ADOPTION OF GREEN BUILDING TECHNOLOGIES IN GHANA: DEVELOPMENT OF A MODEL OF GREEN BUILDING TECHNOLOGIES AND ISSUES INFLUENCING THEIR ADOPTION

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Adoption of Green Building Technologies in Ghana: Development of a Model of Green Building Technologies and Issues Influencing Their Adoption

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CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

____________(Signed)

Amos Darko (Name of student)

DEDICATION

I dedicate this thesis to God, the Almighty, my family (especially my mother – Mrs. Mary Oppong Adipa and Wife – Mrs. Cynthia Akotoa Darko), and friends.

ABSTRACT

Adoption of green building technologies (GBTs) in buildings is crucial to implementing global sustainable development. However, GBTs adoption is influenced by numerous issues and its promotion is a difficult task for especially developing countries. To effectively promote GBTs adoption, it is critical to understand GBTs and the issues influencing their adoption. This study aims to achieve this. Specifically, this study has five objectives: (1) to identify the important GBTs to achieve sustainable housing development in Ghana, and to contextualize the GBTs as a model to assist sustainable housing development; (2) to identify the major drivers for GBTs adoption in Ghana, and to examine the influences of the drivers on GBTs adoption; (3) to identify the critical barriers to GBTs adoption within Ghana, and to examine the influences of the barriers on GBTs adoption; (4) to identify the important strategies to promote GBTs adoption in Ghana, and to examine the possible influences of the strategies on GBTs adoption; and (5) to develop an implementation strategy, based upon the study results, to help in promoting GBTs adoption in Ghana. Ghana is a developing country in West Africa, which is currently attempting to achieve major progress in GBTs adoption and development. Therefore, this study's outcomes should be useful for Ghana and other developing countries. It is worth mentioning that while numerous studies have been conducted on most of the issues being addressed in this study, the studies in the developing countries' context, as well as those analyzing the influences of barriers, drivers, and promotion strategies on GBTs adoption are inadequate.

The objectives were achieved via comprehensive literature reviews and questionnaire surveys with professionals with green building experience in Ghana. Data were analyzed using various quantitative analysis techniques. On the GBTs to achieve sustainable housing development in

Ghana, results indicated that application of natural ventilation, application of energy-efficient lighting systems, optimizing building orientation and configuration, application of energy-efficient HVAC system, and installation of water-efficient appliances and fixtures were the five most important GBTs. Based on AHP, a model of the important GBTs is built to aid sustainable housing development in Ghana. On the GBTs adoption drivers in Ghana, 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 drivers. Factor analysis revealed that the underlying drivers for the 16 significant drivers were environment-related, company-related, economy and health-related, cost and energy-related, and industry-related drivers. On the GBTs adoption barriers, 20 barriers were critical. The top five most critical barriers were higher costs of GBTs, lack of government incentives, lack of financing schemes, unavailability of GBTs suppliers, and lack of local institutes and facilities for GBTs R&D. Factor analysis showed that the underlying barriers of the 20 critical barriers were government-related, human-related, knowledge and information-related, market-related, and cost and risk-related barriers. Regarding the strategies to promote GBTs adoption in Ghana, more publicity through media, GBTs-related educational and training programs for key stakeholders, availability of institutional framework for effective GBTs implementation, a strengthened GBTs R&D, and financial and further market-based incentives were the top five strategies. Factor analysis indicated that the underlying strategy groupings were: government regulations and standards; incentives and R&D support; awareness and publicity programs; education and information dissemination; and awards and recognition. This research study also compared the top GBTs adoption drivers, barriers, and promotion strategies within Ghana with those within other (developed) countries.

The PLS-SEM results indicated that (1) government-related barriers have a significant negative influence on GBTs adoption, (2) company-related drivers have a significant positive influence on GBTs adoption, and (3) two promotion strategies – “government regulations and standards” and “incentives and R&D support” – would have significant positive influences upon the GBTs adoption. Quantitative models elucidating the influences of barriers, drivers, and promotion strategies on GBTs adoption are developed. Based on the PLS-SEM results, an implementation strategy to promote the GBTs adoption is also proposed. This implementation strategy and the GBTs model are further validated by industry practitioners in Ghana to confirm their credibility and reliability.

This study not only makes valuable contributions to the green building literature, especially for developing countries, but also helps policy makers, practitioners, and advocates promote GBTs adoption in the construction industry. Overall, this study can benefit the construction industry’s sustainable development.

Keywords: Green building technologies; Adoption; Drivers; Barriers; Promotion strategies; Construction industry; Developing countries; Ghana.

LIST OF RESEARCH PUBLICATIONS

The following provides a list of research publications that the author of this thesis made during his Ph.D. study, and, as shown within the text, chapters of this thesis have been fully or partially published in those that are directly relevant to this thesis.

A. Refereed Journal Papers (published/ accepted) (2016 – 2019)

Those Directly Relevant to This Thesis

1. **Darko, A.**, and Chan, A. P. C. (2018). Strategies to promote green building technologies adoption in developing countries: The case of Ghana. *Building and Environment* **(Impact Factor = 4.539)**, 130, 74-84.

2. **Darko, A.**, Chan, A. P. C., Yang, Y., Shan, M., He, B. J., and Gou, Z. (2018). Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case. *Journal of Cleaner Production* **(Impact Factor = 5.651)**, 200, 687-703.

3. Chan, A. P. C., **Darko, A.**, Olanipekun, A. O., and Ameyaw, E. E. (2018). Critical barriers to green building technologies adoption in developing countries: the case of Ghana. *Journal of Cleaner Production* **(Impact Factor = 5.651)**, 172, 1067-1079.

4. **Darko, A.**, Chan, A. P. C., and Owusu, E. K. (2018). What are the green technologies for sustainable housing development? An empirical study in Ghana. *Business Strategy and Development*, 1(2), 140-153.

5. **Darko, A.**, Chan, A. P. C., Ameyaw, E. E., Owusu, E. K., Pärn, E., and Edwards, D. J. (2018). Review of application of analytic hierarchy process (AHP) in construction. *International Journal of Construction Management,* doi:10.1080/15623599.2018.1452098.

6. **Darko, A.**, Chan, A. P. C., Gyamfi, S., Olanipekun, A. O., He, B. J., and Yu, Y. (2017). Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. *Building and Environment* **(Impact Factor = 4.539)**, 125, 206-215.

7. **Darko, A.**, Chan, A. P. C., Owusu-Manu, D. G., and Ameyaw, E. E. (2017). Drivers for implementing green building technologies: An international survey of experts. *Journal of Cleaner Production* **(Impact Factor = 5.651)**, 145, 386-394.

8. **Darko, A.**, Chan, A. P. C., Ameyaw, E. E., He, B. J., and Olanipekun, A. O. (2017). Examining issues influencing green building technologies adoption: The United States green building experts' perspectives. *Energy and Buildings* **(Impact Factor = 4.457)**, 144, 320-332.

9. **Darko, A.**, Zhang, C., and Chan, A. P. C. (2017). Drivers for green building: A review of empirical studies. *Habitat International* **(Impact Factor = 3.000)**, 60, 34-49. **("Highly Cited Paper" in the field of Social Sciences – Web of Science Core Collection, 2018)**.

10. **Darko, A.**, and Chan, A. P. C. (2017). Review of barriers to green building adoption. *Sustainable Development* **(Impact Factor = 2.750)**, 25(3), 167-179.

11. Chan, A. P. C., **Darko, A.**, and Ameyaw, E. E. (2017). Strategies for promoting green building technologies adoption in the construction industry—An international study. *Sustainability* **(Impact Factor = 2.075)**, 9(6), 969.

