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Critical Barriers to Green Building Technologies Adoption in Developing Countries: The Case of Ghana

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Abstract

Although green building technologies (GBTs) have been advocated in the construction industry to address sustainability issues, their adoption is still plagued with barriers. The barriers that hinder GBTs adoption need detailed investigation. However, few studies have been conducted on the barriers to GBTs adoption in developing countries such as Ghana. This study aims to investigate the critical barriers to GBTs adoption with reference to the Ghanaian construction market. To achieve the objective, 26 barriers were identified from a comprehensive literature review, and a questionnaire survey was performed with 43 professionals with green building experience. The ranking analysis results indicated that 20 barriers were critical. The top three most critical barriers were higher costs of GBTs, lack of government incentives, and lack of financing schemes (e.g., bank loans). A comparative analysis showed that while the most critical barriers to GBTs adoption in the developing

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country of Ghana mostly vary from those in the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all the countries. Furthermore, factor analysis revealed that the underlying grouped barriers for the 20 critical barriers were government-related, human-related, knowledge and information-related, market-related, and cost and risk-related barriers. This study also showed that the most dominant of the five underlying groups was government-related barriers, which highlights the government's role in promoting GBTs adoption in Ghana. This study adds to the green building literature by analyzing GBTs adoption barriers within the context of a developing country, which could help policy makers and practitioners take suitable measures to mitigate the barriers and thereby promote the GBTs adoption. Future research will investigate the interrelationships between the critical barriers and their impacts on the GBTs adoption activity.

Keywords: Green building technologies; Barriers; Construction market; Sustainability; Developing countries; Ghana.

1. Introduction

It is widely accepted that the construction industry has harmful impacts on the environment, economy, and society. The construction industry consumes up to 40% of the total energy and accounts for up to 30% of the total annual greenhouse gas emissions at the global level (United Nations Environment Programme (UNEP), 2011). The construction industry is also considered a resource-intensive industry that consumes about 70% of the cement products and 25% of the steel products in many countries (Wang and Zhang, 2008). Due to a growing public concern about these impacts nowadays, much attention has been paid to implementing sustainability or sustainable development within the construction industry. According to the World Commission on Environment and Development (WCED) (1987), "sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development has three dimensions, i.e., environmental, economic, and social sustainability. Green building has been well received by governments around the world as a strategy for improving the sustainability of the construction industry (Shen et al., 2017a).

Green building is considered “the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s lifecycle” (US Environmental Protection Agency (USEPA), 2016). It has been viewed as an effective alternative to traditional building, which has a significant role in reducing or eliminating the negative impacts of construction activities on the environment and climate change (Hwang et al., 2016; World Green Building Council (WorldGBC), 2017a). However, green building is not achievable without the adoption of green building technologies (GBTs). In this study, GBTs are defined as technologies that are incorporated into building design and construction to make the end product sustainable (Ahmad et al., 2016). Several GBTs, such as green roof technology, solar technology, and prefabricated concrete technology, have been introduced for developing green projects. Adopting these GBTs offers a range of significant sustainability benefits that are not likely to be derived from adopting traditional building technologies. It was reported by the UNEP (2009) that with the adoption of appropriate GBTs, a 30-80% cut in building energy consumption is attainable. Moreover, numerous researchers and organizations have indicated that GBTs adoption provides several other environmental, economic, and social benefits, such as increased water efficiency, improved productivity, enhanced human health and wellbeing, improved indoor environmental quality, and higher property value (WorldGBC, 2017b; Darko et al., 2017a, b).

Because of these sustainability benefits, over the last two decades, the promotion of GBTs adoption has been of great importance to many countries. However, GBTs adoption is not free of barriers and challenges. What are the barriers hindering the adoption of GBTs in the construction market? For an effective and efficient promotion of GBTs adoption, it is essential that the barriers to adoption are first recognized and addressed (Mao et al., 2015). Hence, a lot of research on barriers to GBTs and practices adoption has been done (Lam et al., 2009, Hwang and Tan, 2012; Shen et al., 2017b). However, few have attempted to analyze barriers to GBTs adoption in developing countries. As identified by a recent critical analysis of green building research (Darko and Chan, 2016a), there is a gap in the literature in terms of green building barriers studies in developing countries. This knowledge gap needs to be bridged, particularly because a better understanding of barriers is necessary for formulating proper strategies to overcome the barriers (Chan et al., 2016). This is especially important in developing countries, such as Ghana, where green building is fairly new to the construction market. Additionally, the criticalities of GBTs adoption barriers should be analyzed in various levels of detail.

Given the above background, the objective of this study is to investigate the critical barriers to GBTs adoption in the construction market with reference to the developing country of Ghana. The findings of this study not only contribute to filling the gap in knowledge concerning green building barriers in developing countries, but also provide valuable reference for helping policy makers and practitioners take suitable measures to mitigate the GBTs adoption barriers and consequently promote GBTs adoption. Moreover, this study would be useful and helpful for international organizations and advocates interested in promoting GBTs adoption in Ghana to ultimately achieve more sustainable building developments. The remainder of this paper is organized into the following five sections: section 2 reviews literature on the topic; section 3 provides detailed description of the research methodology; section 4 presents the survey results; section 5 discusses the results; and section 6 concludes the study.

2. Literature review

The many barriers hindering the adoption of GBTs and practices in construction have been investigated by a number of green building researchers and practitioners. Prior studies have shown that barriers to GBTs and practices adoption exist in both developed and developing countries. In terms of developed countries, Ahn et al. (2013) identified the top five barriers to green building in the US: first cost premium, long payback periods, tendency to maintain current practices, limited subcontractors' knowledge and skills, and higher costs of green products and materials. Chan et al. (2016) found resistance to change, higher costs of GBTs, lack of knowledge and awareness, lack of expertise, and lack of government incentives as the most critical barriers affecting GBTs adoption in the US. There are several other US studies on the barriers to green building development (Meryman and Silman, 2004; Mulligan et al., 2014; Rodriguez-Nikl et al., 2015; Darko et al., 2017c).

Hwang and Tang (2012) and Hwang and Ng (2013) studied the barriers faced during green building projects management in Singapore. They identified the following as crucial barriers: higher costs of green equipment and materials, lack of interest and communication amongst project team members, lack of research, lack of interest from clients and market demand, lengthy preconstruction process, and uncertainty with green equipment and materials. Hwang et al. (2017) identified that higher initial costs and lack of government support were two of the top three barriers to green business parks adoption in Singapore. Ofori and Kien (2004) also pointed out that higher cost was a key barrier to green building in Singapore.

In Kong Hong, Lam et al. (2009) showed that extra costs and delays caused by green requirements, limited availability of reliable green suppliers, and limited knowledge were the most dominant barriers to integrating green specifications in construction. Lack of government incentives and promotion and high maintenance costs were identified by Zhang et al. (2012) as the top barriers to adopting extensive green roof systems in Hong Kong. Other researchers who carried out studies to investigate the green building barriers in Hong Kong include Gou et al. (2013) and Qian et al. (2015). As for Chan et al. (2009), they surveyed the views of designers from both Singapore and Hong Kong and indicated that higher upfront costs, lack of education, lack of incentives, and lack of awareness were the most important barriers to green building.

Bond (2011) showed that cost and lack of information were major barriers to green building in Australia and New Zealand. Love et al. (2012) identified lack of government incentives, lack of knowledge and experience, lack of building codes and regulations, and poor relationship between stakeholders as the main barriers to implementing GBTs in Australia. Tagaza and Wilson (2004) also highlighted the major barriers to green building in Australia: higher costs of green materials, risks and uncertainties involved, unfamiliarity with GBTs, lengthy GBTs implementation time, and lengthy planning and approval process for new GBTs within a firm.

Williams and Dair (2007) presented twelve barriers to sustainable building in England, five of which were cost, lack of demand from clients, unavailability of sustainable materials and products, lack of information and awareness, and inadequate expertise. Winston (2010) found that inadequate building regulations and limited knowledge and expertise were barriers that hinder sustainable housing development in Ireland. There are other studies in the literature that primarily focused on green building barriers within the context of developed countries such as Sweden (Persson and Grönkvist, 2015), Brazil (Kasai and Jabbour, 2014), and Finland (Häkkinen and Belloni, 2011).

Regarding green building barriers studies in developing countries, Bin Esa et al. (2011), Zainul Abidin et al. (2012, 2013), Samari et al. (2013), and Yusof and Jamaludin (2014) all focused specifically on Malaysia. Also, all of these studies: Zhang et al. (2011a, b, c), Shi et al. (2013), Zhang and Wang (2013), Du et al. (2014), Mao et al. (2015), and Shen et al.

(2017b) focused specifically on China. Major barriers identified by the Malaysian and Chinese studies included, but not limited to, lack of knowledge and expertise, lack of market demand, lack of green building codes and regulations, lack of incentives, and lack of databases and information. Other green building barriers studies conducted within the context of developing countries are the studies of Potbhare et al. (2009) and Luthra et al. (2015) in India, Aktas and Ozorhon (2015) in Turkey, and Djokoto et al. (2014) in Ghana.

The above literature review identifies that except China and Malaysia, developing countries have seen very few studies identifying the barriers to GBTs and practices adoption. As different regulations and conditions exist in different countries, it is necessary to better understand the barriers facing GBTs adoption in specific countries (Aktas and Ozorhon, 2015). That will help in efforts to address the barriers and promote the adoption of GBTs. However, comprehensive investigations and surveys on the barriers inhibiting the adoption of GBTs in Ghana are scarce. The related study by Djokoto et al. (2014) was limited to the viewpoint of consultants on the barriers to sustainable construction in general. Therefore, a comprehensive analysis of the GBTs adoption barriers in Ghana combining the views of different stakeholders is worthwhile.

3. Research methodology

3.1. Identification of barriers to GBTs adoption

Previous studies (Lam et al., 2009; Zhang et al., 2011a, b) have reported that several barriers hindered GBTs and practices adoption in the construction industry. After a thorough review of these studies, 26 potential barriers to GBTs adoption were identified in this study, as listed in Table 1. This is a list of factors that are well documented in previous research and therefore are more applicable. For example, cost, lack of information, and lack of awareness are commonly acknowledged in the literature as crucial barriers to the adoption of GBTs and practices. Thus, the identification of the set of 26 potential barriers focused mainly on factors that have received considerable attention in previous studies conducted in different countries and contexts. Rowlinson (1988) argued that it is more appropriate to use well-known factors for a research study, as that would allow respondents to respond easily.

<Insert Table 1 about here>

3.2. Data collection

The questionnaire survey is a systematic technique of data collection based on a sample (Tan, 2011). It has been extensively used to solicit professional opinions in green building research (Wong et al., 2016; Shen et al., 2016). In this study, to investigate the criticalities of various barriers to GBTs adoption, a questionnaire survey was carried out. Thus, the research reported in this paper is a quantitative research (Creswell, 2014). The development of the questionnaire was supported by the comprehensive literature review. Prior to the questionnaire survey, a two-step procedure was followed to assess the appropriateness and rationality of the questionnaire. First, the questionnaire was reviewed by an international expert (a professor who had over 10 years of experience in green building) on question construction, ensuring that ambiguous expressions were not contained in the survey and that appropriate technical terms were used. Second, interviews were conducted with four professionals who had several years' experience in the local construction industry and possessed relevant experience in green building. They were requested to assess whether the questionnaire covered all potential barriers, considering the background of GBTs adoption in the Ghanaian construction market, and whether any factors could be added to, or removed from the survey. Based on the feedback, the questionnaire was finalized. In the finalized questionnaire, the objectives of the research and contact details were first presented, followed by questions meant to gather background information of the respondents. Afterward, the respondents were asked to rate the criticalities of the 26 barriers in GBTs adoption using a five-point Likert scale (1 = not critical, 2 = less critical, 3 = neutral, 4 = critical, and 5 = very critical). To have a better understanding of the survey, a sample of the survey questionnaire is provided in Appendix A; however, due to the space/word limitation, the section on background information of respondents is excluded.

The population comprised all industry practitioners with knowledge and understanding of GBTs use in Ghana. Since there was no sampling frame for this study, the sample was a nonprobability sample (Zhao et al., 2014). The nonprobability sampling technique can be utilized to acquire a representative sample (Patton, 2001). It is appropriate when a completely random sampling method cannot be used to select respondents from the whole population, but the respondents can rather be selected on the basis of their willingness to partake in the research (Wilkins, 2011). Thus, a snowball sampling method was used in this study to obtain a valid and effective overall sample size. The snowball method was also used in previous construction management studies (Zhang et al., 2011b; Mao et al., 2015), and it allows the gathering and sharing of information and respondents through referral or social networks. Local companies that have been directly involved in the construction of green buildings in Ghana were approached to identify the initial respondents. In the Ghanaian context, this study defines green buildings as buildings that have either obtained the South Africa's Green Star certification or the US's Leadership in Energy and Environmental Design (LEED) certification. The initially identified respondents were asked to share information regarding other knowledgeable participants. Using this approach, a total of 96 survey questionnaires were administered to collect responses from contractor, consultant, and developer companies. Finally, 43 sets of questionnaires with valid responses were returned, yielding a 44.8% response rate. Although the sample size was relatively small, statistical analyses could still be performed because according to the commonly accepted rule, with a sample size of 30 or above, the central limit theorem holds true (Ott and Longnecker, 2010; Hwang et al., 2015).

Moreover, because GBTs have not been widely adopted in the construction market of Ghana, it is difficult to obtain a very large sample of experienced professionals.

The profiles of the respondents are shown in Table 2. The respondents consisted of 13 engineers, 11 quantity surveyors, 9 architects, 9 project managers, and 1 contracts manager, among which 16, 14, and 13 respondents were from consultant, contractor, and developer companies, respectively.

<Insert Table 2 about here>

3.3. Data analysis techniques

3.3.1. Cronbach's alpha technique

One of the most popular methods for assessing the reliability of scales is Cronbach's alpha method. Cronbach's alpha determines the average correlation or internal consistency among factors in a survey questionnaire to assess the questionnaire's reliability. The Cronbach's alpha coefficient (α) value ranges from 0 to 1 and can be used in describing the reliability of factors extracted from multipoint and/or dichotomous formatted scales or questionnaires (Santos, 1999). The higher the α value, the more reliable is the adopted scale of measurement. However, the general rule is that to conclude that the scale is reliable, the α value must not be less than 0.70 (Nunnally, 1978). Using the SPSS 20.0 statistical software, the computed α value for the 26 GBTs adoption barriers was 0.867, indicating that the measurement using the five-point Likert scale was reliable at the 5% level of significance. The collected sample can, therefore, be treated as a whole and thus suitable for further ranking analysis as well as factor analysis (FA) in the following sections (Mao et al., 2015).

3.3.2. Mean score ranking technique

As a typical quantitative analysis method for ranking the relative importance/criticality of factors (Cheng and Li, 2002; Chan et al., 2010), the mean score ranking technique (MS) was used in previous green building studies (Darko et al., 2017b, c). In this study, the MS was used to determine the relative ranking of the 26 GBTs adoption barriers in descending order of criticality, as perceived by the respondents. If two or more barriers happened to have the same mean score, the barrier with the lowest standard deviation (SD) was assigned the highest rank. The normalized values of the mean scores were then calculated to identify the critical barriers among the 26 GBTs adoption barriers (Xu et al., 2010; Zhao et al., 2014).

