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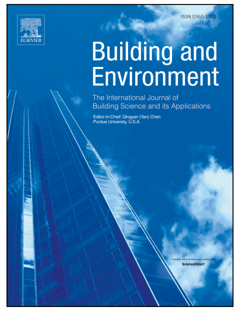

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Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective

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Abstract

As a response to mitigate various negative environmental effects of the construction industry, recent years have witnessed a growing interest in green building technologies (GBTs) adoption and development. Consequently, many studies have been conducted on the forces driving the GBTs adoption in different countries. However, there have been few studies identifying the driving forces (DFs) for GBTs adoption in developing countries such as Ghana. This study aims to identify the major DFs for GBTs adoption within the developing country of Ghana. To achieve the objective, 21 DFs were identified from a comprehensive

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literature review. Through a questionnaire survey with 43 professionals with green building experience, the results first indicated that "setting a standard for future design and construction", "greater energy efficiency", "improved occupants' health and well-being", "non-renewable resources conservation", and "reduced whole lifecycle costs" were the top five forces driving the GBTs adoption. Further comparative analysis showed that the topmost rank of "setting a standard for future design and construction" is unique for GBTs adoption in only the developing country of Ghana, not in the developed country of the US. Additionally, factor analysis revealed that the underlying forces for the 16 significant DFs were environment-related, company-related, economy and health-related, cost and energy-related, and industry-related forces. This study improves understanding of the major DFs for GBTs adoption, providing a valuable reference for practitioners and policy makers to promote the wider adoption of GBTs. Future study will investigate the interrelationships between the significant DFs and their impacts on the GBTs adoption process. Future work is also required to employ a larger sample and investigate in greater detail the differences between the GBTs adoption DFs in Ghana and many other specific countries.

Keywords: Green building technologies adoption; Driving forces; Construction industry; Sustainability; Developing country; Ghana.

1. Introduction

The construction industry consumes a great deal of energy and other natural resources and has a significant effect on the environment, economy, and society. In 2010, for example, the construction industry was responsible for up to 32% of the total global energy consumption, 19% of the total global energy-related greenhouse gas (GHG) emissions, nearly one-third of the total global carbon emissions, and an eighth to a third of fluorinated gas (F-gas) emissions (Zhang et al., 2017). This energy consumption and the associated emissions might double or potentially even triple in the next centuries owing to several key trends

(Intergovernmental Panel on Climate Change (IPCC), 2014). As a result of an increasing public concern on the negative impacts of construction activities in recent years, green or sustainable building development has attracted a growing attention from both the public and private sectors (Zuo and Zhao, 2014; Darko and Chan, 2016; Zuo et al., 2017). Green building is one of the measures introduced for implementing environmental, economic, and social sustainability in the construction industry. It is "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). Green buildings are not only designed, built, and operated to have better environmental performance, but to also improve productivity and the health and well-being of occupants (U.S. Green Building Council (USGBC), 2003; MacNaughton et al., 2016).

It is urgent to implement green building through green building technologies (GBTs) adoption so that the detrimental environmental impacts of buildings can be reduced effectively. However, GBTs adoption and development is not free of barriers and difficulties. Barriers such as higher cost and a lack of knowledge and awareness affect GBTs adoption in the construction industry (Zhang et al., 2011a, b; Chan et al., 2016). In light of these barriers, there are several forces that drive and shape the adoption of GBTs among construction practitioners and stakeholders in different countries and regions. A lot of research on forces driving GBTs adoption has been done (e.g., Love et al., 2012; Ahn et al., 2013; Darko et al., 2017a). In spite of the existence of numerous studies on the driving forces (DFs) for GBTs adoption, such studies within the context of developing countries are rarely reported in the literature. A recent review study by Darko et al. (2017b) indicated that very few studies have attempted to analyze factors driving the adoption of GBTs in developing countries. In this light, the objective of this study is to identify the major DFs for GBTs adoption in the construction industry with reference to the developing country of Ghana. This study is important first because, given the limited number of studies examining GBTs adoption DFs in developing countries, its empirical findings add significantly to the existing green building literature. Moreover, this study improves understanding of the relevant DFs for GBTs adoption, which is necessary for guiding the GBTs adoption decision making of the industrial practitioners. Furthermore, the research findings also help policy makers and advocates identify key DFs that can be widely promoted in society to encourage the widespread adoption of GBTs to ultimately achieve the sustainable buildings development.

The remainder of the paper is organized into the following four main sections. A review of relevant literature is provided in section 2, followed by a brief overview of the present situation of GTs adoption in Ghana. In section 3, a detailed description of the research methodology is presented. Section 4 presents and discusses the results of the study. The study is then concluded in section 5.

2. Literature review on GBTs adoption DFs

GBTs are defined as technologies – such as green roof and wall technologies, solar system technology, and prefabricated concrete technology – that are incorporated into building design and construction to make the end product sustainable (Zhang et al., 2011a, b; Ahmad et al., 2016). The DFs also refer to the persuasions that encourage the adoption of GBTs, and can be broadly defined to encompass both the benefits of adopting GBTs and actions (such as policy initiatives) outside the benefits that lead people to take part in GBTs adoption (Darko et al., 2017b). It should be clarified that the research presented in this paper forms the second phase of a much larger research study on the promotion of GBTs adoption in a developing country in which only the benefits of GBTs adoption are treated as DFs and the actions outside the benefits are reasonably treated as promotion strategies. Because of the word/space limitation, this paper is only able to present the outcomes about the DFs. The future research paper will present the outcomes on the promotion strategies that form the fourth phase of the aforesaid larger study.