12. **Darko, A.**, and Chan, A. P. C. (2016). Critical analysis of green building research trend in construction journals. *Habitat International* **(Impact Factor = 3.000)**, 57, 53-63. **("Highly Cited Paper" in the field of Social Sciences – Web of Science Core Collection, 2018)**.

13. Chan, A. P. C., **Darko, A.**, Ameyaw, E. E., and Owusu-Manu, D. G. (2016). Barriers affecting the adoption of green building technologies. ASCE's *Journal of Management in Engineering* **(Impact Factor = 2.282)**, doi:10.1061/(ASCE)ME.1943-5479.0000507, 0401 6057.

14. **Darko, A.**, Chan, A. P., Huo, X., and Owusu-Manu, D. G. (2019). A scientometric analysis and visualization of global green building research. *Building and Environment*, 149, 501-511.

The candidate's level of contribution to the above papers

Under the full supervision of his supervisor – Ir. Professor Albert P. C. Chan – the candidate – Amos Darko – explored and developed the ideas for and fully drafted the initial drafts of all the above papers. The candidate also revised and improved the quality of the papers based on feedback from his supervisor on the initial drafts. On some of the papers, in order for us to demonstrate our ability to work collaboratively with others, other scientists in the field were invited to co-author the papers with us by generally providing feedback for further improvements of the papers. The candidate further revised and improved the papers based upon the feedback from these scientists. It is also worthy to mention that the candidate drafted all of the above papers in English without employing professional English language editing services. Lastly, the candidate was the corresponding author of all of the above papers and carried out all revisions of the papers based on journal reviewer comments and responded to those comments accordingly.

Others

1. Chan, A. P. C., Yang, Y., and **Darko, A.** (2018). Construction accidents in a large-scale public infrastructure project: severity and prevention. ASCE's *Journal of Construction Engineering and Management* **(Impact Factor = 2.201)**, doi:10.1061/(ASCE)CO.1943-7862.0001545, 05018010.

2. Yu, Y., **Darko, A.**, Chan, A. P. C., Chen, C., and Bao, F. (2018). Evaluation and ranking of risk factors in transnational public-private partnerships projects: Case study based on the

intuitionistic fuzzy analytic hierarchy process. ASCE's *Journal of Infrastructure Systems* **(Impact Factor = 1.356)**, doi:10.1061/(ASCE)IS.1943-555X.0000448, 04018028.

3. Yu, Y., Chan, A. P. C., Chen, C., and **Darko, A.** (2018). Critical risk factors of transnational public–private partnership projects: Literature review. ASCE's *Journal of Infrastructure Systems* **(Impact Factor = 1.356)**, doi:10.1061/(ASCE)IS.1943-555X.0000405, 04017042.

4. Bao, F., Chan, A. P. C., Chen, C., and **Darko, A.** (2018). Review of public–private partnership literature from a project lifecycle perspective. ASCE's *Journal of Infrastructure Systems* **(Impact Factor = 1.356)**, doi:10.1061/(ASCE)IS.1943-555X.0000424, 04018008.

5. Olanipekun, A. O., Xia, B., Hon, C., and **Darko, A.** (2018). Effect of motivation and owner commitment on the delivery performance of green building projects. ASCE's *Journal of Management in Engineering* **(Impact Factor = 2.282)**, doi:10.1061/(ASCE)ME.1943-5479.0000559, 04017039.

6. He, B. J., Zhao, D. X., Zhu, J., **Darko, A.**, and Gou, Z. H. (2018). Promoting and implementing urban sustainability in China: An integration of sustainable initiatives at different urban scales. *Habitat International* **(Impact Factor = 3.000)**, doi:10.1016/j.habitatint.2018.10.001.

7. Durdyev, S., Ismail, S., Ihtiyar, A., Bakar, N. F. S. A., and **Darko, A.** (2018). A partial least squares structural equation modeling (PLS-SEM) of barriers to sustainable construction in Malaysia. *Journal of Cleaner Production* **(Impact Factor = 5.651)**, 204, 564-572.

8. Khoshbakht, M., Gou, Z., Xie, X., He, B., and **Darko, A.** (2018). Green building occupant satisfaction: Evidence from the Australian higher education sector. *Sustainability* **(Impact Factor = 2.075)**, 10(8), 2890.

9. Zhang, Y., Zheng, J., and **Darko, A.** (2018). How does transformational leadership promote innovation in construction? The mediating role of innovation climate and the multilevel moderation role of project requirements. *Sustainability* **(Impact Factor = 2.075)**, 10, 1506, doi:10.3390/su10051506.

10. Zhang, Y., Gu, J., Shan, M., Xiao, Y., and **Darko, A.** (2018). Investigating private sectors' behavioral intention to participate in PPP projects: An empirical examination based on the theory of planned behavior. *Sustainability* **(Impact Factor = 2.075)**, 10(8), 2692.

11. Meng, F. Q., He, B. J., Zhu, J., Zhao, D. X., **Darko, A.**, and Zhao, Z. Q. (2018). Sensitivity analysis of wind pressure coefficients on CAARC standard tall buildings in CFD simulations. *Journal of Building Engineering*, 16, 146-158.

12. Ameyaw, E. E., Pärn, E., Chan, A. P. C., Owusu-Manu, D. G., Edwards, D. J., and **Darko, A.** (2017). Corrupt practices in the construction industry: Survey of Ghanaian experience. ASCE's *Journal of Management in Engineering* **(Impact Factor = 2.282)**, doi:10.1061/(ASCE)ME.1943-5479.0000555, 05017006.

13. Zhao, Z. Q., He, B. J., Li, L. G., Wang, H. B., and **Darko, A.** (2017). Profile and concentric zonal analysis of relationships between land use/land cover and land surface temperature: Case study of Shenyang, China. *Energy and Buildings* **(Impact Factor = 4.457)**, 155, 282-295.

14. **Darko, A.**, Owusu-Manu, D. G., Pärn, E. A., and Edwards, D. J. (2016). Identifying potential critical risks in the construction supply chain – An empirical study in Ghana. *Mindanao Journal of Science and Technology*, 14, 79-100.

15. Owusu, E. K., Chan, A. P. C., **Darko, A.** (accepted). Thematic overview of corruption in infrastructure procurement process. ASCE's *Journal of Infrastructure Systems* **(Impact Factor = 1.356)**, Ref.: Ms. No. ISENG-1475R1.

16. Hosseini, M. R., Martek, I., Chan, A. P. C., **Darko, A.**, Banihashemi, S., Tahmasebi, M. (accepted). Distinguishing characteristics of corruption risks in Iranian construction projects: A weighted correlation network analysis. *Science and Engineering Ethics* **(Impact Factor = 1.859)**, Manuscript ID: JSEE-D-18-00103R1.

The candidate's level of contribution to the above papers

The candidate contributed to the above papers in many ways ranging from thorough English language editing to reviewing, proofreading, and providing effective feedback and suggestions for further improvements of initial drafts of the papers. In some cases, the candidate played key roles in re-working and re-structuring of the initial drafts of the papers in attempts to improve their quality prior to the journal submissions, and also helped in revising the papers based on journal reviewer comments and in responding to those comments accordingly.

B. Refereed Journal Papers (under review for the first or second time)

1. **Darko, A.**, Chan, A. P. C., Adabre, M. A., Edwards, D. J., Hosseini, R. M., and Ameyaw, E. E. (under review). A scientometric analysis of artificial intelligence research in the construction industry. ASCE's *Journal of Construction Engineering and Management*, Ref.: Ms. No. COENG-7776.

