result agrees with that of previous studies on sustainable construction drivers by Augenbroe and Pearce (2009) and Ahn et al. (2013) in the US, and

Manoliadis et al. (2006) in Greece. The finding also agrees with other researchers (Windapo, 2014; Brotman, 2016), who found that rising energy costs is the most important driving force behind green innovations implementation. Energy efficiency is indeed a high-priority in many developed countries (Pacheco et al., 2012). In the US, the Department of Energy (DOE) is one of the well-known government agencies established to ensure the country's prosperity and security by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions (US DOE, 2016). The US DOE believes that energy efficiency is one of the easiest and most cost effective ways to mitigate climate change, improve the competitiveness of businesses, improve air quality, and reduce energy costs. As buildings account for a significant amount of energy use, improving building energy efficiency is a critical effort to dramatically reduce unstainable energy needs. This study suggests that stakeholders place value on the application of GBTs, because it helps them achieve high energy-efficient buildings. Today, stakeholders are seeking ways to reduce their energy-related expenditures, recognizing that innovative solutions can reduce energy use by 25 to 40% (Vanderpool, 2011). Love et al. (2012) established that the most notable benefit from implementing GBTs is a reduction in energy consumption. Savings in energy costs of 20-50% are common through the utilization of energy-saving technologies, natural daylight and ventilation, renewable energy technologies, and light-reflective materials (USGBC, 2003), which means that stakeholders could reduce their utility bills and thus save money over a GB's lifecycle. It is true that such an economic benefit can substantially increase the motivation of stakeholders to take part in GBTs implementation, because economic benefits are the most essential issues for the business survival of every stakeholder (Chan et al., 2009).

GBs are commonly known to have reduced whole lifecycle cost. This reduced lifecycle cost can be attributed to savings on water and energy, typically 30 to 50% (Yudelson, 2008), made possible through proper integration and performance of innovative green technologies. Therefore, just after greater energy-efficiency, 'greater water-efficiency' was ranked by the experts as the second major driver for implementing GBTs. GBTs such as permeable surface technology, water reuse and water-saving appliances minimize impacts on water quality to gain water efficiency (Zhang et al., 2011a).

The results of this study provide evidence that the third major driving force behind the adoption of GBTs is 'company image and reputation/marketing strategy'. This finding has been supported by the literature (Andelin et al., 2015; Zhang et al., 2015). In this modern competitive business environment, establishing a good image and reputation has become crucial for companies' survival. This study suggests that construction stakeholders see the adoption of GBTs as a wise decision to enhance their reputation and gain competitive advantages such as market differentiation. Employing GBTs could improve the public reputation and image of stakeholders, because it is a helpful way to develop GBs that contribute to improving public health. The good public reputation and image can translate into marketing benefits for the company adopting GBTs, especially when customers demand for green living environments and energy-efficient buildings. Thus, companies that build green can attract high-income buyers with higher sales price (Zhang et al., 2011b). Therefore, as most stakeholders, e.g., developers, act as "rational economic men" who pursue profit (Mao et al., 2015), GBTs could be attractive to them.

As ranked by the experts, other highly ranked motivations for engaging in the implementation of GBTs include 'improved occupants' health, comfort, and satisfaction', 'reduced environmental impact', 'reduced whole lifecycle costs', 'attract premium clients/increased building value', 'better indoor environmental quality', and 'high rental returns and increased lettable space', all of which are commonly known benefits associated with GB and it is comforting to note that the industry appreciate that they could help drive the adoption of GBTs. Advocates should take time to come up with strategies to widely promote these drivers in society in order to influence the interest people have in GBTs.

'Efficiency in construction processes and management practices' was ranked as the least important driver for adopting GBTs. This may be because the adoption of GBTs may not automatically improve the efficiency of the construction process; other management approaches may be required for process efficiency.