3.3.3. Agreement analysis techniques

Kendall's coefficient of concordance (Kendall's *W*) is a nonparametric test commonly used to ascertain the overall agreement among sets of rankings (Siegel and Castellan, 1988). This method does not require any specific distribution of the tested data (Lam et al., 2015). As such, Kendall's *W* test was conducted to check whether different respondents within a certain group agreed on the ranking of the barriers. The null hypothesis of the Kendall's *W* test is that "there is no agreement among the rankings given by the respondents". Kendall's *W* ranges in value from 0 to 1, where a value of 0 indicates "no agreement" and 1 indicates "complete agreement". If the Kendall's *W* value generated from the test is at a low significance (significance level $\leq$ 0.001), then the null hypothesis can be rejected, and conclusion that some degree of agreement exists among the respondents can be drawn (Siegel and Castellan, 1988). In addition to the Kendall's *W* test, as the respondents were from different companies (consultant, contractor, and developer companies), it was important to check whether significant differences exist among respondents from different companies. To this end, analysis of variance (ANOVA) test was performed to determine whether the differences in mean scores from the three respondent groups according to company type were statistically significant. ANOVA is a widely used method that is suitable for comparing the mean scores from three or more groups (Pallant, 2011, Chan et al., 2016).

3.3.4. Factor analysis technique

FA was used to identify the underlying grouped barriers for the critical GBTs adoption barriers identified in this study. FA is a statistical method whose purpose is to identify a relatively small number of factor groupings that can be used to represent relationships among sets of many interrelated variables (Norusis, 2008). It is a powerful method for regrouping and reducing a large number of factors to a smaller and more critical set by factor scores of the responses (Li et al., 2011). However, the appropriateness of FA for the factor extraction needs to be examined before applying FA. Thus, in this research, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to determine the appropriateness of FA.

The KMO is a measure of sampling adequacy that represents the ratio of the squared correlation between the variables to the squared partial correlation between the variables (Field, 2013). The KMO value ranges from 0 to 1. A value of 0 is an indication that the sum of partial correlations is large relative to the sum of correlations, indicating diffusion in the pattern of correlations and thus FA would be inappropriate (Norusis, 2008). On the other hand, a value close to 1 is an indication that patterns of correlations are relatively compact and thus FA would yield reliable and distinct factors (Field, 2013). For a satisfactory FA to proceed, the KMO value should be above the acceptable threshold of 0.50 (Kaiser, 1974; Norusis, 2008; Field, 2009). However, the level of acceptance of KMO value varies depending on the KMO value, as shown in Table 3.

<Insert Table 3 about here>

Bartlett's test of sphericity is a statistical test that highlights the presence of correlations between the variables (Chan et al., 2010). It is used to assess whether the original correlation matrix is an identity matrix, which would indicate that there is no relationship among the variables and hence FA would be inappropriate (Pett et al., 2003). When the value of the test statistic for sphericity is large and the associated significance level is small, the population correlation matrix is not an identity matrix and hence FA would be appropriate (Pallant, 2011).

4. Survey results

Two main approaches have been used to analyze the barriers to GBTs adoption: ranking analysis and FA. This section presents the analysis results. The section first presents the results of the ranking analysis and then compares them with some developed countries. Afterward, the section presents the results of the FA.

4.1. Results of ranking analysis

The summary of the ranking analysis results on the barriers to GBTs adoption is shown in Table 4. The mean scores of the criticality of the barriers range from 2.93 to 4.51. Barriers with normalized values not less than 0.50 are identified as critical barriers hindering the adoption of GBTs in Ghana.

<Insert Table 4 about here>

Table 4 indicates that 20 out of the initial 26 barriers have normalized values not less than 0.50, and are therefore deemed critical barriers. Expectedly, “higher costs of GBTs” was ranked first with the highest mean score (mean = 4.51), indicating that cost is the most critical barrier inhibiting the adoption of GBTs in the Ghanaian construction market. This finding agrees with the findings of numerous previous studies conducted within the context of developing countries (Potbhare et al., 2009; Zhang et al., 2011a, b). The second, as ranked by the respondents, was “lack of government incentives” (mean = 4.26), followed by “lack of financing schemes (e.g., bank loans)” as the third (mean = 4.12), and “unavailability of GBTs suppliers” as the fourth (mean = 4.07). “Lack of local institutes and facilities for R&D of GBTs” was ranked as the fifth most critical barrier (mean = 4.02).

The Kendall’s *W* value for ranking the 26 barriers was 0.097, and the significance level of Kendall’s *W* was at 0.000, which indicates that a significant degree of agreement exists among all the respondents in a particular group regarding the ranking of barriers to GBTs adoption. From the ANOVA results, the significance values of 25 barriers were greater than 0.05 (Table 4). The result indicates that there were no statistically significant differences in the perceptions of the criticality of these barriers from consultants, contractors, and developers. For the barrier "lack of GBTs promotion by government", the differences in perceptions were statistically significant. The perception of the criticality of this barrier from the developers (mean = 4.46, rank 1) was higher than that from the consultants (mean = 3.81, rank 13) and contractors (mean = 3.57, rank 20), which may imply that the lack of promotion by government affected the developers' adoption of GBTs more. The role of the government is known to be a factor that usually has a significant influence on developers' green building behaviors (Shen et al., 2016).

4.1.1. Comparison with developed countries

After identifying the top five barriers to GBTs adoption in Ghana's construction market, based upon the results from this study and that from Chan et al. (2016), the top five most critical GBTs adoption barriers in the developing country of Ghana and that in three selected developed countries – the US, Canada, and Australia – were compared, as shown in Table 5. Albeit other studies could have been selected for this results comparison, Chan et al.'s (2016) study was selected because it analyzed a set of GBTs adoption barriers, similar to what is analyzed in this study. In the study of Chan et al. (2016), the views of the top five most critical GBTs adoption barriers among the US, Canada, and Australia were compared. Expanding Chan et al.'s (2016) comparison to include views from developing countries can provide insights that would be useful for policy makers and practitioners in both developed and developing countries. As such, this study compares the views among Ghana, the US, Canada, and Australia. As shown in Table 5, the barriers that occurred in the top five ranked GBTs adoption barriers in Ghana as well as in any of the three selected developed countries are marked with the symbol "√". And those that did not occur in the top five ranked barriers in any of the three selected developed countries are marked with the symbol "–". In any case, Table 5 also shows the respective rank (in bracket) of a certain barrier in a particular country.

<Insert Table 5 about here>

It is interesting to note that higher costs of GBTs is the only barrier appearing in the top five GBTs adoption barriers in Ghana and in all the three selected develop countries, with its ranks across all the countries being close (Table 5). This implies that the higher costs of GBTs is a top barrier affecting GBTs adoption not only in Ghana's construction market, but also in the construction markets of many developed countries including the US, Canada, and Australia. Nguyen et al. (2017) also pointed out that higher cost is the most recognized barrier to green building adoption in both developed and developing markets. The finding of the present study suggests that the development of cheaper yet efficient GBTs can help further the adoption of GBTs in the construction market worldwide.

On the other hand, it is worth noting that lack of government incentives appeared in the top five GBTs adoption barriers in only Ghana and the US, and it is rather close to becoming one of the top five barriers in Canada and Australia. Furthermore, it can be noted that these three barriers – lack of financing schemes (e.g., bank loans), unavailability of GBTs suppliers, lack of local institutes and facilities for R&D of GBTs – did not appear in the top five barriers in the US, Canada, and Australia, and their ranks in these countries are very different from the Ghanaian ranks. For example, while unavailability of GBTs suppliers was ranked fourth in Ghana, it was ranked fourteenth, twenty-fifth, and thirteenth in the US, Canada, and Australia, respectively. The results reveal that the most critical GBTs adoption barriers in the developing country of Ghana mostly differ from those in the developed countries of the US, Canada, and Australia. The reason for the differences could be attributed to the maturity of the GBTs adoption activity in Ghana in comparison with that in developed countries; the Ghanaian GBTs adoption activity is less mature compared to that of developed countries (Darko et al., 2017d). This further explains why it is necessary to better understand the critical barriers encountered in GBTs adoption in specific countries so that appropriate measures can be put in place for GBTs adoption promotion. To conclude, the above comparison has shown that while the most critical GBTs adoption barriers in the developing country of Ghana mostly vary from those in the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all the countries.

4.2. Results of factor analysis

In order to better understand the barriers to GBTs adoption in Ghana, the 20 critical barriers (variables) identified in this study were subjected to FA. The KMO value of this study is 0.562, which is acceptable as it satisfies the threshold of 0.50 (Table 3). It is values below 0.50 that should lead the researcher "to either collect more data or rethink which variables to include" (Field, 2013, p. 685). The KMO value could easily be improved through deleting some of the variables for FA using certain exclusion criteria. However, a number of factors, such as the contribution of the variable to the interpretation of the factor group, should be taken into consideration in the decision to delete a variable. It is recommended that variables with factor loadings exceeding or being close to 0.50 should be retained because they are significant in contributing to the interpretation of the factor group (Akintoye, 2000; Matsunaga, 2010). Table 6 shows that all factor loadings exceeded or were close to 0.50, with 18 (90%) of them exceeding 0.50; therefore, all the variables were included in the FA. In this research, the chi-square value in Bartlett's sphericity test is large (383.730) and the associated significance level is small (0.000), suggesting that the population correlation matrix is not an identity matrix. This further reinforces the appropriateness of using FA.

<Insert Table 6 about here>

For factor extraction, principal component analysis technique was employed to identify underlying grouped barriers. Table 6 summarizes the results of FA after varimax rotation. Five underlying groupings (components) with eigenvalues greater than 1 were extracted, explaining 62.82% of the variance. This indicates that with these five components, the highest percentage (> 50%) of the variance is explained by GBTs adoption barriers. Moreover, the 62.82% of total variance explained compares favorably with the 58.68% of total variance explained in a recent study (Osei-Kyei and Chan, 2017). In this study, the remaining 15 components altogether explained only 37.18% of the total variance, indicating that a model with the five extracted components can adequately be used to represent the data (Li et al., 2011; Chan et al., 2016).

As shown in Table 6, the 20 independent variables are split into five meaningful groupings, with seven variables belonging to grouping 1, five variables belonging to grouping 2, three variables each belonging to groupings 3 and 4, and two variables belonging to grouping 5. To facilitate further discussion, it is necessary to rename the five extracted groupings based on the analysis results. Hence, the five underlying grouped barriers can be renamed as follows:

- Grouping 1: Government-related barriers;
- Grouping 2: Human-related barriers;
- Grouping 3: Knowledge and information-related barriers;
- Grouping 4: Market-related barriers; and
- Grouping 5: Cost and risk-related barriers.

5. Discussion of results

5.1. Grouping 1: Government-related barriers

This underlying group highlights the government's role in the promotion of GBTs adoption in Ghana, and it is represented by seven critical barriers: (1) lack of green building rating systems and labeling programs, (2) lack of green building codes and regulations, (3) lack of green building technological training for project staff, (4) lack of GBTs promotion by government, (5) lack of demonstration projects, (6) lack of local institutes and facilities for R&D of GBTs, and (7) lack of government incentives. The seven critical barriers under this group cover issues that fall within the purview of government. This group is the most dominant among all the five groups, explaining the greatest variance (27.03%) from a statistical point of view (Table 6).

Although lack of government incentives has the least factor loading in this group, it is the most critical barrier in this group according to the results of this study (Table 4). At the current stage of GBTs adoption in Ghana, lack of government incentives is a major barrier to GBTs adoption. Ozdemir (2000, p. 13) define an incentive as "something that influences people to act in certain ways". In essence, in the context of green building, incentives act as motivators compelling people to actually adopt GBTs in their construction projects. Therefore, without incentives from the government, industry practitioners and stakeholders might not adopt GBTs. As GBTs adoption in Ghana is still in its infancy (Darko et al., 2017d), currently, there exist no government incentives to motivate GBTs adoption in the country. This situation may explain why lack of government incentives is considered a critical barrier to GBTs adoption in Ghana. In order to promote GBTs adoption, it is necessary for the government to establish effective incentive schemes. For example, the government could provide financial incentives (e.g., tax credits) and non-financial incentives (e.g., expedited permitting) for GBTs adopters. Similar to the finding of this study, Shen et al. (2017b) found that lack of government incentives is a significant barrier to the adoption of green procurement in China.

Another critical barrier is the lack of local institutes and facilities for R&D of GBTs. Hwang and Tan (2012) stressed the importance of R&D to the adoption and development of green building systems. However, a huge gap exists between funding for building related R&D and that for R&D in other vital sectors. By any conventional yardstick, public and private sectors typically make minimal R&D or innovation investment in the building sector (US Green Building Council (USGBC), 2003). Compared to developed countries, developing countries have much smaller percentage of government's R&D budget allocated to the building sector. For example, in China, only 0.4 to 0.6% of the government's R&D budget is allocated to the building sector, which lags behind the 0.6 to 1% allocated by developed countries such as the UK (Shen, 2008). The finding of this study suggests that there is an absence of accredited institutions that conduct credible scientific research on GBTs and their benefits in Ghana, resulting in poor market demand for GBTs. It would therefore be useful if the government of Ghana could provide necessary funding for the establishment of green technology research institutes and centers.

The lack of demonstration projects probably reflects the immaturity of the green building industry in Ghana. Demonstration projects are helpful for testing the performance of a technology in different operational environments; they also help to shorten the time a particular technology takes to make its way from development and prototype to wider adoption by users (Lefevre, 1984; Karlström and Sandén, 2004). More importantly, demonstration projects can demonstrate the effectiveness of different GBTs at enabling successful development of green buildings. Unless there is adequate availability of experienced professionals in the industry, government funded demonstration projects may be required to accelerate the adoption of new GBTs (Brown and Hendry, 2009). This study has found that the implementation of GBTs in the construction market of Ghana is greatly hindered by the lack of demonstration projects. A similar situation was identified by Potbhare et al. (2009), where the lack of demonstration projects was a barrier to the adoption of green building guidelines in India.

Lack of green building codes and regulations hinders the adoption of GBTs. Government policies and regulations are important instruments for promoting GBTs adoption. Government should be aware that in the early stages of GBTs adoption, its guidance and support are essential for successful and widespread adoption. That is to say, the promotion of GBTs adoption in the construction industry is to a large extent dependent upon government policies and regulations (Gou et al., 2013; Zhang, 2015). If expectations from GBTs adoption are clearly defined in the form of regulatory requirements, then stakeholders would comply. In developing countries where GBTs adoption is fairly new to the construction market, it is expected that organizations and individuals dither to take relevant actions without regulations in place. Thus, a lack of green building codes and regulations inhibits GBTs adoption in Ghana at the moment. This finding is consistent with findings of studies done in Malaysia (Samari et al., 2013) and India (Luthra et al., 2015). The finding implies that the Ghanaian government should assume a more active role in the pursuit of implementing sustainability in the construction industry by developing policies and regulations to promote GBTs adoption. That would even be a more efficient and preferred way to promote GBTs adoption, as in the current economic conditions, it may not be easy for the government to offer grants or soft loans to GBTs adopters.

Training of staff is highly essential for the success of implementing new technology and software (Succar et al., 2013). The implementation of green building projects differs from that of traditional building projects not only in terms of the processes, design, and materials, but also the technologies involved. The use of GBTs is a key component of the implementation of green building projects. Therefore, a lack of training for project staff to efficiently operate GBTs can have a negative impact on the successful implementation of green building projects. The government allocating funds for green building trainings to educate the industrial practitioners or the public (Hwang et al., 2017) would significantly assist in facilitating the use of GBTs in the construction industry.