2. Ma, X., **Darko, A.**, Chan, A. P. C., Wang, R., and Zhang, B. (under review). Barriers to BIM implementation in construction projects: Empirical evidence from China. *Engineering, Construction and Architectural Management*, Manuscript ID: ECAM-10-2018-0452R1.

3. Yu, Y., **Darko, A.**, Chan, A. P. C., Chuan, C., and Jing, X. (under review). Risk allocation in transnational public-private partnerships projects: Case study based on the bargaining game theory. *Engineering, Construction and Architectural Management*, Manuscript ID: ECAM-09-2018-0363.

4. Yang, Y., Chan, A. P. C., **Darko, A.**, Gao, R., and Zahoor, H. (under review). Factors affecting structural steelwork adoption from a project lifecycle perspective: The case of Hong Kong. *Journal of Cleaner Production*, Manuscript number: JCLEPRO-D-18-09529.

5. Olanipekun, A. O., and **Darko, A.** (under review). Understanding corporate social responsibility in the construction sector: The state of the art and other issues. *Engineering, Construction and Architectural Management*, Manuscript ID: ECAM-11-2017-0252.R1.

6. Huo, X., Yu, A. T. W., **Darko, A.**, and Wu, Z. (under review). Critical factors in site planning and design of green buildings: A case of China. *Journal of Cleaner Production*, Manuscript number: JCLEPRO-D-18-03840R1.

7. Mahdoudi, B., Gou, Z., **Darko, A.**, and Man, J. C. F. (under review). A systematic review of drivers for the adoption of prefabrication in the construction industry. *Journal of Cleaner Production*, Manuscript number: JCLEPRO-D-18-06444R1.

8. Torku, A., Bayrak, T., Chan, A. P. C., Yung, E. H. K., Owusu-Manu, D. G., and **Darko, A.** (under review). Are the ageing workforce satisfied with the construction work environment? *Ageing & Society*, Manuscript number: AGE-18-0372.

C. Refereed Conference Papers (published)

1. **Darko, A.**, Chan, A. P. C., Owusu, E. K., and Antwi-Afari, M. F. (2018). Benefits of green building: A literature review. *RICS COBRA 2018*, 23 – 24 April 2018, London, UK.

2. Owusu, E. K, Chan A. P. C., and **Darko, A.** (2018). What are the barriers that affect the potency of anti-corruption measures in construction and infrastructure procurement? A systematic review. *EBEN 2018 Research Conference*, 6 – 8 September 2018, Vienna, Austria.

3. Antwi-Afari, M. F., Yu, Y., Li, H., **Darko, A.**, Seo, J., and Wong, A. Y. (2018). Automated detection and classification of construction workers' awkward working postures using wearable insole pressure sensors. *1st Postgraduate Applied Research Conference in Africa*, 21 – 23 February 2018, Accra, Ghana.

4. **Darko, A.**, and Chan, A. P. C. (2017). Major barriers hindering green building technologies adoption within Ghana. *Shenzhen-Kong Kong Academic Conference About Sustainable Construction Based on the Guangdong-Hong Kong-Macao Greater Bay Area*, 1 – 3 December 2017, Shenzhen, China.

5. Yu, Y., Chen, C., Chan, A. P. C., and **Darko, A.** (2017). Critical risk factors for transnational public-private partnership projects: A literature review. *CRIOCM 2017 22nd International Conference on Advancement of Construction Management and Real Estate*, 20 – 23 November 2017, Melbourne, Australia.

D. Book Chapter (accepted)

1. **Darko, A.**, and Chan, A. P. C. (accepted). Adoption of green building technologies in Ghana. *Green building development in the third world*, Springer International Publishing.

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CHAPTER 1 INTRODUCTION [1]

1.1 INTRODUCTION

The construction industry plays an important role in socio-economic development. According to the United Nations Environment Programme (UNEP) (2009), the construction industry accounts for 10-40% of countries' gross domestic product (GDP) and represents, on a global average, 10% of country-level employment. Likewise, the construction industry makes great contribution to the national economy via playing a core role in urbanization; it provides living and working spaces for humans (Zuo and Zhao, 2014; Zhang, 2015). However, the construction industry can also have negative effects on the environment, economy, and society. Construction activities and operations generate large quantities of dust, solid waste, noise, wastewater, and smoke (Tam and Tam, 2008; Shen et al., 2017a). Additionally, the construction industry has been regarded a resource-intensive industry (Shi et al., 2017) that consumes 40% of the global raw materials (sand, gravel, and stone), 25% of the global timber resources, and 12-16% of the global water available (Arena and De Rosa, 2003; Son et al., 2011; Berardi, 2013a). Also, more than 40% of the total global energy is consumed by the construction industry; thus, the industry

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[1] This chapter is largely based upon:

Chan, A. P. C., Darko, A., Olanipekun, A. O., and Ameyaw, E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production*, 172, 1067-1079.

Darko, A., and Chan, A. P. C. (2016). Critical analysis of green building research trend in construction journals. *Habitat International*, 57, 53-63.

Darko, A., Chan, A. P. C., Gyamfi, S., Olanipekun, A. O., He, B. J., and Yu, Y. (2017a). Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. *Building and Environment*, 125, 206-215.

Darko, A., Chan, A. P. C., Ameyaw, E. E., He, B. J., and Olanipekun, A. O. (2017b). Examining issues influencing green building technologies adoption: The United States green building experts' perspectives. *Energy and Buildings*, 144, 320-332.

Darko, A., Zhang, C., and Chan, A. P. C. (2017c). Drivers for green building: A review of empirical studies. *Habitat International*, 60, 34-49.

Darko, A., Chan, A. P. C., and Owusu, E. K. (2018a). What are the green technologies for sustainable housing development? An empirical study in Ghana. *Business Strategy and Development*, 1(2), 140-153.

is responsible for emitting more than 40% of the total global energy-related greenhouse gases (International Energy Agency (IEA), 2013a, b). These greenhouse gas emissions are a leading cause of climate change, which has been a major global concern for years (Intergovernmental Panel on Climate Change, 2007, 2014, 2018). In the current scenario, it has been predicted that, if nothing is done to improve the energy efficiency of buildings, the energy consumption within the construction industry and the associated greenhouse gas emissions would increase by more than 50% by 2050 (IEA, 2014; Berardi, 2017).

Green building has emerged as a way to mitigate negative impacts of the construction industry on the environment, economy, and society. Essentially, it helps to enhance the sustainability of the construction industry in terms of energy and natural resource consumption, greenhouse gas emissions, human health and well-being, and productivity. As a result of the emergence of the green building concept, several green building technologies (GBTs) have been introduced for developing green building projects. The adoption of GBTs is a vital part of the implementation of green building. That is to say, green building is not achievable without GBTs adoption (Chan et al., 2018). As a result of innumerable characteristics, such as distinctive climatic conditions, environmental, economic, and social priorities, unique cultures and traditions, and diverse building types and regulations, of different countries and regions, the green building approach varies amongst countries (World Green Building Council (WorldGBC), 2017a). Many scholars also agree that the green building method and assessments are not the same worldwide (Schulte, 2009; Li et al., 2014; Zuo and Zhao, 2014). Furthermore, Kates and Clark (1999) argued that context cannot be ignored in efforts to achieve sustainability, as society’s developmental goals and priorities ought to be met within such efforts. These issues suggest that GBTs adoption has a context-sensitive nature; it is highly influenced by contextual issues or factors. It is therefore necessary to understand how to promote GBTs adoption in specific countries and regions. The promotion of GBTs adoption in various countries can contribute to the success of implementing green building, and thus achieving more sustainable building developments, worldwide.