6.3. Promotion strategies

Various strategies are required to overcome the barriers affecting the adoption of GBTs, for successful and widespread adoption. This study has explored the most important strategies to promote the adoption of GBTs. The GB experts from the US perceived 'financial incentives and further market-based incentives' as the most important promotion strategy. This result agrees with Mulligan et al. (2014), who found that increased incentives was the greatest opportunity to increase the adoption of GB in the US. Incentive schemes are measures to promote green innovations and increase the motivation of stakeholders to meet higher standards (Qian et al., 2016). Financial and further market-based incentives are of great importance to GBTs adoption promotion, because of the compensation they provide to stakeholders who implement GBTs. Thus, as an economic support, incentives provided by local governments or financial institutions serve to compensate stakeholders for the additional cost and/or efforts that may be required to incorporate GBTs into their projects. Such an economic support can greatly influence GB project funding (Zhang, 2015) and thus can have a significant impact on the development of GBTs in a country. Given that most stakeholders are mainly concerned with profit, the higher costs of GBTs present a considerable loss of money. Therefore, cost reduction strategies or strategies to reduce cost burden for stakeholders could accelerate the adoption of GBTs. As cost is one of the main reasons for stakeholders to be reluctant to innovate, the provision of more attractive and encouraging incentives could not only be a solution to the lack of incentives and higher cost barriers, but also to the resistance to change which has become the most critical barrier to the adoption of GBTs (see Table 4). The government and other public policy makers should pay a more careful attention to incentive programs in GBTs adoption promotion. The findings of this study suggest that the related incentives, allowances, and tax credits can stimulate demand for GBTs, but to speed up the adoption process, the government needs to reinforce incentive policies. More incentive schemes could be provided in every state to create a more supportive environment for GBTs implementation to flourish. Such incentives should apply to both residential and commercial markets and to all groups of stakeholders who patronize GBTs, ranging from developers to customers or tenants. If this is not taken into consideration, then widespread adoption of GBTs would remain a challenge.

The second rank of 'availability of better information on cost and benefits of GBTs' implies that the experts attached great importance to this promotion strategy, as information is essential for the acquisition of relevant knowledge and for the creation of public awareness and acceptance (Rogers, 2003). According to Potbhare et al. (2009), availability of better information on cost and benefits of GB guidelines was the most important strategy to catalyze the adoption of GB guidelines in India. In the construction industry, stakeholders who have easy access to information are keener on adopting energy-efficient technologies (Pinkse and Dommissse, 2009). This study confirms that the provision of relevant information concerning GBTs and their benefits to the public is crucial to create market demand. In the US, although information regarding GBTs exists within some states and local governments and federal agencies, it is often difficult to find. To catalyze the adoption of GBTs, advocates can develop stronger advertising and communication strategies that make good and maximum use of available research studies, fact sheets, and documentations demonstrating the 'big picture' benefits of GBTs. GBTs information should be disseminated more widely and released in ways that are readily accessible and helpful. A comprehensive national database of GBTs and their benefits would be valuable for promoting GBTs adoption. An increased public awareness of the sustainability benefits of GBTs could help stakeholders overcome the concern about cost and be more willing to adopt GBTs.

'Green labelling and information dissemination' was ranked as the third most important strategy to further the application of GBTs in the US. This reinforces the argument of Qian and Chan (2007, 2010) that green labelling and information dissemination is an essential government measure to promote building energy-efficiency/GB. Aktas and Ozorhon (2015) asserts that it is nearly impossible for stakeholders to successfully implement green innovations without any guidance or support. They believe that a local rating system could help overcome this problem. Today, there are many GB rating systems and labelling programs in the US that provide useful information on GB to the public, including systems at the national, regional, and state levels, such as LEED, ENERGY STAR, Green Seal, and Green Globes. These rating systems have been instrumental in mainstreaming GB development, and the experts agreed that they are important to promote the adoption of GBTs. Sustainability in the construction industry is often measured by the level of, for instance, LEED certification issued by the USGBC. Hence, much of the popularity gained by GBTs in the US can be credited to the introduction of the GB concept by the USGBC through its LEED rating system in 1993 (Karakhan, 2016). Since its introduction, the LEED rating system has been applied increasingly on public and private projects nationally and internationally. One advantage of LEED is that it creates a brand that is attractive to stakeholders, helping make GBTs more attractive (Rodriguez-Nikl et al., 2015). Although the LEED program is a voluntary rating system, some states, local jurisdictions, and federals mandate its application on projects they fund. This mandate may explain the relatively high concentration of GBTs application in states like Washington (Center for Construction

Research and Training (CPWR), 2013). Therefore, mandating the use of LEED on more public and private projects would increase the rate of adoption of GBTs.