Government's endorsement and promotion of a GBT can accelerate its adoption in a country because that can validate the effectiveness of the technology to the public (Potbhare et al., 2009). Consequently, a lack of GBTs promotion by government can be a critical barrier to GBTs adoption. The study result suggests that there are no government initiatives in the form of local authorities and strategies to promote the adoption of GBTs in Ghana. Djokoto et al. (2014) also found that lack of strategy to promote is a major barrier to sustainable construction in Ghana. It is therefore considered that the formation of promotion strategies and promotion teams that can influence the public would be effective means for the Ghanaian government to promote GBTs adoption.

Lack of green building rating systems and labeling programs is another critical barrier in this group. Internationally recognized green building rating systems, such as the LEED, could be useful for promoting GBTs adoption at both international and national levels. However, localized green building rating systems would be more effective at the local level, as they are developed with much more attention given to local sustainability priorities. At present, Ghana does not have its own green building rating systems, which has been identified as a critical barrier affecting GBTs adoption in the country. This finding indicates that localized green building rating systems are needed to encourage and incentivize the industrial practitioners to push the boundaries on sustainability. While the Ghana Green Building Council (GHGBC) has the most important role to play in this respect, the government and other non-governmental organizations ought to be supportive.

5.2. Grouping 2: Human-related barriers

This underlying group explains 11.56% of the total variance and consists of five critical barriers: (1) lack of importance attached to GBTs by senior management, (2) resistance to change from the use of traditional technologies, (3) unavailability of GBTs suppliers, (4) unfamiliarity of construction professionals with GBTs, and (5) lack of financing schemes (e.g., bank loans). These five barriers are much related to the attitudes and behaviors of people.

Lack of financing schemes (e.g., bank loans) ranks among the top five barriers, which is in line with previous studies carried out in developing countries (Samari et al., 2013; Luthra et al., 2015). This finding clearly shows that financial/economic issues are crucial for the adoption and development of GBTs in Ghana. The lack of financing schemes, as a barrier to GBTs adoption, is closely related to the barrier higher costs of GBTs. It is deadly to GBTs adoption because without a better financial foundation, companies and industry practitioners would not be able to purchase and use expensive GBTs. Thus, the lack of financing schemes could explain why higher costs of GBTs was also ranked among the top five barriers. To overcome the lack of financing schemes barrier, banks and other financial institutions should provide financial supports, e.g., soft loans and grants, for GBTs adoption. Learning from the experiences of developed countries would be a very helpful approach to promote GBTs adoption in developing countries. In Hong Kong, for instance, it is "not difficult to obtain financing from banks for green projects" (Gou et al., 2013, p. 169), helping green building development in the country. Using public-private partnership financing schemes in the green building domain would also afford an opportunity to deal with the lack of financing schemes barrier.

Suppliers play a crucial role in successful adoption of GBTs. They are not only the vendors who provide the industry with the needed GBTs, but also the main sources of information regarding the GBTs. Therefore, the unavailability of GBTs suppliers is considered a critical barrier to GBTs adoption in the Ghanaian construction market. To improve sustainability performance in an industry, experiences from several other industries have demonstrated that there is the need to integrate suppliers into sustainability management initiatives (Zhu et al., 2007; Shen et al., 2016). This barrier is closely related to the barrier unavailability of GBTs in the local market in that if the suppliers of the GBTs are unavailable, then the GBTs themselves would also be unavailable. The research finding of unavailability of GBTs suppliers concurs with studies in China (Shi et al., 2013) and Hong Kong (Lam et al., 2009; Gou et al., 2013). This suggests that the current GBTs supply chain is immature with a shortage of suppliers.

Lack of importance attached to GBTs by senior management is a critical barrier to GBTs adoption because if top management do not perceive GBTs as a priority, it is a challenge for firms to introduce them in their projects. The adoption of GBTs requires top management's involvement and support. It is almost impossible to adopt especially new GBTs without the top management's commitment or approval. Given that GBTs adoption is a top-down approach where senior management have more influence and authority than employees in the lower hierarchy of firms (Ball, 2002), the commitment, leadership, and support of senior management and the board of directors are pivotal conditions for GBTs adoption. Lam et al. (2009) argued that there is an important relationship between the degree of support from senior management on adoption and the willingness to adopt green practices. Senior management's commitment and support can foster a conducive environment for innovation. In most cases, the senior management's commitment to GBTs adoption tends to result from the level of importance they attach to GBTs (Chan et al., 2016). Otherwise, the commitment from top management towards GBTs adoption would have to be driven by external forces such as the need to comply with regulatory requirements.

Another critical barrier to GBTs adoption is resistance to change from the use of traditional technologies, resulting from stakeholders' deep rooted traditional ideas. According to DuBose et al. (2007), because liability is a serious issue within the construction industry, construction stakeholders are naturally resistant to change. This barrier is also closely associated with other barriers such as the higher costs of GBTs, the lack of financing schemes, the lack of awareness of GBTs and their benefits, the lack of professional knowledge and expertise, the lack of information, and the unfamiliarity with GBTs. Although the resistance to change has been found the most critical barrier to GBTs adoption in some previous studies (Du et al., 2014; Chan et al., 2016; Darko et al., 2017c), based on the results of this study, it can be stated that within the Ghanaian context, resistance to change is only deemed a critical (not the most critical) barrier; cost and financial barriers are much more critical in GBTs adoption.

Unfamiliarity of construction professionals with GBTs inhibits the adoption of GBTs in Ghana. Arditi and Gunaydin (1997) mentioned that in order to ensure construction quality, the construction technologies used by the contractor must be familiar to the design professionals. Zhang et al. (2011a) also indicated that the unfamiliarities with GBTs and technical difficulties can result in delays in the design and construction processes of green building projects. Owing to these issues, unfamiliarity of construction professionals with GBTs can cause them to accept only those traditional construction projects involving technologies that they are already most familiar with. The results of this study suggest that as most GBTs are relatively new and not available in the Ghanaian construction market, many construction professionals in Ghana are not familiar with them, causing them to eschew GBTs adoption.

5.3. Grouping 3: Knowledge and information-related barriers

This underling group explains 10.42% of the total variance and consists of three critical barriers: (1) lack of professional knowledge and expertise in GBTs, (2) lack of GBTs databases and information, and (3) lack of awareness of GBTs and their benefits.

Having professional knowledge and expertise is a key factor in successful GBTs adoption. The global trend towards GBTs adoption creates an increasing and urgent need for green skilled professionals and workers. To achieve high performance results in an organization, skilled workers are required in every department (Ozorhon and Karahan, 2016). This is even more necessary in GBTs adoption because the workers need to be skilled to efficiently handle every aspect of the adoption process, including the technological, the managerial, and the technical aspects. With the presence of skilled workers within an organization, the needs could be identified without difficulty, and successful adoption could be attained in a rapid manner (Ozorhon and Cinar, 2015). On the other hand, the absence of workers with the necessary skills, expertise, and knowledge would make it difficult for an organization to adopt GBTs. As barriers to GBTs adoption, the lack of knowledge and expertise has been found to be more critical than the lack of training for project staff, which are assumed to be knotted to each other.

Lack of GBTs databases and information cannot encourage the market to adopt GBTs, as access to relevant information is of strategic importance to GBTs adoption. Darko et al. (2017c) indicated that availability of better information is essential for GBTs adoption. This study has identified that lack of GBTs databases and information hampers the adoption of GBTs in Ghana. This shows that it is difficult for practitioners within the current construction market of Ghana to find information and data relating to GBTs, which could be attributed to the lack of GBTs suppliers. This barrier should be removed in order to increase the pace of adoption of GBTs. To this end, the development of a comprehensive national database or an information system to provide the public with timely, accurate, and updated information about GBTs is proposed. Besides, industry associations could play an essential role by sharing relevant GBTs information between construction firms and government departments (Shi et al., 2013).

Lack of awareness of GBTs and their benefits also critically affects GBTs adoption in Ghana. Since it is costly to adopt GBTs, the sustainability benefits associated with GBTs play a huge role in pushing for their adoption (Chan et al., 2017). The finding of this study suggests that a lack of awareness of the sustainability benefits of GBTs is a major barrier for Ghanaian practitioners and the public to adopt GBTs. This barrier is closely related to the lack of R&D of GBTs. Kibert (2008) claimed that it is mainly because of insufficient research affirming the benefits of GBTs that awareness within the industry is lacking. Educating the industry practitioners and the public on the benefits of GBTs would help promote the adoption of GBTs. For this purpose, new research studies demonstrating the benefits of GBTs could be conducted or existing studies and fact sheets could be well utilized.

5.4. Grouping 4: Market-related barriers

Similar to group 3, this underlying group also consists of three critical barriers, namely, (1) unavailability of GBTs in the local market, (2) lack of interest from clients and market demand, and (3) limited experience with the use of nontraditional procurement methods. However, this underlying group explains 7.33% of the total variance.

Lack of interest from clients and market demand is considered a critical barrier to GBTs adoption in the Ghanaian construction market. This indicates that construction practitioners in Ghana are in a market where demand for GBTs is low. Djokoto et al. (2014) also identified that lack of demand is a key barrier to sustainable construction in Ghana. Consumer interest and demand is a significant factor in determining the level of GBTs adoption and development. Market demand directly affects the costs and supply of GBTs. A difficult situation for every businessman is the lack of market demand; when there is a lack of market demand, businessmen worry about the feasibility of their business. As long as most construction stakeholders and practitioners remain businessmen, a lack of market demand could give them a valid reason to refrain from GBTs adoption. Because clients are key decision makers in GBTs adoption (Hwang and Tan, 2012), a lack of interest from them can negatively affect GBTs adoption. The lack of market demand for GBTs can be attributed to the lack of awareness on the part of the public and consumers (Mao et al., 2015). Therefore, increasing public awareness of the benefits of GBTs would stimulate market demand for GBTs.

Unavailability of GBTs in the local market is a widely recognized barrier to GBTs adoption in developing countries (Aktas and Ozorhon, 2015; Shen et al., 2017b). It is one of the major barriers in Ghana because most GBTs are not manufactured and sold locally. Mao et al. (2015) argued that, to a certain extent, the adoption of GBTs depends on the GBTs available in the local construction market, making the availability of GBTs in the local market crucial for GBTs adoption. The research findings suggest that Ghanaian practitioners have a hard time trying to find GBTs suppliers in the local market. The GBTs often have to be imported from other countries, such as the US and China, where the GBTs markets are relatively better developed. Although the global suppliers could offer innovative solutions, that may come with high costs, which has also been recognized as a critical barrier.

Limited experience with the use of nontraditional procurement methods is another critical barrier that prevents the adoption of GBTs. The procurement of green technologies and materials – which is known as green procurement – differs from traditional procurement. While green procurement factors "environmental concerns into major purchasing strategies, policies, and directives" (Green Council, 2010), the traditional procurement method does not. As such, to eliminate possible errors in the green procurement process, extensive experience in green procurement is crucial; that is, without extensive experience in green procurement, it would be difficult to adopt GBTs.

5.5. Grouping 5: Cost and risk-related barriers

This underlying group explains 6.47% of the total variance and comprises two critical barriers: (1) higher costs of GBTs and (2) risks and uncertainties involved in adopting new technologies.

Cost is considered a key and sensitive barrier to the adoption of GBTs in Ghana. The higher costs of GBTs, identified as the most critical barrier in this study (Table 4), is emphasized by industry practitioners who show concern about cost when considering the application of GBTs. As identified in section 4.1.1, cost is a major barrier to GBTs adoption not only in Ghana, but also in many developed countries. It is well known that GBTs cost significantly more than their traditional counterparts (Kibert, 2008; Gou et al., 2013). For example, as a green substitute for traditional plywood, compressed wheat board costs about 10 times more than traditional plywood (Hwang and Tan, 2012). Consequently, many industry practitioners believe that the application of GBTs can increase project cost by 10-20% (WorldGBC, 2013). In the developing country of Ghana where poverty is widespread and entrenched in many areas of the country (Cooke et al., 2016), the higher costs associated with adopting GBTs can greatly hinder GBTs adoption. This cost barrier is closely related to other barriers, including the lack of government incentives, the lack of financing schemes, and the lack of awareness of GBTs and their benefits. Thus, although it is anticipated that with more experience, practitioners would be able to deal with the cost barrier (Chan et al., 2016), incentives can offset the extra costs involved in GBTs adoption. The cost barrier can also be overcome by using successful green building projects to show the real cost and benefits of adopting GBTs in the Ghanaian market.

Risks and uncertainties involved in adopting new technologies is also considered a critical barrier faced in GBTs adoption in the Ghanaian construction market. According to Ozorhon and Karahan (2016, p. 7), “the more diffused a certain technology in the construction market, the less risky it will become to implement it”. Therefore, as GBTs adoption is relatively new to the Ghanaian construction market, it is difficult to convince many construction stakeholders to adopt GBTs. It is not uncommon for construction stakeholders to be uncertain about the system performance of new GBTs. Uncertainty in the performance of GBTs can also be deadly to a green building project because it can reduce the overall efficiency of the project (Shi et al., 2013). This may explain why Ghanaian practitioners avoid GBTs adoption because of the uncertainties involved. The finding of this study suggests that how much risk stakeholders are willing to accept plays a major role in the adoption of new GBTs.

6. Concluding remarks

As a way of implementing sustainability within the construction industry, GBTs adoption has received a high level of global attention in recent times. However, GBTs adoption in the developing country of Ghana is still in its infancy and facing numerous barriers. These barriers need to be addressed in order to facilitate the successful and widespread adoption of GBTs. To this end, this study aimed to investigate the critical barriers to GBTs adoption in Ghana. To achieve the aim, 26 barriers were identified from a comprehensive literature review. Through a questionnaire survey with 43 professionals in Ghana, the results first indicated that 20 out of the 26 barriers were critical barriers to GBTs adoption, with the most critical barriers being higher costs of GBTs, lack of government incentives, and lack of financing schemes (e.g., bank loans). Moreover, a comparative analysis pointed out that while the most critical barriers to GBTs adoption in the developing country of Ghana mostly vary from those in the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all the countries. Furthermore, factor analysis revealed that the underlying grouped barriers for the 20 critical barriers were government-related, human-related, knowledge and information-related, market-related, and cost and risk-related barriers. The results also showed that the most dominant of the five underlying groups was government-related barriers. This implies that there is a need for the government to play a more active role in promoting GBTs in Ghana.

The findings of this study not only contribute to filling the gap in knowledge concerning green building barriers in developing countries, but also provide valuable reference for helping policy makers and practitioners take suitable measures to mitigate the GBTs adoption barriers and consequently promote GBTs adoption. Moreover, this study would be useful and helpful for international organizations and advocates interested in promoting GBTs adoption in Ghana to ultimately achieve more sustainable building developments.

Although the objective was achieved, this study still has some limitations that are worth mentioning. These limitations not only warrant future research, but must also be considered when interpreting and generalizing the results. First, the criticalities assessment made in this study could be influenced by the respondents' attitudes and experiences, as it was subjective. Apart from that, although the sample size and the KMO value of this study were adequate for conducting statistical analyses, it is appreciated that they are nevertheless relatively small. Increasing the sample size could improve the KMO value; thus, future research with a larger sample size would be useful to see whether the results would significantly differ from those reported in this study. Moreover, future study could analyze the differences between the GBTs adoption barriers in Ghana and many more developed countries. Lastly, albeit the findings of this study might be of use to policy makers and practitioners in other developing countries the world over, data gathered from a different country may produce different findings. Therefore, using the proposed GBTs adoption barriers, similar studies could be undertaken in different developing countries to observe market-specific differences, which would help in developing market-specific solutions to remove the barriers.