A review of relevant published literature was conducted to identify the DFs for GBTs adoption. A summary of the analysis of the literature is shown in Table 1. For a more comprehensive review of the literature concerning the DFs for GBTs and practices adoption, the reader is referred to Darko et al. (2017b). As Table 1 indicates, 21 typical DFs for GBTs adoption were identified from the literature review. Table 1 also shows the number of times each of the identified DFs was mentioned in the sampled/analyzed literatures to indicate the attention it has attracted. These DFs can motivate the adoption of GBTs (Darko et al. 2017a) and therefore a better understanding of them would play a crucial role in promoting the wider adoption of GBTs in Ghana. Detailed descriptions of the DFs can be found in the analysis results and discussion section.

Table 1

List of identified DFs for GBTs adoption from published literature.

Code	DFs for GBTs adoption	References																				Total number of references for a certain DF
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
DF01	Greater energy efficiency		x	x	x	x	x	x	x		x			x					x		x	11
DF02	Reduced whole lifecycle costs	x	x	x	x					x	x	x	x	x	x	x			x	x	x	14
DF03	Company image and reputation		x	x	x				x	x	x	x		x	x	x		x	x		x	13
DF04	Improved occupants' health and well-being	x	x	x	x			x			x			x					x		x	9
DF05	Improved occupants' productivity		x	x	x	x		x							x		x			x	x	9
DF06	Non-renewable resources conservation		x	x	x	x	x												x			6
DF07	Reduced environmental impact	x	x	x	x	x	x	x		x						x			x		x	11
DF08	Improved indoor environmental quality		x	x	x	x	x				x			x								7
DF09	Greater water efficiency		x	x	x	x					x										x	6
DF10	Commitment to social responsibility		x	x				x	x	x	x					x		x			x	9
DF11	Waste reduction		x	x		x	x				x											5
DF12	High return on investment			x					x							x				x	x	5
DF13	Reduced use of construction materials in the economy		x																			1
DF14	Attraction and retention of quality employees		x	x																x		3
DF15	Enhanced marketability	x		x				x	x			x		x	x	x		x		x	x	11
DF16	High rental income	x	x	x	x			x						x							x	7
DF17	Better workplace environment		x		x												x					3
DF18	Increased building value		x	x	x			x												x	x	6
DF19	Setting a standard for future design and construction		x		x								x									3
DF20	Job creation opportunity		x																	x		2
DF21	Facilitating a culture of best practice sharing		x										x									2

References: 1. Love et al. (2012); 2. Darko et al. (2017a); 3. Darko et al. (2017b); 4. Darko et al. (2017c); 5. Ahn et al. (2013); 6. Manoliadis et al. (2006); 7. Gou et al. (2013); 8. Low et al. (2014); 9. Zhang et al. (2011b); 10. Aktas and Ozorhon (2015); 11. Serpell et al. (2013); 12. Mondor et al. (2013); 13. Windapo (2014); 14. Windapo and Goulding (2015); 15. Abidin and Powmya (2014); 16. Edwards (2006); 17. Lai et al. (2017); 18. Arif et al. (2009); 19. Chan et al. (2009); 20. Andelin et al. (2015).

2.1. A brief overview of the present GBTs adoption situation in Ghana

In order to help better understand the context within which this research was conducted, a brief overview of the present situation of GTs adoption in Ghana is presented in this section. The adoption of GBTs in Ghana is slow and still in its infancy stage. The Ghana Green Building Council (GHGBC), which is the main organization to help advance GBTs adoption in Ghana, was only recently established in 2009 (GHGBC, 2010). However, Ghana is among the few developing countries that are trying to achieve major progresses in GBTs adoption and development. For example, Ghana has successfully launched the first green commercial office building in West Africa, which is the One Airport Square, and Africa's first LEED-certified hospital, which is the Ridge Hospital. In terms of policy, albeit there exist no governmental policies and regulations for mandating GBTs adoption in building developments in Ghana at the moment, the Ghanaian government still aims to promote GBTs use. In 2007, for instance, with the advice of the Energy Commission of Ghana (ECG), the government took the initiative to procure and distribute six million energy-efficient compact fluorescent lamps (CFLs) for free as a direct replacement of six million traditional incandescent lamps (ECG, 2009). This was an initiative toward dealing with the 2007 energy crisis in Ghana. Another important action by the government was the introduction of Ghana's Sustainable Development Action Plan in 2009 (Alfris, 2013), which focuses on sustainable production and consumption programs that will manage scarce resources utilization to enable both the present and future generations to thrive. This is closely related to and supports GBTs adoption in construction projects in Ghana. This study can be helpful to relevant Ghanaian government departments in their efforts to further motivate GBTs adoption. Green building rating systems – systems for measuring green building performance – are also considered effective instruments for leading the construction industry towards GBTs adoption. Presently, there are two primary rating systems applied in Ghana: the Green Star of South Africa (Green

Star SA) and the Leadership in Energy and Environmental Design of the US (LEED). The GHGBC is nowadays still in the process of developing a localized green building rating system for Ghana. In line with this, in 2012, the council launched the Eco-Communities National Framework which is "a vision, set of guided principles, and aspirations serving as the basis for the development of the rating system for communities, neighborhood, and cities development in Ghana" (GHGBC, 2012).

In Ghana, the private and commercial sectors have seen most of the GBTs implementations. That is, GBTs have been implemented in commercial office buildings that are mainly owned by individual organizations (e.g., private developers) rather than government (public) bodies. This situation could be attributed to the lack of policies and authoritative green building rating systems in Ghana (Djokoto et al., 2014) to mandate the application of GBTs in government-funded projects. In the Ghanaian residential sector, although some buildings have adopted certain green technologies, until they have obtained a green certification, it does not suffice to regard them as green buildings. Furthermore, it is worth noting that the health sector has also made good efforts toward adopting GBTs in Ghana. Analyzing the different types of green technologies being applied in various sectors of the construction industry is beyond the scope of this study; this study focusses only on providing a deeper understanding of the influences that drive the industry to adopt such technologies.