Having an efficient legal framework is a key factor in successful GBTs implementation. Gann and Salter (2000) argued that government regulatory policies have strong influence on demand and on the direction of technological innovations. Endorsement of a GBT by the government can accelerate its maturity in a country. Even though the high rank of 'mandatory GB codes and regulations' (ranked fourth) clearly shows that mandatory government policies play a crucial role in promoting the implementation of GBTs, it is surprising to find that this promotion strategy which forces GBTs adoption was not ranked as the most important strategy to promote GBTs adoption in the US. One possible explanation for this is that the respondents may have been GB experts who showed more concern about financial support (economic issue). This result is not consistent with Chan et al. (2009), who claimed that mandatory government regulation is the most essential means to promote the GB market. The study provides evidence that governmental initiatives in the form of policies and regulations are important to drive stakeholders to take relevant actions for GBTs adoption. In the US, while the federal government has played a critical role in promoting green innovations, much of the push for green innovations comes from state legislatures. Legislators from states around the US have considered using mandatory policies and regulation to promote green innovations. In the state of Michigan, for example, Mulligan et al. (2014) have recognized some of the recent GB policies. Korkmaz (2007) found that strict local codes and regulations are playing important roles in promoting green innovations in states like Washington and California. To further the use of GBTs, the government should regularly monitor, assess, and strengthen state policies to maximize their effectiveness at promoting GBTs implementation.

The results of this study also indicate that 'a strengthened GB technology research and education, and communication of new technologies' and 'educational programs for developers, contractors, and policy makers related to GBTs' are the fifth and sixth important strategies to promote the adoption of GBTs, respectively. These results suggest that greater GBTs research, education, and training efforts are pivotal for continuous promotion of GBTs adoption in the US. Increasing funding for GBTs research would help to further promote the adoption of GBTs. To help solve the high cost problem, robust scientific researches and analyses – based on lifecycle costing – can be conducted to quantify the real costs of and benefits resulting from implementing GBTs. Comprehensive and accurate economic tools can be adopted to assist this quantification, which should be capable of educating stakeholders to better comprehend the concept of 'total cost of ownership' over the lifecycle of a building and convince them that, although the initial investment may be high, investing in GBTs is a good and fruitful business practice. The presence of GBTs education and training champions who could help build the knowledge of stakeholders on current GBTs on the market, their system performance, and benefits can also catalyze the adoption of GBTs.

7. Conclusions and future research

It is projected that the adoption of GBTs in the construction industry will continue to grow in the future. This study investigates the major issues influencing the adoption of GBTs from the perspectives of US GB experts. Thus, given the limited empirical studies on issues influencing GBTs adoption, the present study contributes to the body of knowledge by identifying the issues that are primary for the US GBTs market stakeholders. It is concluded that several issues influence and shape GBTs implementation. A wide range of barriers, drivers, and promotion strategies of GBTs adoption were identified and examined by using a combination of research methods, including literature review and a questionnaire survey. The issues influencing GBTs adoption were further analyzed by using ranking technique, thus providing a clear understanding of the key issues that are worthwhile to pay more attention to in GBTs adoption promotion efforts.

This study examined 26 barriers, 21 drivers, and 12 promotion strategies from the perspectives of GB experts. 15 out of the 26 barriers were recognized as critical barriers to the use of GBTs, with the most critical barrier being resistance to change from the use of traditional technologies, followed by a lack of knowledge and awareness of GBTs and their benefits, and higher costs of GBTs. With respect to the GBTs adoption drivers, 20 out of the 21 drivers were recognized as significant drivers, with the top three drivers being greater energy-efficiency, greater water-efficiency, and company image and reputation/marketing strategy. All of the 12 promotion strategies of GBTs adoption were recognized as significantly important strategies, with the most important strategy being providing financial and further market-based incentives, followed by availability of better information on cost and benefits of GBTs, and green labelling and information dissemination. The results of this study display a consensus of rankings amongst the GB experts, as verified by the Kendall's coefficient of concordance. While the identified barriers were cited in this study as barriers that inhibit the implementation of GBTs, most of them could be offset or otherwise overcome by taking advantage of the identified drivers and promotion strategies.

This study's results are expected to contribute information valuable for policy-making in the construction industry and in the implementation of GBTs in the future. The findings contribute to deepened understanding of the major issues that influence GBTs implementation. The results are relevant for the US GBTs market, but might also be useful for policy makers in other countries. Moreover, foreign entities attempting to develop GBs and thus use GBTs in the US could learn lessons from the opinions of local GB experts who have had some years of experience in the adoption of GBTs.

There are some limitations of this study that warrant future research attention. First, although the sample size was adequate to conduct statistical analysis, it is appreciated that it is nevertheless a relatively small sample. Future research is required to employ a larger sample to see whether the results would differ from what have been reported in this paper. Second, future research could use more advanced statistical analysis techniques, e.g., structural equation modelling, to verify the exact influences of the specific factors on the adoption of GBTs. Lastly, future study could compare the views of GB experts from different countries on the GBTs adoption issues to observe market-specific differences.

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Highlights

- Critical barriers inhibiting green building technologies adoption are investigated.
- Major drivers for adopting green building technologies are investigated.
- Important strategies to promote green building technologies adoption are investigated.