From the perspective of the developing country of Ghana, this study focuses on four issues that are core to the successful adoption and promotion of GBTs: (1) GBTs for sustainable housing development; (2) drivers for GBTs adoption; (3) barriers to GBTs adoption; and (4) strategies to promote GBTs adoption. Analyzing these issues affords invaluable insights for governments and other public policy makers, industry practitioners and stakeholders, as well as advocates to promote GBTs adoption within the construction industry. Within extant literature, only limited attempts have been made to analyze and model these important issues of GBTs adoption within developing countries such as Ghana.

1.2 BACKGROUND

1.2.1 Sustainable Development and Green Building

The concept of sustainability is most generally known in relation with sustainable development (Manoliadis et al., 2006). While various definitions have been offered, the World Commission on Environment and Development (WCED) (1987) offered the first definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development has three aspects, environmental, economic, and social sustainability, which are most commonly referred to as the three pillars or the triple bottom line of sustainable development. Ensuring that human beings thrive both today and tomorrow without damaging the environment is a monumental challenge. At the heart of environmental sustainability are environmental protection, natural resource conservation, and encouragement of the development and use of renewable resources (Abidin and Pasquire, 2007). In addition, the model of environmental sustainability emphasizes that all environmental life-support systems, e.g., water, soil, and air, must be healthy, meaning that their environmental service capacity must be sustained (Goodland, 1995). While the means to realizing environmental sustainability in every country, region, or sector might differ, the sustainable development goals are constant. Economic sustainability, which is about achieving economic growth, focuses on improving economic efficiency and performance, profitability, and prosperity (Thomsen, 2013). From a social sustainability perspective, sustainability issues cover promoting social progress, health, and well-being, aesthetic values, human quality of life, equity, social cohesion, and culture (Goodland, 1995; Lombardi, 2001). Goodland (1995) noted that overlaps exist amongst the three pillars of sustainable development. To achieve sustainable development, development initiatives need to consider all of these three pillars (environmental, economic, and social sustainability).

Since the WCED (1987) drew the world's attention to environmental problems and sustainable development, sustainable development has been generally recommended in various industries. The construction industry has been identified as an industry that can significantly contribute to all aspects of sustainable development, owing to the large environmental, economic, and social effects of construction activities (UNEP, 2009; Sev, 2009). Among the various measures being implemented and promoted by governments and construction experts to implement sustainable development within the construction industry, green building has attracted much attention and acceptance in recent years (Zuo and Zhao, 2014; Zhang, 2015; Darko and Chan, 2016). Several interchangeable terms, e.g., sustainable building, sustainable construction, high-performance building, high-performance construction, and green construction, are used within the literature to refer to "green building" (US Green Building Council (USGBC) Research Committee, 2008; Kibert, 2012). However, only the term green building is used in this thesis for consistency.

Also, there are many different definitions of green building within the literature (see Darko and Chan (2016) and Dwaikat and Ali (2016)). The definitions seem to suggest that green building represents an efficient way to implement sustainable development principles in the construction industry, as it incorporates the triple bottom line of environmental, economic, and social sustainability and performance throughout the whole lifecycle of buildings. In this light, in this research, green building can be considered the practice of planning and designing, constructing, operating and maintaining, renovating, and eventually demolishing buildings in a resource-efficient, environmentally friendly, and healthy manner (US Environmental Protection Agency (USEPA), 2016). This advocates that lifecycle thinking should be considered in green building. Kibert (2012) contended that the outcome of applying green building approaches to creating a green and responsible built environment is often referred to as "green buildings". According to the WorldGBC (2017a), "a green building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment". The WorldGBC further advocated, "Green buildings preserve precious natural resources and improve our quality of life". Globally, numerous green building rating systems have been developed to assess and certify green buildings. In other words, green building rating systems are used to recognize buildings that satisfy certain green requirements or standards (WorldGBC, 2017b). At the moment, the Leadership in Energy and Environmental Design (LEED) from the US and the Green Star South Africa (Green Star SA) from South Africa are the two primary green building rating systems being applied in Ghana. Thus, within the Ghanaian context, this study defines green buildings as buildings that have either obtained the LEED certification or the Green Star SA certification (Darko et al., 2017a).

1.2.2 Origin of Green Building

Giessen David, custodian of Architecture and Design Library in American National Building Museum, argued that the origin of green building could be traced back to several centuries ago (Li et al., 2014). According to him, the construction of the Galleria Vittorio Emmanuele in the early 19th century in Milan, Italy, and that of the British Palace during the period of the first world expo first introduced the use of passive systems, such as underground air cooling boxes and roof fans, in regulating indoor temperature. Additionally, in the early 20th century, wherein the New York Times Building and the Flatiron Building, both in the US, installed windows that were entrenched into walls to control and reduce sunlight penetration, the core idea of green building – architectural designs and construction practices that take account of the natural environment and ecological systems – was introduced (Li et al., 2014). In the 1960s, Paolo Soleri, an Italian-American architect who was popularly known for the development of "eco-building or ecological building" concept, combined the ecology and architecture and termed this combination "Arcology" (Soleri, 1969). What this means is that the green building concept was initially put to the fore as "Arcology" by Paolo Soleri. In 1969, Ian Lennox McHarg, an American Architect, also published a book entitled "Design with Nature", which officially marked the birth of "ecological building" (Gao, 2010). Moreover, during the 1970s oil crisis, the attention of stakeholders in the construction industry shifted to the need for building energy efficiency because human developments were not able to further sustain high levels of energy consumption (Zhang et al., 2015). Furthermore, in the 1980s, occupants' mental and physical health begun to be adversely affected by excessive energy saving applications, which called for the need to direct more attention to healthy buildings (Zhang et al., 2015; Mao et al., 2017). All of the above historical events may have created the grounds for what has nowadays become a popular phenomenon for addressing the need for sustainability in the construction industry –

green building – and indicate that green building has its roots in ecological building. In recent years, with the growing global interest in sustainability and the increasing awareness of climate change, there has been an apparent shift throughout the world towards green buildings (Hwang et al., 2017a, b). Thus, it is crucial to promote GBTs adoption among construction stakeholders and organizations so that more green building developments can be eventually achieved.

1.2.3 Green Innovation

The term innovation has no standard definition; its definitions differ depending upon a number of factors, such as the sector or industry within which innovation occurs. However, innovation could be generically defined as "any idea, practice, or material artifact perceived to be new to the relevant adopting unit" (Czepiel, 1974). The Organization for Economic Cooperation and Development (2005) considered innovation to be "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations." In the innovation adoption and diffusion theory, innovation is often perceived as a vital ingredient in the recipe for creating competitive advantage, market differentiation, and new markets for products and processes (Christensen et al., 2004; Von Hippel, 2005; Chesbrough et al., 2006; Bowonder et al., 2010). In the construction context, innovation is "the actual use of a nontrivial change and improvement in a process, product, or system that is new to the institution developing the change" (Slaughter, 1998).