3. Research methodology

3.1. Data collection

In this study, an empirical questionnaire survey was carried out to collect the professional views on the DFs for GBTs adoption in Ghana. The questionnaire survey method has been widely used in green building research (Wong et al., 2016; Hwang et al., 2017a), and it is advantageous for achieving "quantifiability and objectiveness" (Ackroyd and Hughes, 1981).

In addition to the literature review which laid the foundation for the development of the survey questionnaire, a two-step procedure was followed to assess the appropriateness and rationality of the questionnaire prior to the questionnaire survey. First, the questionnaire was reviewed by an international expert (a professor who had more than 10 years' experience in green building) on question construction, ensuring that ambiguous expressions were not contained in the survey and that appropriate technical language/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 DFs, considering the background of GBTs adoption in the Ghanaian construction industry, 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 objective of the research and contact details were first presented, followed by questions meant to gather background information of the respondents. Afterward, the questionnaire presented the 21 identified DFs and asked the respondents to rate their degree of agreement on each DF using a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). This study adopted the five-point Likert scale because it provides unambiguous results that are easy to interpret (Ekanayake and Ofori, 2014).

The population comprised all industry practitioners with knowledge and understanding of GBTs adoption 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. This 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 Green Star SA certification or the 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). In addition, because GBTs have not been widely implemented in Ghana's construction industry, the number of experienced professionals is limited. Moreover, the sample size was adequate compared with previous green building studies (e.g., 30 in Zhoa et al., 2016; 39 in Shen et al., 2016; and 40 in Hwang et al., 2017b).

The questionnaire survey was conducted in Accra of Ghana from January to April, 2017. The main reason for selecting Accra for the survey lies in the fact that Accra is not only the capital city of Ghana, but also one of the largest and flourishing construction markets in the country. Accra has been attracting most of the leading Ghanaian contractors and developers to invest in building developments, hence most of the largest contractor, developer, and consultant companies are located in this city of Ghana (Ofori-Kuragu et al., 2016). Moreover, the majority of the green-certified buildings in Ghana are situated in Accra, and most of the local companies that were directly involved in their construction also operate in this city.

Thus, Accra is concentrated with most of the green building projects and experts in Ghana. However, it should be understood that most of these experts and their companies maintain offices and conduct building projects in other cities of Ghana as well. Being the most active local construction market in Ghana, it is considered that the investigation to Accra can offer valuable insights into the current situation of GBTs adoption DFs in major cities of Ghana. Nevertheless, further investigation of the views of construction professionals in other cities of Ghana could be considered in future research.

The survey respondents consisted of experienced practitioners in the industry. As Fig 1 shows, the major portion (37, 86%) of the respondents had more than 5 years of industrial experience, whereas only 6 (14%) had 1–5 years of experience. Of the total number of respondents, 24 (56%) had 1–3 years of experience in green building, 11 (25%) had 4–6 years of experience, and 8 (19%) had more than 6 years of experience (Fig. 2). Given the few green building projects launched in Ghana in recent years, this result could be deemed reasonable. In light of the respondents' industrial and green building experience, their views were representative for this study to guarantee the reliability of the findings. As for the respondents' companies, Fig. 3 shows that 16 (37%), 14 (33%), and 13 (30%) of the respondents were from consultant, contractor, and developer companies, respectively. Furthermore, with the professions of the respondents, engineers (13, 30%) formed the majority, followed by quantity surveyors (11, 26%), project managers (9, 21%), and architects (9, 21%) (Fig. 4).

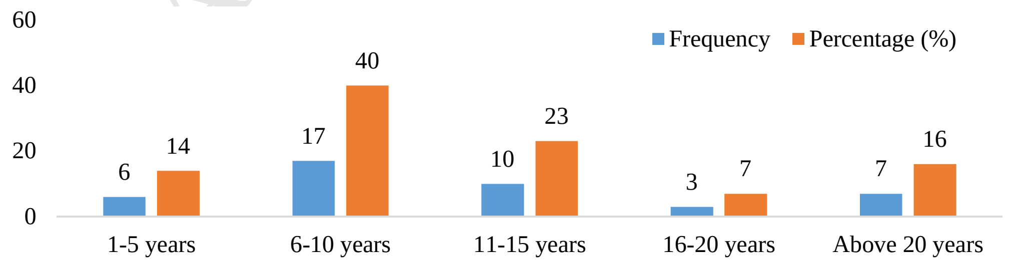


Fig. 1. Years of the respondents' practical experience in the construction industry.

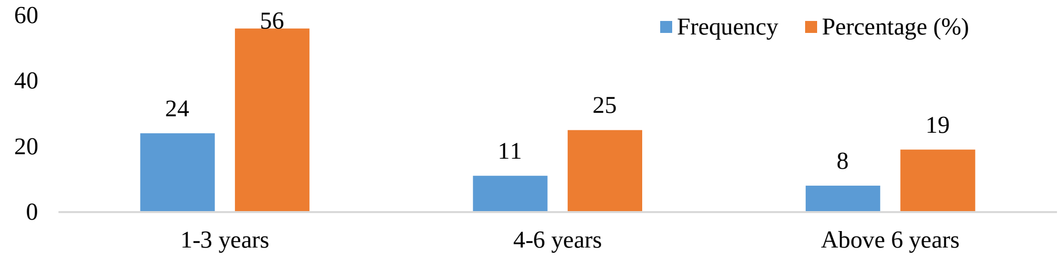


Fig. 2. Years of the respondents' experience in green building.