This paper reports upon the partial findings of a large-scope research on the promotion of GBTs adoption in a developing country. While this paper reports only the outcomes on the

GBTs adoption barriers, the future research paper will report the empirical findings on the strategies to overcome the barriers and thereby promote the wider adoption of GBTs. As a future study, the interrelationships among the critical barriers and their impacts on the GBTs adoption activity will also be investigated/modeled.

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Appendix A. Sample of the survey questionnaire.

Please assess how critical each of the following barriers is to the adoption of green building technologies (GBTs) in Ghana. Use the following rating scale: 1 = not critical; 2 = less critical; 3 = neutral; 4 = critical; 5 = very critical.

<Insert Table 7 about here>

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Table 1

List of potential GBTs adoption barriers identified from the literature.

Code	Barrier Factors	References
B01	Higher costs of GBTs	Williams and Dair (2007), Lam et al. (2009), Chan et al. (2009), Zhang et al. (2011a, b, c), Hwang and Tang (2012), Shi et al. (2013), Chan et al. (2016), Darko et al. (2017c)
B02	Lack of GBTs databases and information	Williams and Dair (2007), Bond (2011), Bin Esa et al. (2011), Samari et al. (2013), Rodriguez-Nikl et al. (2015), Akadiri (2015)
B03	Lack of professional knowledge and expertise in GBTs	Eisenberg et al. (2002), Tagaza and Wilson (2004), Williams and Dair (2007), Lam et al. (2009), Winston (2010), Love et al. (2012), Ahn et al. (2013), Chan et al. (2016)
B04	Lack of awareness of GBTs and their benefits	Williams and Dair (2007), Chan et al. (2009), Zhang et al. (2011b, c), Bin Esa et al. (2011), AlSanad (2015), Chan et al. (2016), Darko et al. (2017c)
B05	Lack of government incentives	Chan et al. (2009), Potbhare et al. (2009), Zhang et al. (2012), Love et al. (2012), Darko and Chan (2016b), Darko et al. (2017c), Shen et al. (2017b)
B06	Lack of local institutes and facilities for research and development (R&D) of GBTs	USGBC (2003), Hwang and Tang (2012)
B07	Lack of green building codes and regulations	Winston (2010), Zhang et al. (2011b, c), Love et al. (2012), Samari et al. (2013), Luthra et al. (2015), AlSanad (2015)
B08	Lack of green building rating systems and labeling programs	Du et al. (2014), Persson and Grönkvist (2015), Kasai and Jabbour (2014)
B09	Unfamiliarity of construction professionals with GBTs	Eisenberg et al. (2002), Tagaza and Wilson (2004), Zhang et al. (2011a, b, c), Chan et al. (2016), Darko et al. (2017c)
B10	High degree of distrust about GBTs	Williams and Dair (2007), Winston (2010), Luthra et al. (2015)
B11	Conflicts of interests among various stakeholders in adopting GBTs	Williams and Dair (2007), Winston (2010), Hwang and Tan (2012), Love et al. (2012), Hwang and Ng (2013)
B12	Lack of interest from clients and market demand	Williams and Dair (2007), Zhang et al. (2011c), Hwang and Tan (2012), Gou et al. (2013), Djotoko et al. (2014), Darko and Chan (2016b)
B13	Unavailability of GBTs in the local market	Williams and Dair (2007), Potbhare et al. (2009), Gou et al. (2013), Aktas and Ozorhon (2015), Shen et al. (2017b)
B14	Adoption of GBTs is time consuming and causes project delays	Tagaza and Wilson (2004), Lam et al. (2009), Shi et al. (2013), Hwang and Ng (2013)
B15	Resistance to change from the use of traditional technologies	Meryman and Silman (2004), Ahn et al. (2013), Du et al. (2014), Darko and Chan (2016b), Chan et al. (2016), Darko et al. (2017c)
B16	Complex and rigid requirements involved in adopting GBTs	Hwang and Tan (2012), Hwang and Ng (2013),

		Chan et al. (2016)
B17	Lack of GBTs promotion by government	Zhang et al. (2012), Samari et al. (2013), Djokoto et al. (2014)
B18	Lack of importance attached to GBTs by senior management	Du et al. (2014), Darko and Chan (2016b)
B19	Risks and uncertainties involved in adopting new technologies	Tagaza and Wilson (2004), Häkkinen and Belloni (2011), Chan et al. (2016)
B20	Lack of green building technological training for project staff	Djokoto et al. (2014), Gou et al. (2013)
B21	Unavailability of GBTs suppliers	Lam et al. (2009), Shi et al. (2013), Gou et al. (2013)
B22	Lack of financing schemes (e.g., bank loans)	Potbhare et al. (2009), Zhang and Wang (2013), Luthra et al., 2015
B23	High market prices and rental charges of green buildings resulting from GBTs application	Häkkinen and Belloni (2011), Chan et al. (2016), Darko and Chan (2016b)
B24	Long payback periods from adopting GBTs	Ahn et al. (2013), Gou et al. (2013)
B25	Lack of demonstration projects	Potbhare et al. (2009), Chan et al. (2016), Darko et al. (2017c)
B26	Limited experience with the use of nontraditional procurement methods	Love at al. (2012), Chan et al. (2016)

Table 2
Profiles of the respondents.

			Years of Experience							
			Construction Industry					Green Building		
Characteristics	Frequency	Percent	1-5	6-10	11-15	16-20	>20	1-3	4-6	>6
Professions										
Engineer	13	30.2	3	2	4	2	2	7	3	3
Quantity surveyor	11	25.6	1	8	2	0	0	5	3	3
Architect	9	20.9	0	4	2	0	3	6	2	1
Project manager	9	20.9	2	2	2	1	2	6	2	1
Contracts manager	1	2.3	0	1	0	0	0	0	1	0
Subtotal	43	100.0	6	17	10	3	7	24	11	8
% by year	-	-	14.0	39.5	23.3	7.0	16.3	55.8	25.6	18.6
Companies										
Consultant	16	37.2	1	8	1	3	3	9	5	2
Contractor	14	32.6	2	8	4	0	0	9	2	3
Developer	13	30.2	3	1	5	0	4	6	4	3
Subtotal	43	100.0	6	17	10	3	7	24	11	8
% by year	-	-	14.0	39.5	23.3	7.0	16.3	55.8	25.6	18.6

Table 3

Level of acceptance of KMO value (Field, 2009).

KMO Value	Level of Acceptance
Above 0.90	Superb
0.80-0.90	Great
0.70-0.80	Good
0.50-0.70	Mediocre
Below 0.50	Unacceptable

Table 4
Ranking of barriers to GBTs adoption.

	All Respondents				Consultant			Contractor			Developer			
Code	Mean	SD	Rank	Normalization[a]	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	ANOVA
B01	4.51	0.668	1	1.00[b]	4.56	0.629	1	4.57	0.514	1	4.38	0.870	2	0.723[c]
B05	4.26	0.928	2	0.84[b]	4.13	0.957	6	4.50	0.650	2	4.15	1.144	7	0.497[c]
B22	4.12	1.005	3	0.75[b]	4.19	0.911	3	4.07	1.072	6	4.08	1.115	12	0.941[c]
B21	4.07	1.078	4	0.72[b]	4.25	1.000	2	4.00	0.961	8	3.92	1.320	14	0.698[c]
B06	4.02	0.938	5	0.69[b]	4.06	0.929	8	3.86	1.027	11	4.15	0.899	6	0.708[c]
B25	4.00	0.926	6	0.68[b]	4.13	0.885	5	3.57	1.089	21	4.31	0.630	4	0.092[c]
B03	4.00	0.926	6	0.68[b]	3.81	0.981	13	3.93	1.141	9	4.31	0.480	3	0.345[c]
B02	4.00	0.951	8	0.68[b]	3.88	1.025	12	3.86	1.027	11	4.31	0.751	5	0.386[c]
B07	3.95	0.999	9	0.65[b]	4.06	0.680	7	3.93	1.141	9	3.85	1.214	15	0.846[c]
B20	3.93	0.856	10	0.63[b]	3.94	0.680	10	4.07	0.917	5	3.77	1.013	18	0.667[c]
B04	3.93	0.910	11	0.63[b]	3.63	1.088	18	4.14	0.770	4	4.08	0.760	8	0.239[c]
B17	3.93	0.986	12	0.63[b]	3.81	0.981	13	3.57	1.016	20	4.46	0.776	1	0.049
B18	3.88	1.074	13	0.60[b]	4.00	0.966	9	3.79	1.051	13	3.85	1.281	17	0.858[c]
B12	3.86	1.014	14	0.59[b]	3.63	1.088	18	4.14	0.663	3	3.85	1.214	15	0.386[c]
B19	3.84	0.974	15	0.58[b]	3.81	1.047	15	3.71	0.994	15	4.00	0.913	13	0.751[c]
B08	3.81	1.006	16	0.56[b]	4.13	0.806	4	3.57	1.158	22	3.70	1.032	21	0.288[c]
B15	3.81	1.118	17	0.56[b]	3.94	0.929	11	3.71	1.267	18	3.77	1.235	20	0.855[c]
B09	3.79	1.226	18	0.54[b]	3.75	1.238	17	4.07	1.072	6	3.54	1.391	23	0.533[c]
B26	3.74	1.049	19	0.51[b]	3.56	0.964	20	3.64	1.151	19	4.08	1.038	9	0.392[c]
B13	3.74	1.049	19	0.51[b]	3.75	1.125	16	3.71	0.994	15	3.77	1.092	19	0.991[c]
B24	3.60	1.094	21	0.42	3.50	1.317	22	3.71	1.139	17	3.62	0.768	22	0.871[c]
B23	3.58	1.220	22	0.41	3.38	1.310	23	3.36	1.216	23	4.08	1.038	9	0.218[c]
B16	3.47	1.386	23	0.34	3.19	1.559	25	3.21	1.369	25	4.08	1.038	9	0.164[c]
B11	3.42	1.096	24	0.31	3.50	1.265	21	3.29	1.139	24	3.46	0.877	24	0.861[c]
B10	3.42	1.118	25	0.31	3.25	1.291	24	3.71	0.914	14	3.31	1.109	25	0.490[c]
B14	2.93	1.121	26	0.00	3.00	1.155	26	2.71	1.204	26	3.08	1.038	26	0.679[c]

Note: SD = Standard deviation; [a] Normalized value = (mean – minimum mean) / (maximum mean – minimum mean); [b] The normalized value indicates that the barrier is a critical barrier (normalized value ≥ 0.50); [c] The ANOVA result is insignificant at the 0.05 significance level (significance level > 0.05). The Kendall's *W* for ranking the 26 barriers was 0.097 with a significance level of 0.000.

Table 5

Occurrence of Ghana's top five GBTs adoption barriers in selected developed countries.

Top Five Barriers to GBTs Adoption in Ghana	Ghana[a] (this study)	US[b] (Chan et al., 2016)	Canada[b] (Chan et al., 2016)	Australia[b] (Chan et al., 2016)
Higher costs of GBTs	√ (rank 1)	√ (rank 2)	√ (rank 3)	√ (rank 2)
Lack of government incentives	√ (rank 2)	√ (rank 5)	– (rank 6)	– (rank 6)
Lack of financing schemes (e.g., bank loans)	√ (rank 3)	– (rank 6)	– (rank 13)	– (rank 15)
Unavailability of GBTs suppliers	√ (rank 4)	– (rank 14)	– (rank 25)	– (rank 13)
Lack of local institutes and facilities for R&D of GBTs	√ (rank 5)	– (rank 11)	– (rank 13)	– (rank 23)

Note: [a] Developing country; [b] Developed country.

Table 6

Results of FA on barriers to GBTs adoption.

Code	Barriers to GBTs Adoption	Barrier Groupings 1	2	3	4	5
Grouping 1: Government-related barriers						
B08	Lack of green building rating systems and labeling programs	0.857	-	-	-	-
B07	Lack of green building codes and regulations	0.817	-	-	-	-
B20	Lack of green building technological training for project staff	0.702	-	-	-	-
B17	Lack of GBTs promotion by government	0.612	-	-	-	-
B25	Lack of demonstration projects	0.561	-	-	-	-
B06	Lack of local institutes and facilities for R&D of GBTs	0.559	-	-	-	-
B05	Lack of government incentives	0.469	-	-	-	-
Grouping 2: Human-related barriers						
B18	Lack of importance attached to GBTs by senior management	-	0.849	-	-	-
B15	Resistance to change from the use of traditional technologies	-	0.679	-	-	-
B21	Unavailability of GBTs suppliers	-	0.668	-	-	-
B09	Unfamiliarity of construction professionals with GBTs	-	0.665	-	-	-
B22	Lack of financing schemes (e.g., bank loans)	-	0.496	-	-	-
Grouping 3: Knowledge and information-related barriers						
B03	Lack of professional knowledge and expertise in GBTs	-	-	0.882	-	-
B02	Lack of GBTs databases and information	-	-	0.813	-	-
B04	Lack of awareness of GBTs and their benefits	-	-	0.740	-	-
Grouping 4: Market-related barriers						
B13	Unavailability of GBTs in the local market	-	-	-	0.782	-
B12	Lack of interest from clients and market demand	-	-	-	0.642	-
B26	Limited experience with the use of nontraditional procurement methods	-	-	-	0.531	-
Grouping 5: Cost and risk-related barriers						
B01	Higher costs of GBTs	-	-	-	-	0.774
B19	Risks and uncertainties involved in adopting new technologies	-	-	-	-	0.640
Eigenvalue		5.406	2.313	2.085	1.466	1.295
Variance (%)		27.030	11.563	10.424	7.329	6.473
Cumulative variance (%)		27.030	38.593	49.017	56.346	62.818

Table 7

Barriers to the adoption of GBTs.

		Level of criticality				
Code	Barriers	1	2	3	4	5
B01	Higher costs of GBTs					
B02	Lack of GBTs databases and information					
B03	Lack of professional knowledge and expertise in GBTs					
B04	Lack of awareness of GBTs and their benefits					
B05	Lack of government incentives					
B06	Lack of local institutes and facilities for research and development (R&D) of GBTs					
B07	Lack of green building codes and regulations					
B08	Lack of green building rating systems and labeling programs					
B09	Unfamiliarity of construction professionals with GBTs					
B10	High degree of distrust about GBTs					
B11	Conflicts of interests among various stakeholders in adopting GBTs					
B12	Lack of interest from clients and market demand					
B13	Unavailability of GBTs in the local market					
B14	Adoption of GBTs is time consuming and causes project delays					
B15	Resistance to change from the use of traditional technologies					
B16	Complex and rigid requirements involved in adopting GBTs					
B17	Lack of GBTs promotion by government					
B18	Lack of importance attached to GBTs by senior management					
B19	Risks and uncertainties involved in adopting new technologies					
B20	Lack of green building technological training for project staff					
B21	Unavailability of GBTs suppliers					
B22	Lack of financing schemes (e.g., bank loans)					
B23	High market prices and rental charges of green buildings resulting from GBTs application					
B24	Long payback periods from adopting GBTs					
B25	Lack of demonstration projects					
B26	Limited experience with the use of nontraditional procurement methods					
If there are any barriers omitted by this questionnaire, please list and assess them.						
B27						
B28						
B29						
B30						
B31						

Critical Barriers to Green Building Technologies Adoption in Developing Countries: The Case of Ghana

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Abstract

Although green building technologies (GBTs) have been advocated in the construction industry to address sustainability issues, their adoption is still plagued with barriers. The barriers that hinder GBTs adoption need detailed investigation. However, few studies have been conducted on the barriers to GBTs adoption in developing countries such as Ghana. This study aims to investigate the critical barriers to GBTs adoption with reference to the Ghanaian construction market. To achieve the objective, 26 barriers were identified from a comprehensive literature review, and a questionnaire survey was performed with 43 professionals with green building experience. The ranking analysis results indicated that 20 barriers were critical. The top three most critical barriers were higher costs of GBTs, lack of government incentives, and lack of financing schemes (e.g., bank loans). A comparative analysis showed that while the most critical barriers to GBTs adoption in the developing

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country of Ghana mostly vary from those in the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all the countries. Furthermore, factor analysis revealed that the underlying grouped barriers for the 20 critical barriers were government-related, human-related, knowledge and information-related, market-related, and cost and risk-related barriers. This study also showed that the most dominant of the five underlying groups was government-related barriers, which highlights the government's role in promoting GBTs adoption in Ghana. This study adds to the green building literature by analyzing GBTs adoption barriers within the context of a developing country, which could help policy makers and practitioners take suitable measures to mitigate the barriers and thereby promote the GBTs adoption. Future research will investigate the interrelationships between the critical barriers and their impacts on the GBTs adoption activity.