There is consensus among the above definitions that the occurrence of innovation is frequently characterized by adopting a new practice (Lansley, 1996). Green building is not widespread in developing countries and is a new practice (Darko and Chan, 2016; Hosseini et al., 2018). Thus, green building might be deemed an innovation. Considering green building as an innovation in the construction industry (Yudelson, 2007; Potbhare et al., 2009; Mollaoglu et al., 2016) has resulted in the term green innovation (Love et al., 2012). Green innovation refers to "products, practices, technologies, materials, and processes that either reduce the energy requirements of buildings and/or reduce the environmental impact of buildings" (Miozzo and Dewick, 2004). Even though this definition overlooks the human health dimension, it submits that GBTs, green building rating systems (or guidelines), and green specifications are typical examples of green innovations in the construction industry (Darko et al., 2017b). Adopting green innovations is essential in order to attain the sustainable development of the construction industry. Therefore, several studies have been carried out to help promote the adoption of green innovations within the construction industry (Chan et al., 2009a; Shi et al., 2013; Ahn et al., 2013). Various issues associated with the green innovations adoption were examined and highlighted to facilitate the promotion process. Nevertheless, despite their undoubted usefulness, these studies focused on the adoption of green innovations in general, and thus do not provide a clear and comprehensive understanding of how specific green innovations can be promoted. Darko et al. (2017b) pointed out that general issues have limitations in the promotion of a specific green innovation adoption in practice. Although some studies have attempted to address this by focusing on specific green innovations, for example, green specifications (Lam et al., 2009) and green building guidelines (Potbhare et al., 2009), adoptions, they have been few. The present research contributes to this scholarship through focusing on GBTs adoption.

GBTs are described as technologies, such as green roof technology, prefabrication technology, and solar technology, that are employed in building design and construction to improve overall sustainability performance (Ahmad et al., 2016; Zhang et al., 2011a). Adoption is considered "the acceptance and continued use of a product, service, or idea. The adoption process refers to a series of mental and behavioral states that a person passes through leading to the adoption or rejection of an innovation" (Howard and Moore, 1988). Essentially, in the GBTs adoption process, issues such as barriers and drivers could lead stakeholders to adopt or reject GBTs. This study analyzes issues that drive or hinder the adoption of GBTs with the aim to promote the GBTs adoption. Precisely, the main issues associated with the GBTs adoption are defined to include barriers, drivers, and promotion strategies (Darko et al., 2017b). Barriers represent the issues that make it difficult for stakeholders to adopt GBTs and can eventually prevent the stakeholders from adopting GBTs. Numerous previous studies considered the drivers for GBTs and practices adoption to broadly cover both the benefits of GBTs adoption and actions outside the benefits (e.g., policy making) that lead stakeholders to adopt GBTs and practices (Darko et al., 2017c). But, as a clear difference exists between benefits and actions that are not benefits, the present research distinguishes between them via treating only the benefits as drivers, while treating the actions outside the benefits as promotion strategies (Darko et al., 2017a, b).

1.3 RESEARCH SCOPE AND PROBLEM

This study principally focuses on the adoption and promotion of GBTs in the Ghanaian context. Context represents any explicit or implicit information about the conditions, events, or issues that influence, or determine judgment of, any particular activity (Parducci, 1995; Kronsbein et al., 2014). As a way of integrating sustainability into construction activities, including projects, GBTs adoption is influenced by contextual issues (Hakiminejad et al., 2015; Hosseini et al., 2018), which might include country-, sector-, and firm-specific barriers, drivers, and promotion strategies. These issues, separately or mutually, may foster or hinder GBTs adoption, therefore promoting GBTs adoption requires a better understanding of the influential contextual issues (Potbhare et al., 2009; Hosseini et al., 2018). It should be stated that the influences of contextual issues may be, to a large extent, dependent on the local economic and social systems, regulatory systems, institutional arrangements, peoples' behaviors, attitudes, and needs, geographical area (such as the country or region at large), cultural backgrounds, etc.

1.3.1 Why Focus on Ghana?

Ghana, Fig. 1.1, is a country located in the West of Africa. It is bordered on the east by Togo, on the west by Côte d'Ivoire, on the north by Burkina Faso, and on the south by the Gulf of Guinea and the Atlantic Ocean (Sosuh, 2011). Ghana has a total land area of 238,533 km^2 (Ameyaw, 2014) and a population of nearly 29.5 million (Worldometers, 2018). The country has a tropical climate but fairly mild for the latitude (Encyclopedia, 2016). While the climatic conditions differ across various regions of Ghana, average temperatures range between 21–32 degrees Celsius, with relative humidity between 50% and 80%. This hot-humid climate causes increased energy consumption in Ghanaian buildings, making the adoption of GBTs that could save energy very important in Ghana. For more background information about Ghana, one may refer to Encyclopedia (2016).

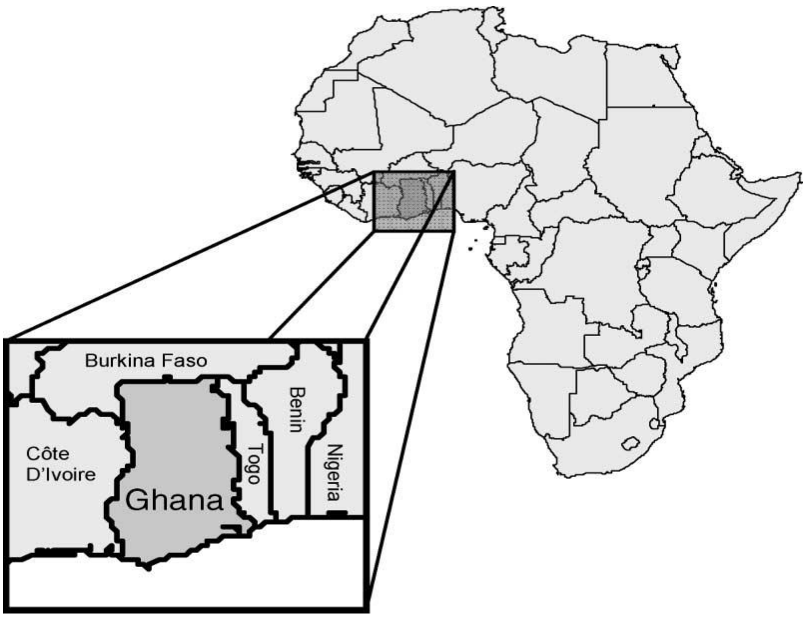

Fig. 1.1 Ghana's location in Africa (Fuest and Haffner, 2007).

The World Economic Situation and Prospects (2014) classifies developing countries as those with gross national income (GNI) per capita of US$12,615 or less. As a developing country, Ghana had a GNI per capita of US$1,380 in 2016 (World Bank, 2017). While it is well-known that developing countries face a number of problems, such as deep poverty, rapid urbanization, weak governance, environmental degradation, and social inequity (Du Plessis, 2007), it was reported in the United Nations Human Development report that 85% of the world's population is still living in developing countries (Klugman, 2011). This is an indication that the impact of developing countries on the world's economy and environment is tremendous, thereby making sustainable development a necessity rather than an option for developing countries (Du Plessis, 2002, 2007). In addition, it has been estimated that the world's population would rise from 3.6 billion in 2011 to 6.3 billion in 2050, with 94% of this increase expected to occur in developing countries (United Nations, 2012). While governments in developing countries have already greatly invested in developing building projects (Gan et al., 2015; Ghoddousi et al., 2015), an increasing trend in new construction is expected, given the projected growth in population, in order to accommodate the ever-growing population. Changing construction practices and going green or sustainable are therefore central to reduce environmental impacts and contribute to the sustainable development of developing countries. The importance of adopting and promoting GBTs in the construction industries of developing countries like Ghana cannot be undermined, particularly as developing countries cause about 60% of the total greenhouse gas emissions of the global construction industry (Huang et al., 2018).