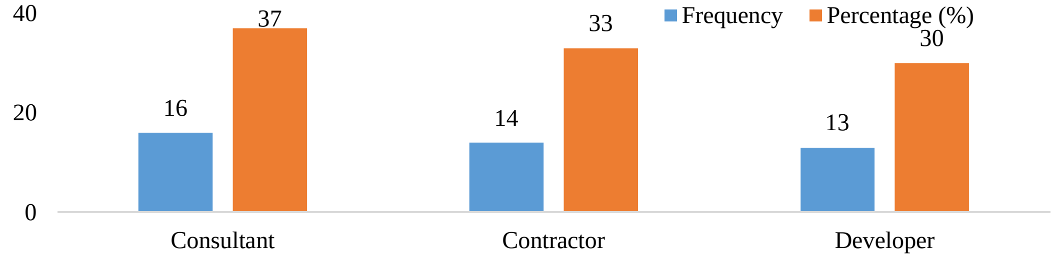
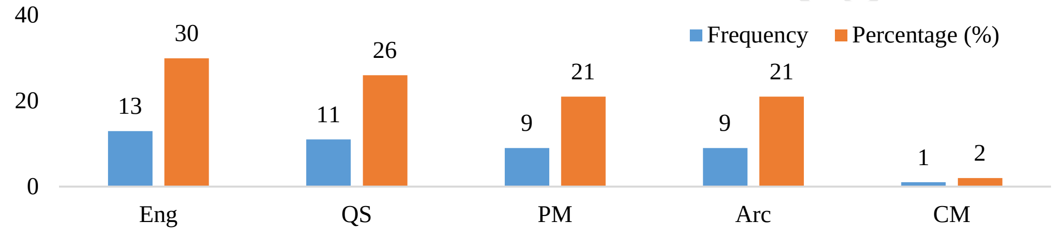


Fig. 3. The respondents' company types.



Note: Eng = Engineer; QS = Quantity surveyor; PM = Project manager; Arc = Architect; CM = Contracts manager.

Fig. 4. The respondents' professions.

In order to measure the internal consistency amongst the various DFs to assess the reliability of the five-point Likert scale, Cronbach's alpha coefficient was used. In this study, the Cronbach's alpha coefficient value was 0.909, which was much higher than the threshold of 0.70 (Norusis, 2011), suggesting that the five-point Likert scale measurement and thus the data collected were highly reliable for further analyses in the following sections.

3.2. Data analysis

Various statistical analyses including descriptive means, one-sample *t*-test, mean difference analysis, analysis of variance (ANOVA), and Kendall's coefficient of concordance (Kendall's *W*) were adopted in this study to analyze the data collected. The mean score ranking technique has been widely used in previous studies to rank the relative significance/importance of specific factors in the green building domain (Shi et al., 2013; Hwang et al., 2016). In this study, the mean score ranking technique was used to determine the relative ranking of the 21 DFs for GBTs adoption in descending order of importance, as the respondents perceived. The mean score of the importance of a DF is computed using the following formula:

$$B_i = \frac{\sum_{j=1}^{n} \alpha_{ij}}{n}$$

where n = the total number of respondents; α_{ij} = the importance of the DF i rated by the respondent j; and B_i = the mean score of the importance of the DF i. The SPSS statistical software (SPSS for Windows, version 20) was used to compute the mean scores of the DFs, and in ranking the DFs, if two or more DFs happened to have the same mean score, the highest rank was assigned to the DF with the lowest standard deviation (SD). The one-sample *t*-test was then applied to test the significance of the mean scores of the DFs against a test value of 3.50 (Darko et al., 2017c). The null hypothesis, H_0, is that "the mean score is not statistically significant", while the alternative hypothesis, H_1, is that "the mean score is statistically significant". The one-sample *t*-test was conducted at a 95% confidence level with a 0.05 *p*-value. The null hypothesis for a DF should be rejected if its *p*-value is below 0.05. Furthermore, Kendall's *W* was employed to measure the agreement between different respondents' rankings of the DFs (Siegel and Castellan, 1988). Without assuming any specify nature of data distribution, Kendall's *W* is a coefficient index for determining the overall agreement among sets of rankings. In addition, since the respondents were from three different types of companies in the construction industry (see Fig. 3), the mean difference analysis was performed to ascertain the actual values of the differences in the mean scores of the DFs from the three respondent groups according to company types (Chan et al., 2017). Finally, ANOVA, which is a suitable method for comparing the mean scores of more than two groups (Pallant, 2011), was carried out to check whether the differences in means from the three respondent groups were statistically significant (Rahman, 2014). The analysis results are presented and discussed in the following section.

4. Analysis results and discussion

The summary of the survey results on the DFs for GBTs adoption is shown in Table 2. The mean scores of the importance of the DFs range from 3.51 to 4.47. It is worth noting that the mean scores of all of the 21 DFs were greater than the test value of 3.50. However, from the results of one-sample *t*-test, 16 DFs were considered to be statistically significant as the *p*-values of these DFs were less than 0.05. The result indicates that these DFs are significantly important in driving and shaping the adoption of GBTs in the Ghanaian construction market. For the DFs "high rental income" (DF16), "waste reduction" (DF11), "enhanced marketability" (DF15), "commitment to social responsibility" (DF10), and "attraction and retention of quality employees" (DF14) they were considered to be insignificant. The reason why "high rental income" (DF16) and "enhanced marketability" (DF15) were not perceived to be significant DFs may be because high rental charges and market prices do not make green buildings appealing to many customers and tenants (Chan et al., 2016). This situation could even be worse in Ghana as poverty remains pervasive and entrenched in many areas of the country (Cooke et al., 2016). From the results of mean, the top five DFs behind the adoption of GBTs (mean $\geq$ 4.21) were "setting a standard for future design and construction" (DF19), "greater energy efficiency" (DF01), "improved occupants' health and well-being" (DF04), "non-renewable resources conservation" (DF06), and "reduced whole lifecycle costs" (DF02), all of which were statistically significant, implying that these DFs were perceived as the most important DFs for GBTs adoption. These five DFs are discussed below.