Keywords: Green building technologies; Barriers; Construction market; Sustainability; Developing countries; Ghana.

1. Introduction

It is widely accepted that the construction industry has harmful impacts on the environment, economy, and society. The construction industry consumes up to 40% of the total energy and accounts for up to 30% of the total annual greenhouse gas emissions at the global level (United Nations Environment Programme (UNEP), 2011). The construction industry is also considered a resource-intensive industry that consumes about 70% of the cement products and 25% of the steel products in many countries (Wang and Zhang, 2008). Due to a growing public concern about these impacts nowadays, much attention has been paid to implementing sustainability or sustainable development within the construction industry. According to the World Commission on Environment and Development (WCED) (1987), "sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development has three dimensions, i.e., environmental, economic, and social sustainability. Green building has been well received by governments around the world as a strategy for improving the sustainability of the construction industry (Shen et al., 2017a).

Green building is considered “the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s lifecycle” (US Environmental Protection Agency (USEPA), 2016). It has been viewed as an effective alternative to traditional building, which has a significant role in reducing or eliminating the negative impacts of construction activities on the environment and climate change (Hwang et al., 2016; World Green Building Council (WorldGBC), 2017a). However, green building is not achievable without the adoption of green building technologies (GBTs). In this study, GBTs are defined as technologies that are incorporated into building design and construction to make the end product sustainable (Ahmad et al., 2016). Several GBTs, such as green roof technology, solar technology, and prefabricated concrete technology, have been introduced for developing green projects. Adopting these GBTs offers a range of significant sustainability benefits that are not likely to be derived from adopting traditional building technologies. It was reported by the UNEP (2009) that with the adoption of appropriate GBTs, a 30-80% cut in building energy consumption is attainable. Moreover, numerous researchers and organizations have indicated that GBTs adoption provides several other environmental, economic, and social benefits, such as increased water efficiency, improved productivity, enhanced human health and wellbeing, improved indoor environmental quality, and higher property value (WorldGBC, 2017b; Darko et al., 2017a, b).

Because of these sustainability benefits, over the last two decades, the promotion of GBTs adoption has been of great importance to many countries. However, GBTs adoption is not free of barriers and challenges. What are the barriers hindering the adoption of GBTs in the construction market? For an effective and efficient promotion of GBTs adoption, it is essential that the barriers to adoption are first recognized and addressed (Mao et al., 2015). Hence, a lot of research on barriers to GBTs and practices adoption has been done (Lam et al., 2009, Hwang and Tan, 2012; Shen et al., 2017b). However, few have attempted to analyze barriers to GBTs adoption in developing countries. As identified by a recent critical analysis of green building research (Darko and Chan, 2016a), there is a gap in the literature in terms of green building barriers studies in developing countries. This knowledge gap needs to be bridged, particularly because a better understanding of barriers is necessary for formulating proper strategies to overcome the barriers (Chan et al., 2016). This is especially important in developing countries, such as Ghana, where green building is fairly new to the construction market. Additionally, the criticalities of GBTs adoption barriers should be analyzed in various levels of detail.

Given the above background, the objective of this study is to investigate the critical barriers to GBTs adoption in the construction market with reference to the developing country of Ghana. The findings of this study not only contribute to filling the gap in knowledge concerning green building barriers in developing countries, but also provide valuable reference for helping policy makers and practitioners take suitable measures to mitigate the GBTs adoption barriers and consequently promote GBTs adoption. Moreover, this study would be useful and helpful for international organizations and advocates interested in promoting GBTs adoption in Ghana to ultimately achieve more sustainable building developments. The remainder of this paper is organized into the following five sections: section 2 reviews literature on the topic; section 3 provides detailed description of the research methodology; section 4 presents the survey results; section 5 discusses the results; and section 6 concludes the study.

2. Literature review

The many barriers hindering the adoption of GBTs and practices in construction have been investigated by a number of green building researchers and practitioners. Prior studies have shown that barriers to GBTs and practices adoption exist in both developed and developing countries. In terms of developed countries, Ahn et al. (2013) identified the top five barriers to green building in the US: first cost premium, long payback periods, tendency to maintain current practices, limited subcontractors' knowledge and skills, and higher costs of green products and materials. Chan et al. (2016) found resistance to change, higher costs of GBTs, lack of knowledge and awareness, lack of expertise, and lack of government incentives as the most critical barriers affecting GBTs adoption in the US. There are several other US studies on the barriers to green building development (Meryman and Silman, 2004; Mulligan et al., 2014; Rodriguez-Nikl et al., 2015; Darko et al., 2017c).

Hwang and Tang (2012) and Hwang and Ng (2013) studied the barriers faced during green building projects management in Singapore. They identified the following as crucial barriers: higher costs of green equipment and materials, lack of interest and communication amongst project team members, lack of research, lack of interest from clients and market demand, lengthy preconstruction process, and uncertainty with green equipment and materials. Hwang et al. (2017) identified that higher initial costs and lack of government support were two of the top three barriers to green business parks adoption in Singapore. Ofori and Kien (2004) also pointed out that higher cost was a key barrier to green building in Singapore.

In Kong Hong, Lam et al. (2009) showed that extra costs and delays caused by green requirements, limited availability of reliable green suppliers, and limited knowledge were the most dominant barriers to integrating green specifications in construction. Lack of government incentives and promotion and high maintenance costs were identified by Zhang et al. (2012) as the top barriers to adopting extensive green roof systems in Hong Kong. Other researchers who carried out studies to investigate the green building barriers in Hong Kong include Gou et al. (2013) and Qian et al. (2015). As for Chan et al. (2009), they surveyed the views of designers from both Singapore and Hong Kong and indicated that higher upfront costs, lack of education, lack of incentives, and lack of awareness were the most important barriers to green building.

Bond (2011) showed that cost and lack of information were major barriers to green building in Australia and New Zealand. Love et al. (2012) identified lack of government incentives, lack of knowledge and experience, lack of building codes and regulations, and poor relationship between stakeholders as the main barriers to implementing GBTs in Australia. Tagaza and Wilson (2004) also highlighted the major barriers to green building in Australia: higher costs of green materials, risks and uncertainties involved, unfamiliarity with GBTs, lengthy GBTs implementation time, and lengthy planning and approval process for new GBTs within a firm.

Williams and Dair (2007) presented twelve barriers to sustainable building in England, five of which were cost, lack of demand from clients, unavailability of sustainable materials and products, lack of information and awareness, and inadequate expertise. Winston (2010) found that inadequate building regulations and limited knowledge and expertise were barriers that hinder sustainable housing development in Ireland. There are other studies in the literature that primarily focused on green building barriers within the context of developed countries such as Sweden (Persson and Grönkvist, 2015), Brazil (Kasai and Jabbour, 2014), and Finland (Häkkinen and Belloni, 2011).

Regarding green building barriers studies in developing countries, Bin Esa et al. (2011), Zainul Abidin et al. (2012, 2013), Samari et al. (2013), and Yusof and Jamaludin (2014) all focused specifically on Malaysia. Also, all of these studies: Zhang et al. (2011a, b, c), Shi et al. (2013), Zhang and Wang (2013), Du et al. (2014), Mao et al. (2015), and Shen et al.

(2017b) focused specifically on China. Major barriers identified by the Malaysian and Chinese studies included, but not limited to, lack of knowledge and expertise, lack of market demand, lack of green building codes and regulations, lack of incentives, and lack of databases and information. Other green building barriers studies conducted within the context of developing countries are the studies of Potbhare et al. (2009) and Luthra et al. (2015) in India, Aktas and Ozorhon (2015) in Turkey, and Djokoto et al. (2014) in Ghana.

The above literature review identifies that except China and Malaysia, developing countries have seen very few studies identifying the barriers to GBTs and practices adoption. As different regulations and conditions exist in different countries, it is necessary to better understand the barriers facing GBTs adoption in specific countries (Aktas and Ozorhon, 2015). That will help in efforts to address the barriers and promote the adoption of GBTs. However, comprehensive investigations and surveys on the barriers inhibiting the adoption of GBTs in Ghana are scarce. The related study by Djokoto et al. (2014) was limited to the viewpoint of consultants on the barriers to sustainable construction in general. Therefore, a comprehensive analysis of the GBTs adoption barriers in Ghana combining the views of different stakeholders is worthwhile.

3. Research methodology

3.1. Identification of barriers to GBTs adoption

Previous studies (Lam et al., 2009; Zhang et al., 2011a, b) have reported that several barriers hindered GBTs and practices adoption in the construction industry. After a thorough review of these studies, 26 potential barriers to GBTs adoption were identified in this study, as listed in Table 1. This is a list of factors that are well documented in previous research and therefore are more applicable. For example, cost, lack of information, and lack of awareness are commonly acknowledged in the literature as crucial barriers to the adoption of GBTs and practices. Thus, the identification of the set of 26 potential barriers focused mainly on factors that have received considerable attention in previous studies conducted in different countries and contexts. Rowlinson (1988) argued that it is more appropriate to use well-known factors for a research study, as that would allow respondents to respond easily.

<Insert Table 1 about here>

3.2. Data collection

The questionnaire survey is a systematic technique of data collection based on a sample (Tan, 2011). It has been extensively used to solicit professional opinions in green building research (Wong et al., 2016; Shen et al., 2016). In this study, to investigate the criticalities of various barriers to GBTs adoption, a questionnaire survey was carried out. Thus, the research reported in this paper is a quantitative research (Creswell, 2014). The development of the questionnaire was supported by the comprehensive literature review. Prior to the questionnaire survey, a two-step procedure was followed to assess the appropriateness and rationality of the questionnaire. First, the questionnaire was reviewed by an international expert (a professor who had over 10 years of experience in green building) on question construction, ensuring that ambiguous expressions were not contained in the survey and that appropriate technical terms were used. Second, interviews were conducted with four professionals who had several years' experience in the local construction industry and possessed relevant experience in green building. They were requested to assess whether the questionnaire covered all potential barriers, considering the background of GBTs adoption in the Ghanaian construction market, and whether any factors could be added to, or removed from the survey. Based on the feedback, the questionnaire was finalized. In the finalized questionnaire, the objectives of the research and contact details were first presented, followed by questions meant to gather background information of the respondents. Afterward, the respondents were asked to rate the criticalities of the 26 barriers in GBTs adoption using a five-point Likert scale (1 = not critical, 2 = less critical, 3 = neutral, 4 = critical, and 5 = very critical). To have a better understanding of the survey, a sample of the survey questionnaire is provided in Appendix A; however, due to the space/word limitation, the section on background information of respondents is excluded.

The population comprised all industry practitioners with knowledge and understanding of GBTs use in Ghana. Since there was no sampling frame for this study, the sample was a nonprobability sample (Zhao et al., 2014). The nonprobability sampling technique can be utilized to acquire a representative sample (Patton, 2001). It is appropriate when a completely random sampling method cannot be used to select respondents from the whole population, but the respondents can rather be selected on the basis of their willingness to partake in the research (Wilkins, 2011). Thus, a snowball sampling method was used in this study to obtain a valid and effective overall sample size. The snowball method was also used in previous construction management studies (Zhang et al., 2011b; Mao et al., 2015), and it allows the gathering and sharing of information and respondents through referral or social networks. Local companies that have been directly involved in the construction of green buildings in Ghana were approached to identify the initial respondents. In the Ghanaian context, this study defines green buildings as buildings that have either obtained the South Africa's Green Star certification or the US's Leadership in Energy and Environmental Design (LEED) certification. The initially identified respondents were asked to share information regarding other knowledgeable participants. Using this approach, a total of 96 survey questionnaires were administered to collect responses from contractor, consultant, and developer companies. Finally, 43 sets of questionnaires with valid responses were returned, yielding a 44.8% response rate. Although the sample size was relatively small, statistical analyses could still be performed because according to the commonly accepted rule, with a sample size of 30 or above, the central limit theorem holds true (Ott and Longnecker, 2010; Hwang et al., 2015).

Moreover, because GBTs have not been widely adopted in the construction market of Ghana, it is difficult to obtain a very large sample of experienced professionals.

The profiles of the respondents are shown in Table 2. The respondents consisted of 13 engineers, 11 quantity surveyors, 9 architects, 9 project managers, and 1 contracts manager, among which 16, 14, and 13 respondents were from consultant, contractor, and developer companies, respectively.

<Insert Table 2 about here>

3.3. Data analysis techniques

3.3.1. Cronbach's alpha technique

One of the most popular methods for assessing the reliability of scales is Cronbach's alpha method. Cronbach's alpha determines the average correlation or internal consistency among factors in a survey questionnaire to assess the questionnaire's reliability. The Cronbach's alpha coefficient (α) value ranges from 0 to 1 and can be used in describing the reliability of factors extracted from multipoint and/or dichotomous formatted scales or questionnaires (Santos, 1999). The higher the α value, the more reliable is the adopted scale of measurement. However, the general rule is that to conclude that the scale is reliable, the α value must not be less than 0.70 (Nunnally, 1978). Using the SPSS 20.0 statistical software, the computed α value for the 26 GBTs adoption barriers was 0.867, indicating that the measurement using the five-point Likert scale was reliable at the 5% level of significance. The collected sample can, therefore, be treated as a whole and thus suitable for further ranking analysis as well as factor analysis (FA) in the following sections (Mao et al., 2015).

3.3.2. Mean score ranking technique

As a typical quantitative analysis method for ranking the relative importance/criticality of factors (Cheng and Li, 2002; Chan et al., 2010), the mean score ranking technique (MS) was used in previous green building studies (Darko et al., 2017b, c). In this study, the MS was used to determine the relative ranking of the 26 GBTs adoption barriers in descending order of criticality, as perceived by the respondents. If two or more barriers happened to have the same mean score, the barrier with the lowest standard deviation (SD) was assigned the highest rank. The normalized values of the mean scores were then calculated to identify the critical barriers among the 26 GBTs adoption barriers (Xu et al., 2010; Zhao et al., 2014).