As highlighted by Zhang et al. (2018), GBTs adoption in buildings is a key step towards global sustainable development. But, GBTs adoption has been slower in developing countries than in developed countries (Mao et al., 2015; Nguyen et al., 2017). First, this could be associated with the fact that sustainability is generally not perceived as a priority in the delivery of construction projects within developing countries (Shen et al., 2010; Tabassi et al., 2016). Second, numerous contextual issues, such as lack of government incentives and regulations and lack of financing schemes, continue to hinder the GBTs adoption and development in developing countries (Mao et al., 2015; Chan et al., 2018). Research on these hindering factors as well as ways and means to overcome them has been suggested as it could provide useful directions for creating effective policies and strategies to promote GBTs adoption (Mulligan et al., 2014; Darko et al., 2017b). In this area, Chan et al. (2009a) found that the state of available literature calls for more focused studies to understand and highlight the actual situations in specific countries. As yet, however, available studies have been largely silent on the issues that influence GBTs adoption within the context of Ghana. Furthermore, more research is required to develop frameworks and models for understanding how various types of issues impact GBTs adoption, especially in developing countries.

In 2016, the estimated GDP of Ghana was US$42.69 billion (Trading Economics, 2018), with the construction industry accounting for US$667.35 million. One of the most serious problems facing Ghana today is the energy crises. In fact, Ghana has in the past four decades, 1984, 1994, 1998, 2007, and 2012, experienced several serious energy crises (Agyarko, 2013), with severe electricity supply challenges regarding power quality and supply security. This condition has not only caused the country to suffer from load shedding from the start of 2013 till now (Gyamfi et al., 2018), but also costs the country an average of US$2.1 million in loss of production per day (Kumi, 2017). Even though there might be other problems, such as environmental pollution and unsustainable use of natural resources, facing Ghana, this research study speaks more about the energy crisis because it is well-documented (Gyamfi et al., 2015; Kumi, 2017; Sakah et al., 2017; Gyamfi et al., 2018). If the sustainable development of Ghana is to be realized, then it is imperative that the energy problems be resolved. As such, energy efficiency, which is globally recognized as a low-cost, readily available resource that can assist in improving the electricity supply security, has emerged as a priority issue in Ghana in recent times and hence has received substantial attention from the regulating agencies (e.g., the Energy Commission of Ghana and Ghana Energy Foundation) in charge of energy issues (Gyamfi et al., 2018). As advocated by Kumi (2017), dealing with Ghana's energy crises needs a range of actions such as diversifying the energy generation mix via the development of renewable energy sources and promoting energy efficiency programs. This suggests that the adoption of GBTs, e.g., renewable energy technologies (solar panels, etc.) and energy-efficient technologies (energy-efficient lighting systems, etc.), has an enormous potential of helping Ghana to deal with the energy crises by improving energy efficiency (Karunathilake et al., 2018). Energy efficiency improvement has a positive impact on the environment and climate through greenhouse gas emissions reduction. However, as Darko et al. (2017a) indicated, GBTs adoption within Ghana is slow and still in its infancy. Clearly, GBTs adoption, and hence green buildings development, is still uncommon in Ghana. This requires stronger efforts to accelerate and promote the widespread adoption of GBTs within the country. Hence, the study aimed at promoting GBTs adoption in the Ghanaian construction industry is timely and significant.

While there may, of course, be some limitations on generalization, which is a common problem associated with country-specific, regional, or focused studies (Zhao and Singhaputtangkul, 2016), as this study focused on the developing country of Ghana, the findings and implications could still be of benefit to policy makers, practitioners, and advocates within other developing countries the world over. Nevertheless, conducting similar studies in different countries is still necessary for taking explicit account of local situations, for observing the country- or market-specific differences, as well as for more effectively and efficiently promoting GBTs adoption within specific countries and contexts.

1.3.2 Why Focus on Housing and the Design Stage?

> *"A home is more than just shelter: homes are the most important buildings in our lives. We think that every building should be a green building – but especially homes"* (USGBC, 2014).

The first objective of this study is to identify the important GBTs to achieve sustainable housing development within Ghana. The terms housing and residential are used interchangeably in this thesis. Although residential buildings play a vital part in serving the daily lives of people, they remain a major contributor to the environmental impacts created by the construction industry. According to the US Energy Information and Administration (USEIA) (2016), 23% of the energy in the US is consumed by residential buildings. In Canada, residential buildings are reported to be responsible for 17% of the energy consumption and 14% of the greenhouse gas emissions (Natural Resources Canada, 2016). In the UK, residential buildings consumed 29% of the total energy in 2016 (Department for Business, Energy & Industrial Strategy, 2017). As for Ghana, it is reported that about 54% of electricity in the country is consumed by residential buildings (Asumadu-Sarkodie and Owusu, 2016). In its 2017 National Energy Statistics, which provides a time series (from 2007 to 2016) data on the energy supply and consumption situation in Ghana, the Energy Commission of Ghana pointed out that the residential sector accounts for the largest share (3,119 ktoe) of the final energy consumption in Ghana (Energy Commission of Ghana, 2017). In the light of the environmental impact of residential buildings, improving the sustainability of housing using GBTs has received considerable attention from researchers and practitioners (Roufechaei et al., 2014; Koebel et al., 2015; Gan et al., 2017). The research identifying the key GBTs to achieve sustainable housing development is expected to help reach the goals of sustainability in housing projects in Ghana.

There are a lot of GBTs that could be used throughout the whole lifecycle of a housing project, from planning and design stage to operation, maintenance and demolishing stage (Zhang et al., 2011a, b). This study is focused on identifying the GBTs in the design stage of housing projects. The sustainability performance of a building is heavily affected by decisions made at the design stage (Dhanjode et al., 2013). While the consideration of sustainability principles is essential at every stage of housing development, the design stage has been recognized as the fundamental stage for starting to integrate green strategies and technologies (Pacheco et al., 2012; Tsai and Chang, 2012). As Hodges (2005) claimed, it is during the design stage that the designer is well positioned to create a green environment. Therefore, in considering environmental issues at the design stage of housing developments, it is essential that appropriate GBTs be put in place. By so doing, residential energy conservation and overall sustainability can be enhanced, and better sustainable housing development can be achieved. Hence, conducting a study to investigate the GBTs to attain sustainability goals from the early stages of housing development is worthwhile.

1.4 RESEARCH AIMS AND OBJECTIVES

This study's aims are twofold: first, to develop a model to outline GBTs to achieve sustainable housing development in Ghana, and second, to develop an implementation strategy to support the promotion of GBTs adoption in Ghana. To attain the aims, the following specific objectives are established:

1. To identify the important GBTs to achieve sustainable housing development in Ghana, and to contextualize the GBTs as a model to assist sustainable housing development;
2. To identify the major drivers for GBTs adoption in Ghana, and to examine the influences of the drivers on the GBTs adoption activity;

3. To identify the critical barriers to GBTs adoption in Ghana, and to examine the influences of the barriers on the GBTs adoption activity;
4. To identify the important strategies to promote GBTs adoption in Ghana, and to examine the likely influences of the strategies on the GBTs adoption activity; and
5. To develop an implementation strategy, based on the study results, to help in promoting GBTs adoption in Ghana.