Table 2

Summary of the survey results on the DFs for GBTs adoption.

	All respondents				Consultant			Contractor			Developer						
Code	Mean	SD	Rank	*p*-value	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Diff. (CS–CT)	Diff. (CS–DP)	Diff. (CT–DP)	ANOVA
DF19	4.47	0.59	1	0.00[a]	4.56	0.51	1	4.29	0.61	4	4.54	0.66	2	0.27	0.02	–0.25	0.39[b]
DF01	4.42	0.59	2	0.00[a]	4.44	0.63	2	4.29	0.61	4	4.54	0.52	1	0.15	–0.10	–0.25	0.54[b]
DF04	4.37	0.69	3	0.00[a]	4.31	0.87	3	4.50	0.52	1	4.31	0.63	6	–0.19	0.00	0.19	0.71[b]
DF06	4.21	0.86	4	0.00[a]	4.13	0.72	5	4.14	1.03	11	4.38	0.87	4	–0.01	–0.25	–0.24	0.69[b]
DF02	4.21	0.99	5	0.00[a]	4.00	1.15	10	4.43	0.76	2	4.23	1.01	9	–0.43	–0.23	0.20	0.51[b]
DF07	4.19	0.91	6	0.00[a]	4.13	0.81	6	4.07	0.73	13	4.38	1.19	5	0.06	–0.25	–0.31	0.64[b]
DF09	4.16	0.84	7	0.00[a]	4.13	0.96	7	4.36	0.74	3	4.00	0.82	12	–0.23	0.13	0.36	0.54[b]
DF08	4.14	0.92	8	0.00[a]	4.06	1.06	8	4.21	0.70	6	4.15	0.99	11	–0.15	–0.09	0.06	0.91[b]
DF18	4.09	1.04	9	0.00[a]	3.94	1.34	11	4.14	0.95	10	4.23	0.73	8	–0.20	–0.29	–0.09	0.74[b]
DF21	4.07	0.86	10	0.00[a]	4.25	0.86	4	3.93	0.92	17	4.00	0.82	12	0.32	0.25	–0.07	0.57[b]
DF20	4.05	0.95	11	0.00[a]	3.63	1.15	17	4.21	0.70	6	4.38	0.77	3	***–0.58***	***–0.75***	–0.17	0.07[b]
DF17	4.00	0.95	12	0.00[a]	4.00	1.10	9	4.14	0.86	8	3.85	0.90	18	–0.14	0.15	0.29	0.73[b]
DF13	3.98	0.96	13	0.00[a]	3.75	1.06	14	3.93	0.83	16	4.31	0.95	7	–0.18	–0.56	–0.38	0.30[b]
DF05	3.93	0.96	14	0.01[a]	3.75	1.06	14	4.07	0.62	12	4.00	1.15	15	–0.32	–0.25	0.07	0.64[b]
DF12	3.93	1.03	15	0.01[a]	3.81	1.05	13	4.14	0.86	8	3.85	1.21	20	–0.33	–0.04	0.29	0.65[b]
DF03	3.91	0.92	16	0.01[a]	3.81	1.17	12	3.79	0.97	18	4.15	0.38	10	0.02	–0.34	–0.36	0.52[b]
DF16	3.81	1.10	17	0.07	3.56	1.26	19	4.00	0.78	14	3.92	1.19	16	–0.44	–0.36	0.08	0.51[b]
DF11	3.81	1.14	18	0.08	3.69	1.01	16	4.00	1.30	15	3.77	1.17	21	–0.31	–0.08	0.23	0.75[b]
DF15	3.79	1.10	19	0.09	3.63	1.31	18	3.79	1.12	19	4.00	0.82	12	–0.16	–0.37	–0.21	0.67[b]
DF10	3.65	0.95	20	0.30	3.50	1.10	20	3.64	1.01	20	3.85	0.69	17	–0.14	–0.35	–0.21	0.63[b]
DF14	3.51	1.10	21	0.95	3.38	1.15	21	3.36	1.15	21	3.85	0.99	19	0.02	–0.47	***–0.49***	0.43[b]

Note: SD = Standard deviation; [a] The one sample *t*-test result is significant at the 0.05 significance level (*p*-value < 0.05) (2-tailed); [b] The ANOVA result is insignificant at the 0.05 significance level (sig. > 0.05); Diff. (CS–CT) = Difference in mean scores from consultant and contractor; Diff. (CS–DP) = Difference in mean scores from consultant and developer; Diff. (CT–DP) = Difference in mean scores from contractor and developer. The Kendall's *W* for ranking the 21 DFs was 0.056 with a significance level of 0.00.

Unexpectedly, "setting a standard for future design and construction" (DF19) was ranked first with a very high mean score (mean = 4.47). The highest rank of this DF was unexpected because setting a standard for future design and construction was ranked low and considered as an insignificant driver for the adoption of GBTs in previous studies done by Darko et al. (2017a, c). However, this result is consistent with the viewpoint of Mondor et al. (2013, p. 28) that "high performing projects can affect their industry standards by setting a standard for future design and construction". The research finding suggests that Ghanaian practitioners think that adopting GBTs today can serve as an empirical benchmarking sustainability-focused practice for motivating stakeholders to meet higher standards in future construction projects. In fact, the more diffused a certain technology in the construction industry, the less risky it is to implement (Ozorhon and Karahan, 2016), and that can influence the interest the industrial practitioners have in the technology. Therefore, when stakeholders have a vision for green building developments, the desire to set the pace for other professionals to follow can greatly drive them to adopt GBTs. The stakeholders and policy makers within the current construction industry of Ghana are working with the vision to "transform the built environment in Ghana towards sustainability" (GHGBC, 2010), which can be realized through the adoption of GBTs.