3.3.3. Agreement analysis techniques

Kendall's coefficient of concordance (Kendall's *W*) is a nonparametric test commonly used to ascertain the overall agreement among sets of rankings (Siegel and Castellan, 1988). This method does not require any specific distribution of the tested data (Lam et al., 2015). As such, Kendall's *W* test was conducted to check whether different respondents within a certain group agreed on the ranking of the barriers. The null hypothesis of the Kendall's *W* test is that "there is no agreement among the rankings given by the respondents". Kendall's *W* ranges in value from 0 to 1, where a value of 0 indicates "no agreement" and 1 indicates "complete agreement". If the Kendall's *W* value generated from the test is at a low significance (significance level $\leq$ 0.001), then the null hypothesis can be rejected, and conclusion that some degree of agreement exists among the respondents can be drawn (Siegel and Castellan, 1988). In addition to the Kendall's *W* test, as the respondents were from different companies (consultant, contractor, and developer companies), it was important to check whether significant differences exist among respondents from different companies. To this end, analysis of variance (ANOVA) test was performed to determine whether the differences in mean scores from the three respondent groups according to company type were statistically significant. ANOVA is a widely used method that is suitable for comparing the mean scores from three or more groups (Pallant, 2011, Chan et al., 2016).

3.3.4. Factor analysis technique

FA was used to identify the underlying grouped barriers for the critical GBTs adoption barriers identified in this study. FA is a statistical method whose purpose is to identify a relatively small number of factor groupings that can be used to represent relationships among sets of many interrelated variables (Norusis, 2008). It is a powerful method for regrouping and reducing a large number of factors to a smaller and more critical set by factor scores of the responses (Li et al., 2011). However, the appropriateness of FA for the factor extraction needs to be examined before applying FA. Thus, in this research, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to determine the appropriateness of FA.

The KMO is a measure of sampling adequacy that represents the ratio of the squared correlation between the variables to the squared partial correlation between the variables (Field, 2013). The KMO value ranges from 0 to 1. A value of 0 is an indication that the sum of partial correlations is large relative to the sum of correlations, indicating diffusion in the pattern of correlations and thus FA would be inappropriate (Norusis, 2008). On the other hand, a value close to 1 is an indication that patterns of correlations are relatively compact and thus FA would yield reliable and distinct factors (Field, 2013). For a satisfactory FA to proceed, the KMO value should be above the acceptable threshold of 0.50 (Kaiser, 1974; Norusis, 2008; Field, 2009). However, the level of acceptance of KMO value varies depending on the KMO value, as shown in Table 3.

<Insert Table 3 about here>

Bartlett's test of sphericity is a statistical test that highlights the presence of correlations between the variables (Chan et al., 2010). It is used to assess whether the original correlation matrix is an identity matrix, which would indicate that there is no relationship among the variables and hence FA would be inappropriate (Pett et al., 2003). When the value of the test statistic for sphericity is large and the associated significance level is small, the population correlation matrix is not an identity matrix and hence FA would be appropriate (Pallant, 2011).

4. Survey results

Two main approaches have been used to analyze the barriers to GBTs adoption: ranking analysis and FA. This section presents the analysis results. The section first presents the results of the ranking analysis and then compares them with some developed countries. Afterward, the section presents the results of the FA.

4.1. Results of ranking analysis

The summary of the ranking analysis results on the barriers to GBTs adoption is shown in Table 4. The mean scores of the criticality of the barriers range from 2.93 to 4.51. Barriers with normalized values not less than 0.50 are identified as critical barriers hindering the adoption of GBTs in Ghana.

<Insert Table 4 about here>

Table 4 indicates that 20 out of the initial 26 barriers have normalized values not less than 0.50, and are therefore deemed critical barriers. Expectedly, “higher costs of GBTs” was ranked first with the highest mean score (mean = 4.51), indicating that cost is the most critical barrier inhibiting the adoption of GBTs in the Ghanaian construction market. This finding agrees with the findings of numerous previous studies conducted within the context of developing countries (Potbhare et al., 2009; Zhang et al., 2011a, b). The second, as ranked by the respondents, was “lack of government incentives” (mean = 4.26), followed by “lack of financing schemes (e.g., bank loans)” as the third (mean = 4.12), and “unavailability of GBTs suppliers” as the fourth (mean = 4.07). “Lack of local institutes and facilities for R&D of GBTs” was ranked as the fifth most critical barrier (mean = 4.02).

The Kendall’s *W* value for ranking the 26 barriers was 0.097, and the significance level of Kendall’s *W* was at 0.000, which indicates that a significant degree of agreement exists among all the respondents in a particular group regarding the ranking of barriers to GBTs adoption. From the ANOVA results, the significance values of 25 barriers were greater than 0.05 (Table 4). The result indicates that there were no statistically significant differences in the perceptions of the criticality of these barriers from consultants, contractors, and developers. For the barrier “lack of GBTs promotion by government”, the differences in perceptions were statistically significant. The perception of the criticality of this barrier from the developers (mean = 4.46, rank 1) was higher than that from the consultants (mean = 3.81, rank 13) and contractors (mean = 3.57, rank 20), which may imply that the lack of promotion by government affected the developers’ adoption of GBTs more. The role of the government is known to be a factor that usually has a significant influence on developers’ green building behaviors (Shen et al., 2016).

4.1.1. Comparison with developed countries

After identifying the top five barriers to GBTs adoption in Ghana’s construction market, based upon the results from this study and that from Chan et al. (2016), the top five most critical GBTs adoption barriers in the developing country of Ghana and that in three selected developed countries – the US, Canada, and Australia – were compared, as shown in Table 5. Albeit other studies could have been selected for this results comparison, Chan et al.’s (2016) study was selected because it analyzed a set of GBTs adoption barriers, similar to what is analyzed in this study. In the study of Chan et al. (2016), the views of the top five most critical GBTs adoption barriers among the US, Canada, and Australia were compared. Expanding Chan et al.’s (2016) comparison to include views from developing countries can provide insights that would be useful for policy makers and practitioners in both developed and developing countries. As such, this study compares the views among Ghana, the US, Canada, and Australia. As shown in Table 5, the barriers that occurred in the top five ranked GBTs adoption barriers in Ghana as well as in any of the three selected developed countries are marked with the symbol "√". And those that did not occur in the top five ranked barriers in any of the three selected developed countries are marked with the symbol "–". In any case, Table 5 also shows the respective rank (in bracket) of a certain barrier in a particular country.

<Insert Table 5 about here>

It is interesting to note that higher costs of GBTs is the only barrier appearing in the top five GBTs adoption barriers in Ghana and in all the three selected develop countries, with its ranks across all the countries being close (Table 5). This implies that the higher costs of GBTs is a top barrier affecting GBTs adoption not only in Ghana's construction market, but also in the construction markets of many developed countries including the US, Canada, and Australia. Nguyen et al. (2017) also pointed out that higher cost is the most recognized barrier to green building adoption in both developed and developing markets. The finding of the present study suggests that the development of cheaper yet efficient GBTs can help further the adoption of GBTs in the construction market worldwide.

On the other hand, it is worth noting that lack of government incentives appeared in the top five GBTs adoption barriers in only Ghana and the US, and it is rather close to becoming one of the top five barriers in Canada and Australia. Furthermore, it can be noted that these three barriers – lack of financing schemes (e.g., bank loans), unavailability of GBTs suppliers, lack of local institutes and facilities for R&D of GBTs – did not appear in the top five barriers in the US, Canada, and Australia, and their ranks in these countries are very different from the Ghanaian ranks. For example, while unavailability of GBTs suppliers was ranked fourth in Ghana, it was ranked fourteenth, twenty-fifth, and thirteenth in the US, Canada, and Australia, respectively. The results reveal that the most critical GBTs adoption barriers in the developing country of Ghana mostly differ from those in the developed countries of the US, Canada, and Australia. The reason for the differences could be attributed to the maturity of the GBTs adoption activity in Ghana in comparison with that in developed countries; the Ghanaian GBTs adoption activity is less mature compared to that of developed countries (Darko et al., 2017d). This further explains why it is necessary to better understand the critical barriers encountered in GBTs adoption in specific countries so that appropriate measures can be put in place for GBTs adoption promotion. To conclude, the above comparison has shown that while the most critical GBTs adoption barriers in the developing country of Ghana mostly vary from those in the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all the countries.

4.2. Results of factor analysis

In order to better understand the barriers to GBTs adoption in Ghana, the 20 critical barriers (variables) identified in this study were subjected to FA. The KMO value of this study is 0.562, which is acceptable as it satisfies the threshold of 0.50 (Table 3). It is values below 0.50 that should lead the researcher "to either collect more data or rethink which variables to include" (Field, 2013, p. 685). The KMO value could easily be improved through deleting some of the variables for FA using certain exclusion criteria. However, a number of factors, such as the contribution of the variable to the interpretation of the factor group, should be taken into consideration in the decision to delete a variable. It is recommended that variables with factor loadings exceeding or being close to 0.50 should be retained because they are significant in contributing to the interpretation of the factor group (Akintoye, 2000; Matsunaga, 2010). Table 6 shows that all factor loadings exceeded or were close to 0.50, with 18 (90%) of them exceeding 0.50; therefore, all the variables were included in the FA. In this research, the chi-square value in Bartlett's sphericity test is large (383.730) and the associated significance level is small (0.000), suggesting that the population correlation matrix is not an identity matrix. This further reinforces the appropriateness of using FA.

<Insert Table 6 about here>

For factor extraction, principal component analysis technique was employed to identify underlying grouped barriers. Table 6 summarizes the results of FA after varimax rotation. Five underlying groupings (components) with eigenvalues greater than 1 were extracted, explaining 62.82% of the variance. This indicates that with these five components, the highest percentage (> 50%) of the variance is explained by GBTs adoption barriers. Moreover, the 62.82% of total variance explained compares favorably with the 58.68% of total variance explained in a recent study (Osei-Kyei and Chan, 2017). In this study, the remaining 15 components altogether explained only 37.18% of the total variance, indicating that a model with the five extracted components can adequately be used to represent the data (Li et al., 2011; Chan et al., 2016).

As shown in Table 6, the 20 independent variables are split into five meaningful groupings, with seven variables belonging to grouping 1, five variables belonging to grouping 2, three variables each belonging to groupings 3 and 4, and two variables belonging to grouping 5. To facilitate further discussion, it is necessary to rename the five extracted groupings based on the analysis results. Hence, the five underlying grouped barriers can be renamed as follows:

- Grouping 1: Government-related barriers;
- Grouping 2: Human-related barriers;
- Grouping 3: Knowledge and information-related barriers;
- Grouping 4: Market-related barriers; and
- Grouping 5: Cost and risk-related barriers.

5. Discussion of results

5.1. Grouping 1: Government-related barriers

This underlying group highlights the government’s role in the promotion of GBTs adoption in Ghana, and it is represented by seven critical barriers: (1) lack of green building rating systems and labeling programs, (2) lack of green building codes and regulations, (3) lack of green building technological training for project staff, (4) lack of GBTs promotion by government, (5) lack of demonstration projects, (6) lack of local institutes and facilities for R&D of GBTs, and (7) lack of government incentives. The seven critical barriers under this group cover issues that fall within the purview of government. This group is the most dominant among all the five groups, explaining the greatest variance (27.03%) from a statistical point of view (Table 6).

Although lack of government incentives has the least factor loading in this group, it is the most critical barrier in this group according to the results of this study (Table 4). At the current stage of GBTs adoption in Ghana, lack of government incentives is a major barrier to GBTs adoption. Ozdemir (2000, p. 13) define an incentive as "something that influences people to act in certain ways". In essence, in the context of green building, incentives act as motivators compelling people to actually adopt GBTs in their construction projects. Therefore, without incentives from the government, industry practitioners and stakeholders might not adopt GBTs. As GBTs adoption in Ghana is still in its infancy (Darko et al., 2017d), currently, there exist no government incentives to motivate GBTs adoption in the country. This situation may explain why lack of government incentives is considered a critical barrier to GBTs adoption in Ghana. In order to promote GBTs adoption, it is necessary for the government to establish effective incentive schemes. For example, the government could provide financial incentives (e.g., tax credits) and non-financial incentives (e.g., expedited permitting) for GBTs adopters. Similar to the finding of this study, Shen et al. (2017b) found that lack of government incentives is a significant barrier to the adoption of green procurement in China.

Another critical barrier is the lack of local institutes and facilities for R&D of GBTs. Hwang and Tan (2012) stressed the importance of R&D to the adoption and development of green building systems. However, a huge gap exists between funding for building related R&D and that for R&D in other vital sectors. By any conventional yardstick, public and private sectors typically make minimal R&D or innovation investment in the building sector (US Green Building Council (USGBC), 2003). Compared to developed countries, developing countries have much smaller percentage of government's R&D budget allocated to the building sector. For example, in China, only 0.4 to 0.6% of the government's R&D budget is allocated to the building sector, which lags behind the 0.6 to 1% allocated by developed countries such as the UK (Shen, 2008). The finding of this study suggests that there is an absence of accredited institutions that conduct credible scientific research on GBTs and their benefits in Ghana, resulting in poor market demand for GBTs. It would therefore be useful if the government of Ghana could provide necessary funding for the establishment of green technology research institutes and centers.

The lack of demonstration projects probably reflects the immaturity of the green building industry in Ghana. Demonstration projects are helpful for testing the performance of a technology in different operational environments; they also help to shorten the time a particular technology takes to make its way from development and prototype to wider adoption by users (Lefevre, 1984; Karlström and Sandén, 2004). More importantly, demonstration projects can demonstrate the effectiveness of different GBTs at enabling successful development of green buildings. Unless there is adequate availability of experienced professionals in the industry, government funded demonstration projects may be required to accelerate the adoption of new GBTs (Brown and Hendry, 2009). This study has found that the implementation of GBTs in the construction market of Ghana is greatly hindered by the lack of demonstration projects. A similar situation was identified by Potbhare et al. (2009), where the lack of demonstration projects was a barrier to the adoption of green building guidelines in India.

Lack of green building codes and regulations hinders the adoption of GBTs. Government policies and regulations are important instruments for promoting GBTs adoption. Government should be aware that in the early stages of GBTs adoption, its guidance and support are essential for successful and widespread adoption. That is to say, the promotion of GBTs adoption in the construction industry is to a large extent dependent upon government policies and regulations (Gou et al., 2013; Zhang, 2015). If expectations from GBTs adoption are clearly defined in the form of regulatory requirements, then stakeholders would comply. In developing countries where GBTs adoption is fairly new to the construction market, it is expected that organizations and individuals dither to take relevant actions without regulations in place. Thus, a lack of green building codes and regulations inhibits GBTs adoption in Ghana at the moment. This finding is consistent with findings of studies done in Malaysia (Samari et al., 2013) and India (Luthra et al., 2015). The finding implies that the Ghanaian government should assume a more active role in the pursuit of implementing sustainability in the construction industry by developing policies and regulations to promote GBTs adoption. That would even be a more efficient and preferred way to promote GBTs adoption, as in the current economic conditions, it may not be easy for the government to offer grants or soft loans to GBTs adopters.

Training of staff is highly essential for the success of implementing new technology and software (Succar et al., 2013). The implementation of green building projects differs from that of traditional building projects not only in terms of the processes, design, and materials, but also the technologies involved. The use of GBTs is a key component of the implementation of green building projects. Therefore, a lack of training for project staff to efficiently operate GBTs can have a negative impact on the successful implementation of green building projects. The government allocating funds for green building trainings to educate the industrial practitioners or the public (Hwang et al., 2017) would significantly assist in facilitating the use of GBTs in the construction industry.