1.5 RESEARCH METHODOLOGY IN BRIEF

This section provides a brief overview of the overall research procedure. A detailed description of the research methodology can be found in Chapter 2. To achieve the aims and objectives of this study, the overall research process was divided into five systematic and sequential phases, as illustrated in Fig. 1.2. As the initial phase of this study, Phase 1 was designed to explore the potential of the research area by reviewing pertinent literature and holding discussions with the author's supervisor and some Ghanaian green building scholars and practitioners. These initial literature reviews and discussions helped in establishing the research aims, objectives, and methodology (including the research methods to be used). Phase 2 involved comprehensive literature reviews relating to the research objectives. Both global and Ghana-based green building literatures were comprehensively reviewed to form a strong theoretical base for this study. In addition, various sources of literature, such as journal and conference papers, books, industrial publications, and reports and publications by green building councils (GBCs), were useful for this study. Within this phase 2, objectives 1, 2, 3, and 4 were partially achieved, as relevant factors to fully achieve these objectives were identified from the comprehensive literature reviews. Phase 3 comprised primary data collection through two types of structured questionnaire surveys, a general survey and an analytic hierarchy process (AHP) survey, with industry professionals in the Ghanaian construction industry, which further contributed to the partial attainment of objectives 1, 2, 3, and 4. Depending mainly on the data collected within phase 3, phase 4 comprised quantitative data analysis and developments of models, which helped to fully achieve objectives 1, 2, 3, and 4, and partially achieve objective 5. As indicated in Chapter 2, various statistical analysis methods, including mean score ranking method, factor analysis, partial least squares structural equation modeling (PLS-SEM), and AHP, were used in this phase 4. The final phase, phase 5, of this research consisted of the development of an implementation strategy to promote GBTs adoption and validation of the study. In this phase, objective 5 was fully achieved.

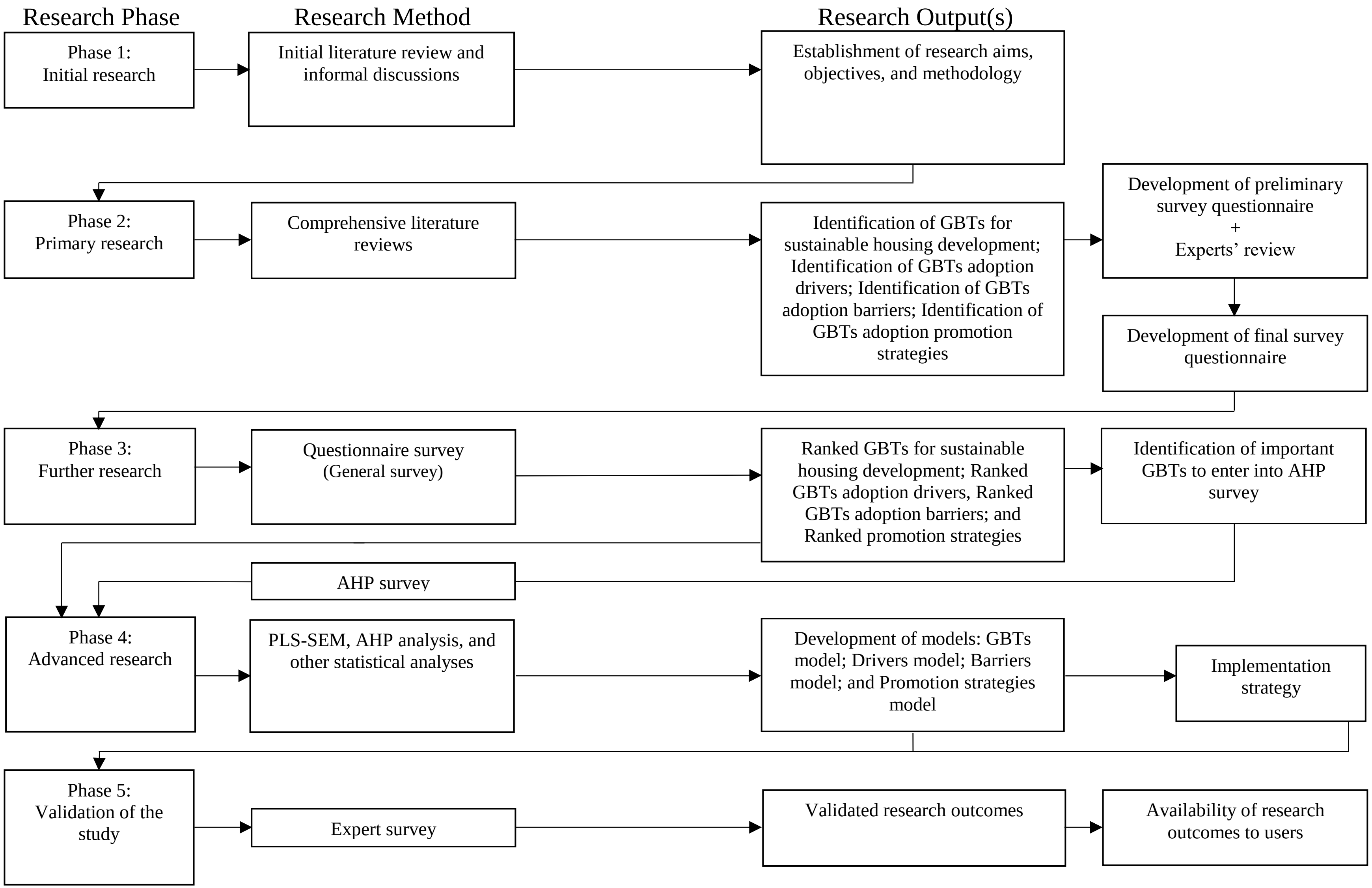

Fig. 1.2 Overall research procedure (Modified from Ameyaw, 2014).

1.6 STRUCTURE OF THESIS

This thesis is structured into ten chapters. Chapter 1 introduces the research, defines key terms and the research scope and problem, outlines the research aims and objectives, and briefly describes the research methodology. Chapter 2 explains the research methodology and methods in greater detail. Chapter 3 first presents a comprehensive literature review about the GBTs for sustainable housing development. The chapter then presents a comprehensive literature review about the drivers for GBTs adoption. Chapter 4 provides a comprehensive literature review on the barriers to GBTs adoption. It also reviews the literature on the strategies to promote GBTs adoption. These comprehensive literature reviews are crucial to understand the potential issues associated with GBTs adoption and to provide theoretical basis for this study. Chapters 5, 6, 7, and 8 present analyses of the questionnaire survey data; concomitant discussions of the results are also presented in these chapters. Chapter 5 presents statistical analyses of GBTs to achieve sustainable housing development; a model, based on AHP, of these GBTs is also presented in the chapter. Chapter 6 presents statistical analyses, including factor analysis, of the drivers for GBTs adoption and compares the results between Ghana and the developed country of the US. Chapter 7 presents statistical analyses, including factor analysis, of the barriers inhibiting GBTs adoption and then compares the results between Ghana and the developed countries of the US, Canada, and Australia. Chapter 8 presents statistical analyses, including factor analysis, of the strategies to promote GBTs adoption and then compares the results among Ghana and the US. Chapter 9 presents and discusses the PLS-SEM results. It presents PLS-SEM models that depict the influences of the various GBTs adoption drivers, barriers, and promotion strategies on the GBTs adoption activity. Moreover, based on the PLS-SEM results, an implementation strategy aimed at helping promote GBTs adoption is proposed in this chapter. In addition, it presents the validation of this research. Chapter 10 concludes this thesis and offers recommendations.

CHAPTER 2 RESEARCH METHODOLOGY [2]

2.1 INTRODUCTION

The influence of methodology on the outcomes and contributions of any research study is great and cannot be undermined. After introducing this research within Chapter 1, the present chapter describes the methodology and methods used in conducting the research. The research methods are explained highlighting their strengths and weaknesses, as well as the justifications for their selection. This chapter encompasses two parts. First, by expanding upon Fig. 1.2, the research

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[2] This chapter is largely based upon:

Chan, A. P. C., Darko, A., Olanipekun, A. O., and Ameyaw, E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production*, 172, 1067-1079.

Darko, A., and Chan, A. P. C. (2018). Strategies to promote green building technologies adoption in developing countries: The case of Ghana. *Building and Environment*, 130, 74-84.