The DF "greater energy efficiency" (DF01) was ranked second (mean = 4.42). As a green building development practice, the adoption of GBTs in Ghana has been overwhelmingly driven by greater energy efficiency which is associated with a reduction in GHG emissions. This is an unsurprising finding as Ghana has over the last four decades (1984, 1994, 1998, 2007, and 2012) faced major energy crises, and consequently the Ghanaian electricity sector has been burdened with difficulties vis-à-vis power quality and supply security from the beginning of 2013 till now (Gyamfi et al., 2017). This creates an urgency for stakeholders to seek ways to improve the efficiency of energy consumption in Ghana. Hence, the importance of greater energy efficiency as a driving force for GBTs adoption in the Ghanaian construction industry is high. Energy efficiency is indeed a high priority for national development in both developed and developing countries (Pacheco et al., 2012). Therefore, given the large amount of energy buildings consume, developing energy efficient buildings could play an essential part in national development. The application of GBTs in building developments could help improve the energy efficiency situation in a country. For example, adopting GBTs such as high energy efficient windows and green wall technology in buildings development can help save 14–20% and 33–60% of operational energy, respectively (Balaras et al., 2007). Furthermore, the employment of light emitting diode (LED) bulbs can help save 70–80% of electricity (Wong, 2012). This finding concurs with the findings of studies conducted by Manoliadis et al. (2006) and Ahn et al. (2013), where energy conservation was identified as a major driver for implementing sustainable construction practices. The finding has also been reinforced by Luo et al. (2017, p. 1), who found that "green energy was the most preferred attribute of green buildings, exerting an even stronger overall effect on consumer choice than price".

The DF "improved occupants' health and well-being" (DF04) received the third position (mean = 4.37). Adopting green technologies in building activities can have an important effect on the health and comfort of occupants. Thatcher and Milner (2016) also pointed out that health and well-being in green buildings was an important motivator for their adoption. According to Kats (2003), with the implementation of natural lighting and ventilation and technologies for enhancing air quality, green buildings typically contribute to improving and protecting the health and comfort of students and employees. Poor health conditions within a building can pose serious problems for occupants including increased risk of illness, frequent sick leave and absenteeism, and decreased job satisfaction. This is mainly because people spend up to 90% of their time indoors, and the levels of pollutants indoors are usually higher than the levels outdoor (USEPA, 2017). Therefore, building technologies that can help improve the health and well-being of occupants could be very attractive to construction professionals. In Ghana, safe and healthy environment including the quality of air has been identified as a factor that has major implications for the health of individuals (World Health Organization (WHO), 2015). This could explain why improved occupants' health and well-being was ranked as the third major DF for adopting GBTs.

The DF "non-renewable resources conservation" (DF06) occupied the fourth position (mean = 4.21). The conservation of non-renewable resources is important for GBTs adoption and implementation because, while non-renewable resources are crucial in sustaining human activities, for a smart and sustainable development in a country whose non-renewable resources are scarce, they need to be protected and conserved. Manoliadis et al. (2006) also identified that resource conservation was one of the top five drivers for adopting sustainable construction practices. It can be inferred from the research finding that the adoption of GBTs offers a promising way to ensure the sustainable use of natural and non-renewable resources like fossil fuels, natural gas, minerals, and land. For instance, with the use of renewable and sustainable energy technologies that consider solar energy, wind energy, and bio-energy, the use of non-renewable energy sources that generate large amounts of GHGs and contribute to air pollution can be significantly reduced (Love et al., 2012). Zhang et al. (2011a, b) also indicated that the adoption of GBTs such as underground space development technology helps save land. As a developing country, Ghana is currently in a critical situation of resource depletion (Shad et al., 2017), and hence GBTs adoption has been considered highly important for the country.

The DF "reduced whole lifecycle costs" (DF02) was ranked fifth (mean = 4.21). The adoption of GBTs contributes to reducing the lifetime costs of operating and maintaining a building facility. A similar situation was also identified by Darko et al. (2017b), where reduced whole lifecycle costs was a key driver for taking up GBTs and practices. The reduced whole lifecycle costs from GBTs adoption can be credited to the cost savings from lower utility bills resulting from the greater energy efficiency and the reduced healthcare costs resulting from the improved and superior health and well-being of occupants. Kats (2003, p. 3) claimed that "green buildings provide financial benefits that conventional buildings do not", which include lower operation and maintenance costs and reduced health costs. She highlighted that due to the greater energy efficiency of green buildings, an amount of US$60,000 can be saved yearly. This financial benefit can be well received by Ghanaian construction stakeholders and thus can significantly drive them to take relevant voluntary actions for GBTs adoption.

In light of the above discussion, it can be summarized from the overall perception of various practitioners that although the adoption and development of GBTs in Ghana is still at the preliminary stage, the commonly recognized benefits of GBTs adoption have been realized, encouraging some industrial practitioners and stakeholders to embrace GBTs. The government and advocates ought to formulate and implement good strategies to educate and increase the public's knowledge and awareness of these benefits in order to promote the more widespread adoption of GBTs. One suggestion is to create awareness through the media, e.g., print media and radio and television programs.