Government's endorsement and promotion of a GBT can accelerate its adoption in a country because that can validate the effectiveness of the technology to the public (Potbhare et al., 2009). Consequently, a lack of GBTs promotion by government can be a critical barrier to GBTs adoption. The study result suggests that there are no government initiatives in the form of local authorities and strategies to promote the adoption of GBTs in Ghana. Djokoto et al. (2014) also found that lack of strategy to promote is a major barrier to sustainable construction in Ghana. It is therefore considered that the formation of promotion strategies and promotion teams that can influence the public would be effective means for the Ghanaian government to promote GBTs adoption.

Lack of green building rating systems and labeling programs is another critical barrier in this group. Internationally recognized green building rating systems, such as the LEED, could be useful for promoting GBTs adoption at both international and national levels. However, localized green building rating systems would be more effective at the local level, as they are developed with much more attention given to local sustainability priorities. At present, Ghana does not have its own green building rating systems, which has been identified as a critical barrier affecting GBTs adoption in the country. This finding indicates that localized green building rating systems are needed to encourage and incentivize the industrial practitioners to push the boundaries on sustainability. While the Ghana Green Building Council (GHGBC) has the most important role to play in this respect, the government and other non-governmental organizations ought to be supportive.

5.2. Grouping 2: Human-related barriers

This underlying group explains 11.56% of the total variance and consists of five critical barriers: (1) lack of importance attached to GBTs by senior management, (2) resistance to change from the use of traditional technologies, (3) unavailability of GBTs suppliers, (4) unfamiliarity of construction professionals with GBTs, and (5) lack of financing schemes (e.g., bank loans). These five barriers are much related to the attitudes and behaviors of people.

Lack of financing schemes (e.g., bank loans) ranks among the top five barriers, which is in line with previous studies carried out in developing countries (Samari et al., 2013; Luthra et al., 2015). This finding clearly shows that financial/economic issues are crucial for the adoption and development of GBTs in Ghana. The lack of financing schemes, as a barrier to GBTs adoption, is closely related to the barrier higher costs of GBTs. It is deadly to GBTs adoption because without a better financial foundation, companies and industry practitioners would not be able to purchase and use expensive GBTs. Thus, the lack of financing schemes could explain why higher costs of GBTs was also ranked among the top five barriers. To overcome the lack of financing schemes barrier, banks and other financial institutions should provide financial supports, e.g., soft loans and grants, for GBTs adoption. Learning from the experiences of developed countries would be a very helpful approach to promote GBTs adoption in developing countries. In Hong Kong, for instance, it is “not difficult to obtain financing from banks for green projects” (Gou et al., 2013, p. 169), helping green building development in the country. Using public-private partnership financing schemes in the green building domain would also afford an opportunity to deal with the lack of financing schemes barrier.

Suppliers play a crucial role in successful adoption of GBTs. They are not only the vendors who provide the industry with the needed GBTs, but also the main sources of information regarding the GBTs. Therefore, the unavailability of GBTs suppliers is considered a critical barrier to GBTs adoption in the Ghanaian construction market. To improve sustainability performance in an industry, experiences from several other industries have demonstrated that there is the need to integrate suppliers into sustainability management initiatives (Zhu et al., 2007; Shen et al., 2016). This barrier is closely related to the barrier unavailability of GBTs in the local market in that if the suppliers of the GBTs are unavailable, then the GBTs themselves would also be unavailable. The research finding of unavailability of GBTs suppliers concurs with studies in China (Shi et al., 2013) and Hong Kong (Lam et al., 2009; Gou et al., 2013). This suggests that the current GBTs supply chain is immature with a shortage of suppliers.

Lack of importance attached to GBTs by senior management is a critical barrier to GBTs adoption because if top management do not perceive GBTs as a priority, it is a challenge for firms to introduce them in their projects. The adoption of GBTs requires top management's involvement and support. It is almost impossible to adopt especially new GBTs without the top management's commitment or approval. Given that GBTs adoption is a top-down approach where senior management have more influence and authority than employees in the lower hierarchy of firms (Ball, 2002), the commitment, leadership, and support of senior management and the board of directors are pivotal conditions for GBTs adoption. Lam et al. (2009) argued that there is an important relationship between the degree of support from senior management on adoption and the willingness to adopt green practices. Senior management's commitment and support can foster a conducive environment for innovation. In most cases, the senior management's commitment to GBTs adoption tends to result from the level of importance they attach to GBTs (Chan et al., 2016). Otherwise, the commitment from top management towards GBTs adoption would have to be driven by external forces such as the need to comply with regulatory requirements.

Another critical barrier to GBTs adoption is resistance to change from the use of traditional technologies, resulting from stakeholders' deep rooted traditional ideas. According to DuBose et al. (2007), because liability is a serious issue within the construction industry, construction stakeholders are naturally resistant to change. This barrier is also closely associated with other barriers such as the higher costs of GBTs, the lack of financing schemes, the lack of awareness of GBTs and their benefits, the lack of professional knowledge and expertise, the lack of information, and the unfamiliarity with GBTs. Although the resistance to change has been found the most critical barrier to GBTs adoption in some previous studies (Du et al., 2014; Chan et al., 2016; Darko et al., 2017c), based on the results of this study, it can be stated that within the Ghanaian context, resistance to change is only deemed a critical (not the most critical) barrier; cost and financial barriers are much more critical in GBTs adoption.

Unfamiliarity of construction professionals with GBTs inhibits the adoption of GBTs in Ghana. Arditi and Gunaydin (1997) mentioned that in order to ensure construction quality, the construction technologies used by the contractor must be familiar to the design professionals. Zhang et al. (2011a) also indicated that the unfamiliarities with GBTs and technical difficulties can result in delays in the design and construction processes of green building projects. Owing to these issues, unfamiliarity of construction professionals with GBTs can cause them to accept only those traditional construction projects involving technologies that they are already most familiar with. The results of this study suggest that as most GBTs are relatively new and not available in the Ghanaian construction market, many construction professionals in Ghana are not familiar with them, causing them to eschew GBTs adoption.

5.3. Grouping 3: Knowledge and information-related barriers

This underling group explains 10.42% of the total variance and consists of three critical barriers: (1) lack of professional knowledge and expertise in GBTs, (2) lack of GBTs databases and information, and (3) lack of awareness of GBTs and their benefits.

Having professional knowledge and expertise is a key factor in successful GBTs adoption. The global trend towards GBTs adoption creates an increasing and urgent need for green skilled professionals and workers. To achieve high performance results in an organization, skilled workers are required in every department (Ozorhon and Karahan, 2016). This is even more necessary in GBTs adoption because the workers need to be skilled to efficiently handle every aspect of the adoption process, including the technological, the managerial, and the technical aspects. With the presence of skilled workers within an organization, the needs could be identified without difficulty, and successful adoption could be attained in a rapid manner (Ozorhon and Cinar, 2015). On the other hand, the absence of workers with the necessary skills, expertise, and knowledge would make it difficult for an organization to adopt GBTs. As barriers to GBTs adoption, the lack of knowledge and expertise has been found to be more critical than the lack of training for project staff, which are assumed to be knotted to each other.

Lack of GBTs databases and information cannot encourage the market to adopt GBTs, as access to relevant information is of strategic importance to GBTs adoption. Darko et al. (2017c) indicated that availability of better information is essential for GBTs adoption. This study has identified that lack of GBTs databases and information hampers the adoption of GBTs in Ghana. This shows that it is difficult for practitioners within the current construction market of Ghana to find information and data relating to GBTs, which could be attributed to the lack of GBTs suppliers. This barrier should be removed in order to increase the pace of adoption of GBTs. To this end, the development of a comprehensive national database or an information system to provide the public with timely, accurate, and updated information about GBTs is proposed. Besides, industry associations could play an essential role by sharing relevant GBTs information between construction firms and government departments (Shi et al., 2013).

Lack of awareness of GBTs and their benefits also critically affects GBTs adoption in Ghana. Since it is costly to adopt GBTs, the sustainability benefits associated with GBTs play a huge role in pushing for their adoption (Chan et al., 2017). The finding of this study suggests that a lack of awareness of the sustainability benefits of GBTs is a major barrier for Ghanaian practitioners and the public to adopt GBTs. This barrier is closely related to the lack of R&D of GBTs. Kibert (2008) claimed that it is mainly because of insufficient research affirming the benefits of GBTs that awareness within the industry is lacking. Educating the industry practitioners and the public on the benefits of GBTs would help promote the adoption of GBTs. For this purpose, new research studies demonstrating the benefits of GBTs could be conducted or existing studies and fact sheets could be well utilized.

5.4. Grouping 4: Market-related barriers

Similar to group 3, this underlying group also consists of three critical barriers, namely, (1) unavailability of GBTs in the local market, (2) lack of interest from clients and market demand, and (3) limited experience with the use of nontraditional procurement methods. However, this underlying group explains 7.33% of the total variance.

Lack of interest from clients and market demand is considered a critical barrier to GBTs adoption in the Ghanaian construction market. This indicates that construction practitioners in Ghana are in a market where demand for GBTs is low. Djokoto et al. (2014) also identified that lack of demand is a key barrier to sustainable construction in Ghana. Consumer interest and demand is a significant factor in determining the level of GBTs adoption and development. Market demand directly affects the costs and supply of GBTs. A difficult situation for every businessman is the lack of market demand; when there is a lack of market demand, businessmen worry about the feasibility of their business. As long as most construction stakeholders and practitioners remain businessmen, a lack of market demand could give them a valid reason to refrain from GBTs adoption. Because clients are key decision makers in GBTs adoption (Hwang and Tan, 2012), a lack of interest from them can negatively affect GBTs adoption. The lack of market demand for GBTs can be attributed to the lack of awareness on the part of the public and consumers (Mao et al., 2015). Therefore, increasing public awareness of the benefits of GBTs would stimulate market demand for GBTs.

Unavailability of GBTs in the local market is a widely recognized barrier to GBTs adoption in developing countries (Aktas and Ozorhon, 2015; Shen et al., 2017b). It is one of the major barriers in Ghana because most GBTs are not manufactured and sold locally. Mao et al. (2015) argued that, to a certain extent, the adoption of GBTs depends on the GBTs available in the local construction market, making the availability of GBTs in the local market crucial for GBTs adoption. The research findings suggest that Ghanaian practitioners have a hard time trying to find GBTs suppliers in the local market. The GBTs often have to be imported from other countries, such as the US and China, where the GBTs markets are relatively better developed. Although the global suppliers could offer innovative solutions, that may come with high costs, which has also been recognized as a critical barrier.

Limited experience with the use of nontraditional procurement methods is another critical barrier that prevents the adoption of GBTs. The procurement of green technologies and materials – which is known as green procurement – differs from traditional procurement. While green procurement factors "environmental concerns into major purchasing strategies, policies, and directives" (Green Council, 2010), the traditional procurement method does not. As such, to eliminate possible errors in the green procurement process, extensive experience in green procurement is crucial; that is, without extensive experience in green procurement, it would be difficult to adopt GBTs.

5.5. Grouping 5: Cost and risk-related barriers

This underlying group explains 6.47% of the total variance and comprises two critical barriers: (1) higher costs of GBTs and (2) risks and uncertainties involved in adopting new technologies.

Cost is considered a key and sensitive barrier to the adoption of GBTs in Ghana. The higher costs of GBTs, identified as the most critical barrier in this study (Table 4), is emphasized by industry practitioners who show concern about cost when considering the application of GBTs. As identified in section 4.1.1, cost is a major barrier to GBTs adoption not only in Ghana, but also in many developed countries. It is well known that GBTs cost significantly more than their traditional counterparts (Kibert, 2008; Gou et al., 2013). For example, as a green substitute for traditional plywood, compressed wheat board costs about 10 times more than traditional plywood (Hwang and Tan, 2012). Consequently, many industry practitioners believe that the application of GBTs can increase project cost by 10-20% (WorldGBC, 2013). In the developing country of Ghana where poverty is widespread and entrenched in many areas of the country (Cooke et al., 2016), the higher costs associated with adopting GBTs can greatly hinder GBTs adoption. This cost barrier is closely related to other barriers, including the lack of government incentives, the lack of financing schemes, and the lack of awareness of GBTs and their benefits. Thus, although it is anticipated that with more experience, practitioners would be able to deal with the cost barrier (Chan et al., 2016), incentives can offset the extra costs involved in GBTs adoption. The cost barrier can also be overcome by using successful green building projects to show the real cost and benefits of adopting GBTs in the Ghanaian market.

Risks and uncertainties involved in adopting new technologies is also considered a critical barrier faced in GBTs adoption in the Ghanaian construction market. According to Ozorhon and Karahan (2016, p. 7), “the more diffused a certain technology in the construction market, the less risky it will become to implement it”. Therefore, as GBTs adoption is relatively new to the Ghanaian construction market, it is difficult to convince many construction stakeholders to adopt GBTs. It is not uncommon for construction stakeholders to be uncertain about the system performance of new GBTs. Uncertainty in the performance of GBTs can also be deadly to a green building project because it can reduce the overall efficiency of the project (Shi et al., 2013). This may explain why Ghanaian practitioners avoid GBTs adoption because of the uncertainties involved. The finding of this study suggests that how much risk stakeholders are willing to accept plays a major role in the adoption of new GBTs.

6. Concluding remarks

As a way of implementing sustainability within the construction industry, GBTs adoption has received a high level of global attention in recent times. However, GBTs adoption in the developing country of Ghana is still in its infancy and facing numerous barriers. These barriers need to be addressed in order to facilitate the successful and widespread adoption of GBTs. To this end, this study aimed to investigate the critical barriers to GBTs adoption in Ghana. To achieve the aim, 26 barriers were identified from a comprehensive literature review. Through a questionnaire survey with 43 professionals in Ghana, the results first indicated that 20 out of the 26 barriers were critical barriers to GBTs adoption, with the most critical barriers being higher costs of GBTs, lack of government incentives, and lack of financing schemes (e.g., bank loans). Moreover, a comparative analysis pointed out that while the most critical barriers to GBTs adoption in the developing country of Ghana mostly vary from those in the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all the countries. Furthermore, factor analysis revealed that the underlying grouped barriers for the 20 critical barriers were government-related, human-related, knowledge and information-related, market-related, and cost and risk-related barriers. The results also showed that the most dominant of the five underlying groups was government-related barriers. This implies that there is a need for the government to play a more active role in promoting GBTs in Ghana.

The findings of this study not only contribute to filling the gap in knowledge concerning green building barriers in developing countries, but also provide valuable reference for helping policy makers and practitioners take suitable measures to mitigate the GBTs adoption barriers and consequently promote GBTs adoption. Moreover, this study would be useful and helpful for international organizations and advocates interested in promoting GBTs adoption in Ghana to ultimately achieve more sustainable building developments.

Although the objective was achieved, this study still has some limitations that are worth mentioning. These limitations not only warrant future research, but must also be considered when interpreting and generalizing the results. First, the criticalities assessment made in this study could be influenced by the respondents' attitudes and experiences, as it was subjective. Apart from that, although the sample size and the KMO value of this study were adequate for conducting statistical analyses, it is appreciated that they are nevertheless relatively small. Increasing the sample size could improve the KMO value; thus, future research with a larger sample size would be useful to see whether the results would significantly differ from those reported in this study. Moreover, future study could analyze the differences between the GBTs adoption barriers in Ghana and many more developed countries. Lastly, albeit the findings of this study might be of use to policy makers and practitioners in other developing countries the world over, data gathered from a different country may produce different findings. Therefore, using the proposed GBTs adoption barriers, similar studies could be undertaken in different developing countries to observe market-specific differences, which would help in developing market-specific solutions to remove the barriers.