In addition to the overall ranking of the DFs, this study also analyzed the agreement between the respondents and the differences in perceptions among respondents from consultant, contractor, and developer companies, as shown in Table 2. As mentioned before, Kendall's *W* was calculated to determine whether the respondents agreed on the ranking of the DFs. The value of Kendall's *W* ranges from 0 to 1, where a value of 0 indicates "no agreement" among the respondents, 1 indicates "complete agreement", and a significant Kendall's *W* value of 0.05 indicates a general agreement among the respondents (Siegel and

Castellan, 1988; Mao et al., 2015). In this study, the value of Kendall's *W* for ranking the 21 DFs was 0.056, and the significance level of Kendall's *W* was at 0.00, indicating that a significant degree of agreement exists among all of the respondents in a particular group regarding the ranking of DFs for GBTs adoption. From the results of mean difference, generally, the perceptions of the importance of the DFs from the contractors and developers were higher than that from the consultants, which may imply that the identified DFs encouraged the contractors and developers more to adopt GBTs. Moreover, the consultants and contractors had the largest difference in the perception of the importance of "job creation opportunity" (DF20, Diff. (CS – CT) = 0.58). Again, the consultants and developers had the largest difference in the perception of the importance of the same DF20 (Diff. (CS – DP) = 0.75). For all of these differences in perceptions, the contractors and developers ranked the DF "job creation opportunity" (DF20) higher than the consultants: while the contractors and developers ranked DF20 sixth and third, respectively, the consultants ranked it lower (ranked seventeenth). This may be because the contractor and developer companies are more responsible for the actual construction works and hence when the project involves adopting GBTs, they tend to employ more, especially green skilled, workers. As for the contractors and developers, they had the largest difference in the perception of the importance of "attraction and retention of quality employees" (DF14, Diff. (CT – DP) = 0.49). However, this mean difference was not statistically large as it was not greater than 0.50. In addition, from the ANOVA results, it can be inferred that all of the differences in perceptions were not statistically significant because the ANOVA (Sig.) values of all of the DFs were above 0.05 (Table 2). This result further corroborated the finding from the Kendall's *W* test that the respondents had a significant degree of agreement regarding the ranking of the DFs for GBTs adoption.

4.1. Comparison of results with the United States

After discussing the results obtained by analyzing the top five DFs for GBTs adoption in the construction industry of Ghana, based on the results from this study and that from Darko et al. (2017a), a comparison was made of the top five most important GBTs adoption DFs in Ghana (a developing country) and that in the US (a developed country), as shown in Table 3. Darko et al.'s (2017a) publication is a publication that examined a set of GBTs adoption DFs, similar to those examined in the present study, within the context of the US construction industry. A similar comparative analysis was also done in the studies of Chan et al. (2010) and Bagaya and Song (2016). As shown in Table 3, the DFs that occurred in the top five highest ranked GBTs adoption DFs in both Ghana and the US are marked with the symbol "√" and those that did not occur in the top five DFs in the US are marked with the symbol "–". In both cases, the respective ranks of a DF are indicated in bracket.

Table 3
Occurrence of Ghana's top five GBTs adoption DFs in the United States.

Top five DFs for GBTs adoption in Ghana	Ghana[a] (this study)	US[b] (Darko et al., 2017a)
Setting a standard for future design and construction	√ (rank 1)	– (rank 16)
Greater energy efficiency	√ (rank 2)	√ (rank 1)
Improved occupants' health and well-being	√ (rank 3)	√ (rank 4)
Non-renewable resources conservation	√ (rank 4)	– (rank 12)
Reduced whole lifecycle costs	√ (rank 5)	– (rank 6)

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

The results in Table 3 show that while setting a standard for future design and construction was the highest ranked DF of GBTs adoption in Ghana's construction industry, it did not appear in the top five highest ranked DFs in the US; it was ranked as low as sixteenth in the US. Based on this finding, it can be stated that setting a standard for future design and construction is the most important DF for GBTs adoption in only the developing country of Ghana, but not in the developed country of the US where the green building industry is relatively better developed. This finding is reasonable as Ghana seek ways to improve and transform its construction industry to match up with the level of green building development in developed countries such as the US (GHGBC, 2010). Furthermore, it can be seen that contrary to the Ghanaian situation, non-renewable resources conservation is not a highly important DF for adopting GBTs in the US. In addition, it is worth noting that these two DFs – greater energy efficiency and improved occupants' health and well-being – appeared in the top five DFs in both Ghana and the US, and their individual ranks across the two countries are very close. For example, greater energy efficiency was ranked second and first in Ghana and in the US, respectively. For the DF reduced whole lifecycle costs, even though it did not appear in the top five DFs in the US, it can still be regarded as a highly important DF for GBTs adoption in the US as its rank in the US (rank 6) is very close to the Ghanaian rank (rank 5). The reason for the differences in ranks and thus importance of the DFs could be attributed to the different conditions and regulations in different countries. However, the results from this study suggest that these three DFs – greater energy efficiency, improved occupants' health and well-being, and reduced whole lifecycle costs – could be highly important in driving all GBTs adoption activities regardless of geographical locations. Therefore, it is suggested that practitioners, stakeholders, and policy makers around the world should bear in mind that these are important benefits that could be derived from the use of GBTs, so they need to make GBTs adoption and its promotion a high priority.

4.2. Factor analysis

The previous empirical studies did not group the DFs for GBTs and practices adoption based on the study results. As such, as a supplement to the analysis conducted in the present study to identify the significant DFs of GBTs adoption, due to the large number of significant DFs identified, this study also briefly applied exploratory factor analysis (EFA) to explore the underlying dimensions of the significant DFs for future research endeavor. However, prior to applying this method, the appropriateness of the data should be examined. Thus, in this study, the Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were used to evaluate the appropriateness of the data for factor analysis. The Bartlett's test of sphericity result of 313.036 with an associated level of significance of 0.00

suggested that the correlation matrix is not an identity matrix (SPSS, 1997; Pallant, 2011). The KMO value of 0.717 was higher than the acceptable threshold of 0.50 (Kaiser, 1970), indicating that the sample is acceptable for factor analysis. The results of these two tests indicate that factor analysis is applicable.

For factor extraction, principal component factor analysis technique was applied to identify underlying grouped forces. The results of factor analysis after varimax rotation are shown in Table 4. Five components with eigenvalues greater than 1 are extracted. With these five components, 71.16% of the variance is accounted for by GBTs adoption DFs (Table 5). As shown in Table 4, the 16 significant DFs are split into five meaningful components that could be named as follows: environment-related forces, company-related forces, economy and health-related forces, cost and energy-related forces, and industry-related forces. Having grouped the DFs, future studies could confirm these groupings through confirmatory factor analysis (CFA), and subsequently examine/model the interrelationships among the DFs and their impacts on the GBTs adoption process using statistical modeling methods, such as structural equation modeling.

Table 4
Results of EFA on DFs for GBTs adoption (rotated component matrix).

Code	DFs for GBTs adoption	Components				
		1	2	3	4	5
Component 1: Environment-related forces						
DF07	Reduced environmental impact	0.832	–	–	–	–
DF08	Improved indoor environmental quality	0.735	–	–	–	–
DF09	Greater water efficiency	0.732	–	–	–	–
DF12	High return on investment	0.615	–	–	–	–
DF06	Non-renewable resources conservation	0.414	–	–	–	–
Component 2: Company-related forces						
DF18	Increased building value	–	0.827	–	–	–
DF03	Company image and reputation	–	0.681	–	–	–
DF05	Improved occupants' productivity	–	0.638	–	–	–
DF17	Better workplace environment	–	0.551	–	–	–
Component 3: Economy and health-related forces						
DF13	Reduced use of construction materials in the economy	–	–	0.839	–	–
DF20	Job creation opportunity	–	–	0.744	–	–
DF04	Improved occupants' health and well-being	–	–	0.580	–	–
Component 4: Cost and energy-related forces						
DF02	Reduced whole lifecycle costs	–	–	–	0.867	–
DF01	Greater energy efficiency	–	–	–	0.789	–
Component 5: Industry-related forces						
DF21	Facilitating a culture of best practice sharing	–	–	–	–	0.826
DF01	Setting a standard for future design and construction	–	–	–	–	0.802

Note: Extraction method = principal component analysis; Rotation method = varimax with Kaiser normalization; Rotation converged in 7 iterations.

Table 5

Total variance explained.

	Initial eigenvalues			Rotation sums of squared loadings		
Component	Total	Percentage of Variance	Cumulative percentage	Total	Percentage of Variance	Cumulative percentage
1	6.080	38.001	38.001	3.024	18.901	18.901
2	1.524	9.526	47.527	2.613	16.334	35.236
3	1.417	8.857	56.384	2.078	12.988	48.224
4	1.203	7.521	63.905	1.940	12.125	60.349
5	1.161	7.258	71.163	1.730	10.814	71.163

5. Conclusions and future research

To promote the wider adoption of GBTs, this study aimed to identify the major DFs for GBTs adoption in the construction industry in the context of Ghana. A comprehensive literature review was conducted to identify 21 DFs that were presented in a questionnaire. Through an empirical questionnaire survey with 43 professionals in Ghana, the results first indicated that “setting a standard for future design and construction”, “greater energy efficiency”, “improved occupants’ health and well-being”, “non-renewable resources conservation”, and “reduced whole lifecycle costs” were the top five forces greatly driving the GBTs adoption. In addition, the importance of 16 DFs in GBTs adoption were statistically significant, and there were no statistically significant differences in the perceptions of the importance of all the DFs. Furthermore, a comparative analysis pointed out that the highest rank of “setting a standard for future design and construction” is unique for GBTs adoption in only the developing country of Ghana, not in the developed country of the US. Moreover, for future research endeavor, factor analysis was performed on the data, and the results showed that the 16 significant DFs could be grouped into five underlying forces: environment-related, company-related, economy and health-related, cost and energy-related, and industry-related forces.

As one of the few empirical studies to present major forces driving GBTs adoption in a developing country, the findings of this study make a significant contribution to the green building literature. Moreover, having an in-depth understanding of the important benefits that could be derived from GBTs adoption, industry practitioners and stakeholders can now make informed decisions regarding whether they should adopt GBTs in their projects. The results of this study can also help policy makers and advocates improve the efficiency and effectiveness of their GBTs adoption promotion efforts by focusing and acting based upon the significant DFs or DFs with high importance. They are advised to pay special attention to formulating and implementing good strategies to educate and increase the knowledge and awareness of the public on these DFs as they are benefits that can naturally stimulate interest in GBTs adoption.

Albeit the objective was achieved, this study was not conducted without limitations. First, the respondents' experiences and attitudes could have an influence on the evaluation of the DFs made in this study because it was subjective. Aside from that, because the sample size was not very large, caution ought to be taken when interpreting and generalizing the results. Moreover, as the first attempt to present the significant DFs of GBTs adoption in Ghana, this study only briefly explored the underlying dimensions of the significant DFs. Thus, future research opportunity exists to examine/model the interrelationships between the DFs in detail as well as their impacts on the GBTs adoption process.

As this study was conducted within the developing country of Ghana, the findings and implications of this study could also be useful to policy makers, stakeholders, and practitioners in other developing countries worldwide. However, data gathered from a different country might produce different results. Therefore, using the proposed DFs, similar studies could be undertaken in different developing countries where different conditions and regulations exist, thus helping to identify country-specific DFs for country-specific GBTs adoption promotion. Building upon this study, future research could also determine the total population of professionals in the green building industry and employ a larger sample to comprehensively analyze the differences between the GBTs adoption DFs in Ghana and many other specific countries. Lastly, future study could validate the findings of this study through case studies of successful green building projects to quantify and show the real benefits from those projects, which could make GBTs more attractive to clients and customers.

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Highlights

- The major DFs for GBTs adoption in Ghana have been identified.
- Comparison was made of the GBTs adoption DFs in Ghana and the US.
- The underlying forces for the significant GBTs adoption DFs have been identified.