This paper reports upon the partial findings of a large-scope research on the promotion of GBTs adoption in a developing country. While this paper reports only the outcomes on the

GBTs adoption barriers, the future research paper will report the empirical findings on the strategies to overcome the barriers and thereby promote the wider adoption of GBTs. As a future study, the interrelationships among the critical barriers and their impacts on the GBTs adoption activity will also be investigated/modeled.

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Appendix A. Sample of the survey questionnaire.

Please assess how critical each of the following barriers is to the adoption of green building technologies (GBTs) in Ghana. Use the following rating scale: 1 = not critical; 2 = less critical; 3 = neutral; 4 = critical; 5 = very critical.

<Insert Table 7 about here>

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Table 1
List of potential GBTs adoption barriers identified from the literature.

Code	Barrier Factors	References
B01	Higher costs of GBTs	Williams and Dair (2007), Lam et al. (2009), Chan et al. (2009), Zhang et al. (2011a, b, c), Hwang and Tang (2012), Shi et al. (2013), Chan et al. (2016), Darko et al. (2017c)
B02	Lack of GBTs databases and information	Williams and Dair (2007), Bond (2011), Bin Esa et al. (2011), Samari et al. (2013), Rodriguez-Nikl et al. (2015), Akadiri (2015)
B03	Lack of professional knowledge and expertise in GBTs	Eisenberg et al. (2002), Tagaza and Wilson (2004), Williams and Dair (2007), Lam et al. (2009), Winston (2010), Love et al. (2012), Ahn et al. (2013), Chan et al. (2016)
B04	Lack of awareness of GBTs and their benefits	Williams and Dair (2007), Chan et al. (2009), Zhang et al. (2011b, c), Bin Esa et al. (2011), AlSanad (2015), Chan et al. (2016), Darko et al. (2017c)
B05	Lack of government incentives	Chan et al. (2009), Potbhare et al. (2009), Zhang et al. (2012), Love et al. (2012), Darko and Chan (2016b), Darko et al. (2017c), Shen et al. (2017b)
B06	Lack of local institutes and facilities for research and development (R&D) of GBTs	USGBC (2003), Hwang and Tang (2012)
B07	Lack of green building codes and regulations	Winston (2010), Zhang et al. (2011b, c), Love et al. (2012), Samari et al. (2013), Luthra et al. (2015), AlSanad (2015)
B08	Lack of green building rating systems and labeling programs	Du et al. (2014), Persson and Grönkvist (2015), Kasai and Jabbour (2014)
B09	Unfamiliarity of construction professionals with GBTs	Eisenberg et al. (2002), Tagaza and Wilson (2004), Zhang et al. (2011a, b, c), Chan et al. (2016), Darko et al. (2017c)
B10	High degree of distrust about GBTs	Williams and Dair (2007), Winston (2010), Luthra et al. (2015)
B11	Conflicts of interests among various stakeholders in adopting GBTs	Williams and Dair (2007), Winston (2010), Hwang and Tan (2012), Love et al. (2012), Hwang and Ng (2013)
B12	Lack of interest from clients and market demand	Williams and Dair (2007), Zhang et al. (2011c), Hwang and Tan (2012), Gou et al. (2013), Djotoko et al. (2014), Darko and Chan (2016b)
B13	Unavailability of GBTs in the local market	Williams and Dair (2007), Potbhare et al. (2009), Gou et al. (2013), Aktas and Ozorhon (2015), Shen et al. (2017b)
B14	Adoption of GBTs is time consuming and causes project delays	Tagaza and Wilson (2004), Lam et al. (2009), Shi et al. (2013), Hwang and Ng (2013)
B15	Resistance to change from the use of traditional technologies	Meryman and Silman (2004), Ahn et al. (2013), Du et al. (2014), Darko and Chan (2016b), Chan et al. (2016), Darko et al. (2017c)
B16	Complex and rigid requirements involved in adopting GBTs	Hwang and Tan (2012), Hwang and Ng (2013),

		Chan et al. (2016)
B17	Lack of GBTs promotion by government	Zhang et al. (2012), Samari et al. (2013), Djokoto et al. (2014)
B18	Lack of importance attached to GBTs by senior management	Du et al. (2014), Darko and Chan (2016b)
B19	Risks and uncertainties involved in adopting new technologies	Tagaza and Wilson (2004), Häkkinen and Belloni (2011), Chan et al. (2016)
B20	Lack of green building technological training for project staff	Djokoto et al. (2014), Gou et al. (2013)
B21	Unavailability of GBTs suppliers	Lam et al. (2009), Shi et al. (2013), Gou et al. (2013)
B22	Lack of financing schemes (e.g., bank loans)	Potbhare et al. (2009), Zhang and Wang (2013), Luthra et al., 2015
B23	High market prices and rental charges of green buildings resulting from GBTs application	Häkkinen and Belloni (2011), Chan et al. (2016), Darko and Chan (2016b)
B24	Long payback periods from adopting GBTs	Ahn et al. (2013), Gou et al. (2013)
B25	Lack of demonstration projects	Potbhare et al. (2009), Chan et al. (2016), Darko et al. (2017c)
B26	Limited experience with the use of nontraditional procurement methods	Love at al. (2012), Chan et al. (2016)

Table 2
Profiles of the respondents.

Characteristics	Frequency	Percent	Years of Experience: Construction Industry 1-5	6-10	11-15	16-20	>20	Green Building 1-3	4-6	>6
Professions										
Engineer	13	30.2	3	2	4	2	2	7	3	3
Quantity surveyor	11	25.6	1	8	2	0	0	5	3	3
Architect	9	20.9	0	4	2	0	3	6	2	1
Project manager	9	20.9	2	2	2	1	2	6	2	1
Contracts manager	1	2.3	0	1	0	0	0	0	1	0
Subtotal	43	100.0	6	17	10	3	7	24	11	8
% by year	-	-	14.0	39.5	23.3	7.0	16.3	55.8	25.6	18.6
Companies										
Consultant	16	37.2	1	8	1	3	3	9	5	2
Contractor	14	32.6	2	8	4	0	0	9	2	3
Developer	13	30.2	3	1	5	0	4	6	4	3
Subtotal	43	100.0	6	17	10	3	7	24	11	8
% by year	-	-	14.0	39.5	23.3	7.0	16.3	55.8	25.6	18.6

Table 3

Level of acceptance of KMO value (Field, 2009).

KMO Value	Level of Acceptance
Above 0.90	Superb
0.80-0.90	Great
0.70-0.80	Good
0.50-0.70	Mediocre
Below 0.50	Unacceptable

Table 4

Ranking of barriers to GBTs adoption.

Code	All Respondents				Consultant			Contractor			Developer			ANOVA
	Mean	SD	Rank	Normalization[a]	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	
B01	4.51	0.668	1	1.00[b]	4.56	0.629	1	4.57	0.514	1	4.38	0.870	2	0.723[c]
B05	4.26	0.928	2	0.84[b]	4.13	0.957	6	4.50	0.650	2	4.15	1.144	7	0.497[c]
B22	4.12	1.005	3	0.75[b]	4.19	0.911	3	4.07	1.072	6	4.08	1.115	12	0.941[c]
B21	4.07	1.078	4	0.72[b]	4.25	1.000	2	4.00	0.961	8	3.92	1.320	14	0.698[c]
B06	4.02	0.938	5	0.69[b]	4.06	0.929	8	3.86	1.027	11	4.15	0.899	6	0.708[c]
B25	4.00	0.926	6	0.68[b]	4.13	0.885	5	3.57	1.089	21	4.31	0.630	4	0.092[c]
B03	4.00	0.926	6	0.68[b]	3.81	0.981	13	3.93	1.141	9	4.31	0.480	3	0.345[c]
B02	4.00	0.951	8	0.68[b]	3.88	1.025	12	3.86	1.027	11	4.31	0.751	5	0.386[c]
B07	3.95	0.999	9	0.65[b]	4.06	0.680	7	3.93	1.141	9	3.85	1.214	15	0.846[c]
B20	3.93	0.856	10	0.63[b]	3.94	0.680	10	4.07	0.917	5	3.77	1.013	18	0.667[c]
B04	3.93	0.910	11	0.63[b]	3.63	1.088	18	4.14	0.770	4	4.08	0.760	8	0.239[c]
B17	3.93	0.986	12	0.63[b]	3.81	0.981	13	3.57	1.016	20	4.46	0.776	1	0.049
B18	3.88	1.074	13	0.60[b]	4.00	0.966	9	3.79	1.051	13	3.85	1.281	17	0.858[c]
B12	3.86	1.014	14	0.59[b]	3.63	1.088	18	4.14	0.663	3	3.85	1.214	15	0.386[c]
B19	3.84	0.974	15	0.58[b]	3.81	1.047	15	3.71	0.994	15	4.00	0.913	13	0.751[c]
B08	3.81	1.006	16	0.56[b]	4.13	0.806	4	3.57	1.158	22	3.70	1.032	21	0.288[c]
B15	3.81	1.118	17	0.56[b]	3.94	0.929	11	3.71	1.267	18	3.77	1.235	20	0.855[c]
B09	3.79	1.226	18	0.54[b]	3.75	1.238	17	4.07	1.072	6	3.54	1.391	23	0.533[c]
B26	3.74	1.049	19	0.51[b]	3.56	0.964	20	3.64	1.151	19	4.08	1.038	9	0.392[c]
B13	3.74	1.049	19	0.51[b]	3.75	1.125	16	3.71	0.994	15	3.77	1.092	19	0.991[c]
B24	3.60	1.094	21	0.42	3.50	1.317	22	3.71	1.139	17	3.62	0.768	22	0.871[c]
B23	3.58	1.220	22	0.41	3.38	1.310	23	3.36	1.216	23	4.08	1.038	9	0.218[c]
B16	3.47	1.386	23	0.34	3.19	1.559	25	3.21	1.369	25	4.08	1.038	9	0.164[c]
B11	3.42	1.096	24	0.31	3.50	1.265	21	3.29	1.139	24	3.46	0.877	24	0.861[c]
B10	3.42	1.118	25	0.31	3.25	1.291	24	3.71	0.914	14	3.31	1.109	25	0.490[c]
B14	2.93	1.121	26	0.00	3.00	1.155	26	2.71	1.204	26	3.08	1.038	26	0.679[c]

Note: SD = Standard deviation; [a] Normalized value = (mean – minimum mean) / (maximum mean – minimum mean); [b] The normalized value indicates that the barrier is a critical barrier (normalized value ≥ 0.50); [c] The ANOVA result is insignificant at the 0.05 significance level (significance level > 0.05). The Kendall's *W* for ranking the 26 barriers was 0.097 with a significance level of 0.000.

Table 5

Occurrence of Ghana's top five GBTs adoption barriers in selected developed countries.

Top Five Barriers to GBTs Adoption in Ghana	Ghana[a] (this study)	US[b] (Chan et al., 2016)	Canada[b] (Chan et al., 2016)	Australia[b] (Chan et al., 2016)
Higher costs of GBTs	√ (rank 1)	√ (rank 2)	√ (rank 3)	√ (rank 2)
Lack of government incentives	√ (rank 2)	√ (rank 5)	– (rank 6)	– (rank 6)
Lack of financing schemes (e.g., bank loans)	√ (rank 3)	– (rank 6)	– (rank 13)	– (rank 15)
Unavailability of GBTs suppliers	√ (rank 4)	– (rank 14)	– (rank 25)	– (rank 13)
Lack of local institutes and facilities for R&D of GBTs	√ (rank 5)	– (rank 11)	– (rank 13)	– (rank 23)

Note: [a] Developing country; [b] Developed country.

Table 6
Results of FA on barriers to GBTs adoption.

Code	Barriers to GBTs Adoption	Barrier Groupings				
		1	2	3	4	5
Grouping 1: Government-related barriers						
B08	Lack of green building rating systems and labeling programs	0.857	-	-	-	-
B07	Lack of green building codes and regulations	0.817	-	-	-	-
B20	Lack of green building technological training for project staff	0.702	-	-	-	-
B17	Lack of GBTs promotion by government	0.612	-	-	-	-
B25	Lack of demonstration projects	0.561	-	-	-	-
B06	Lack of local institutes and facilities for R&D of GBTs	0.559	-	-	-	-
B05	Lack of government incentives	0.469	-	-	-	-
Grouping 2: Human-related barriers						
B18	Lack of importance attached to GBTs by senior management	-	0.849	-	-	-
B15	Resistance to change from the use of traditional technologies	-	0.679	-	-	-
B21	Unavailability of GBTs suppliers	-	0.668	-	-	-
B09	Unfamiliarity of construction professionals with GBTs	-	0.665	-	-	-
B22	Lack of financing schemes (e.g., bank loans)	-	0.496	-	-	-
Grouping 3: Knowledge and information-related barriers						
B03	Lack of professional knowledge and expertise in GBTs	-	-	0.882	-	-
B02	Lack of GBTs databases and information	-	-	0.813	-	-
B04	Lack of awareness of GBTs and their benefits	-	-	0.740	-	-
Grouping 4: Market-related barriers						
B13	Unavailability of GBTs in the local market	-	-	-	0.782	-
B12	Lack of interest from clients and market demand	-	-	-	0.642	-
B26	Limited experience with the use of nontraditional procurement methods	-	-	-	0.531	-
Grouping 5: Cost and risk-related barriers						
B01	Higher costs of GBTs	-	-	-	-	0.774
B19	Risks and uncertainties involved in adopting new technologies	-	-	-	-	0.640
Eigenvalue		5.406	2.313	2.085	1.466	1.295
Variance (%)		27.030	11.563	10.424	7.329	6.473
Cumulative variance (%)		27.030	38.593	49.017	56.346	62.818

Table 7
Barriers to the adoption of GBTs.

		Level of criticality				
Code	Barriers	1	2	3	4	5
B01	Higher costs of GBTs					
B02	Lack of GBTs databases and information					
B03	Lack of professional knowledge and expertise in GBTs					
B04	Lack of awareness of GBTs and their benefits					
B05	Lack of government incentives					
B06	Lack of local institutes and facilities for research and development (R&D) of GBTs					
B07	Lack of green building codes and regulations					
B08	Lack of green building rating systems and labeling programs					
B09	Unfamiliarity of construction professionals with GBTs					
B10	High degree of distrust about GBTs					
B11	Conflicts of interests among various stakeholders in adopting GBTs					
B12	Lack of interest from clients and market demand					
B13	Unavailability of GBTs in the local market					
B14	Adoption of GBTs is time consuming and causes project delays					
B15	Resistance to change from the use of traditional technologies					
B16	Complex and rigid requirements involved in adopting GBTs					
B17	Lack of GBTs promotion by government					
B18	Lack of importance attached to GBTs by senior management					
B19	Risks and uncertainties involved in adopting new technologies					
B20	Lack of green building technological training for project staff					
B21	Unavailability of GBTs suppliers					
B22	Lack of financing schemes (e.g., bank loans)					
B23	High market prices and rental charges of green buildings resulting from GBTs application					
B24	Long payback periods from adopting GBTs					
B25	Lack of demonstration projects					
B26	Limited experience with the use of nontraditional procurement methods					
If there are any barriers omitted by this questionnaire, please list and assess them.						
B27						
B28						
B29						
B30						
B31						