Darko, A., Chan, A. P. C., Gyamfi, S., Olanipekun, A. O., He, B. J., and Yu, Y. (2017a). Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. *Building and Environment*, 125, 206-215.

Darko, A., Zhang, C., and Chan, A. P. C. (2017c). Drivers for green building: A review of empirical studies. *Habitat International*, 60, 34-49.

Darko, A., and Chan, A. P. C. (2017). Review of barriers to green building adoption. *Sustainable Development*, 25(3), 167-179.

Chan, A. P. C., Darko, A., and Ameyaw, E. E. (2017). Strategies for promoting green building technologies adoption in the construction industry—An international study. *Sustainability*, 9(6), 969.

Darko, A., Chan, A. P. C., Owusu-Manu, D. G., and Ameyaw, E. E. (2017d). Drivers for implementing green building technologies: An international survey of experts. *Journal of Cleaner Production*, 145, 386-394.

Chan, A. P. C., Darko, A., Ameyaw, E. E., and Owusu-Manu, D. G. (2016). Barriers affecting the adoption of green building technologies. *Journal of Management in Engineering*, 10.1061/(ASCE)ME.1943-5479.0000507, 04016057.

Darko, A., Chan, A. P. C., Yang, Y., Shan, M., He, B. J., and Gou, Z. (under review). Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case. *Journal of Cleaner Production*, Manuscript ID: JCLEPRO-D-17-09500R1.

Darko, A., Chan, A. P. C., Ameyaw, E. E., Owusu, E. K., Pärn, E., and Edwards, D. J. (2018b). Review of application of analytic hierarchy process (AHP) in construction. *International Journal of Construction Management*, 10.1080/15623599.2018.1452098.

Darko, A., Chan, A. P. C., and Owusu, E. K. (2018a). What are the green technologies for sustainable housing development? An empirical study in Ghana. *Business Strategy and Development*, 1(2), 140-153.

methods are described, dividing them into data collection methods and data analysis methods. Second, the background information of the respondents is presented in this chapter. To ensure the attainment of the research objectives, it is crucial to choose the right research methodology (Steele, 2000; Fellows and Liu, 2015). Applying proper research methods allows a construction management research to achieve meaningful results and contribute significantly to theory and practice (Walker, 1997). Abowitz and Toole (2010) stated that drawing on the knowledge and experience of industrial professionals is imperative to enrich the outcomes of a research study. Hence, this study drew primarily on the knowledge, understanding, experience, and perceptions of industry professionals in examining the issues under study.

Previous studies (Chan et al., 2009a; Zhang et al., 2011a, b; Hwang and Tan, 2012; Shi et al., 2013; Roufechaei et al., 2014) used a variety of research methods to examine GBTs and drivers, barriers, and promotion strategies of GBTs and practices adoption within various countries and contexts. Comprehensive literature review, interview, case study, and questionnaire survey are some of the popular methods adopted in previous studies, with the most popular method being questionnaire survey (Darko et al., 2017c). In the present research, questionnaire survey was adopted as the main source of data collection. Extensive literature reviews and interviews with industry professionals supported the development of the survey questionnaire. Section 2.2.1.2 provides details of the questionnaire survey. Data analyses were carried out using the Statistical Package for Social Science (SPSS version 20.0), SmartPLS 3.2.7 software, and Expert Choice software. The results were descriptively expressed mainly using means and standard deviations (SD). Factor analysis was used to establish the underlying structures of various variables. PLS-SEM was used to examine and model the influences of various types of GBTs adoption drivers, barriers, and promotion strategies on GBTs adoption. AHP was applied to model and prioritize GBTs to achieve sustainable housing development.

2.2 RESEARCH METHODS FOR THIS STUDY

Given that the selection of research methods is influenced by the types of research objectives, questions, and settings (Fellows and Liu, 2015), there are no hard and fast rules for selecting research methods, neither is there anything called "best research methods" (Yin, 1994). Thus, the kind of data needed to achieve the research objectives should be given careful consideration in the selection of research methods (Akadiri, 2011). It should also be noted that the adoption of well-known and widely used methods not only helps to ensure meaningful results that could be easily compared with the results of other studies that used similar methods, but it also hones the reproducibility of the research and results (ALwaer and Clements-Croome, 2010). Table 2.1 shows the main methods utilized in achieving each research objective. The data collection methods include literature review and questionnaire survey, whereas the data analysis methods include mean score ranking, factor analysis, AHP, and PLS-SEM.

Table 2.1 Research objectives and methods for achieving them.

	Research methods					
	Data collection methods		Data analysis methods			
Research objectives	Extensive literature review	Questionnaire survey	Mean score ranking	Factor analysis	AHP	PLS-SEM
To identify the important GBTs to achieve sustainable housing development in Ghana, and to contextualize the GBTs as a model to assist sustainable housing development	√	√	√		√	
To identify the major drivers for GBTs adoption in Ghana, and to examine the influences of the drivers on the GBTs adoption activity	√	√	√	√		√
To investigate the critical barriers to GBTs adoption in Ghana, and to examine the influences of the barriers on the GBTs adoption activity	√	√	√	√		√
To identify the important strategies to promote GBTs adoption in Ghana, and to examine the potential influences of the strategies on the GBTs adoption activity	√	√	√	√		√

Note: Other statistical tests, such as Kendall's coefficient of concordance, Kruskal-Wallis H test, and Wilcoxon's signed rank test, were also conducted in this study.

2.2.1 Data Collection Methods

2.2.1.1 Comprehensive literature review

Literature review provides a solid foundation for developing the knowledge base in a particular research area (Webster and Watson, 2002) and is done by consolidating and analyzing previous related studies (Chow, 2005). As Koebel et al. (2015) noted, "theory and previous research findings help in identifying the variables to include". To identify the variables to include, this study commenced with comprehensive literature reviews. While the literature reviews focused more on academic publications in peer-reviewed journals, conference papers, research reports, doctoral theses, text books, and internet data were also considered where necessary. As GBCs are the "organizations that empower industry leaders to effect the transformation of the local construction industry toward sustainability" (WorldGBC, 2016), pertinent publications and reports by them were also considered in the literature reviews. The literature reviews allowed the acquisition of relevant background knowledge of green building and the issues influencing the adoption of GBTs and practices. It is also via the literature reviews a firm theoretical basis was established for this study. That is, the literature reviews were a key part of the groundworks for achieving the research aims and objectives and hence addressing the research problems of this study.

Throughout this study, literature reviews were carried out with the objectives to: (1) develop an overall theoretical framework for understanding the research problems; (2) identify the GBTs for sustainable housing development (reported in Darko et al., 2018a); (3) identify the drivers for the GBTs and practices adoption (reported in Darko et al., 2017c); (4) identify the barriers that hinder the GBTs and practices adoption (reported in Darko and Chan, 2017); (5)

identify the strategies to promote GBTs and practices adoption (reported in Chan et al., 2017); and (6) prepare for developing the questionnaire and survey. The literature reviews are summarized, analyzed, and reported in two chapters of this thesis. Chapter 3 reviews GBTs, with particular emphasis on those for sustainable housing development, and the drivers for GBTs and practices adoption. Chapter 4 reviews the barriers to GBTs and practices adoption and strategies that can be used to overcome the barriers and consequently promote the GBTs and practices adoption. The main aim of these chapters is to provide an understanding of GBTs and the issues influencing their adoption. In the construction industry, the issues that influence GBTs adoption might be internal or external issues. For instance, whereas stakeholders' resistance to change may be regarded as an internal issue, lack of support from the government might be regarded as an external issue (Chan et al., 2016). Understanding all of these internal and external issues shaped the basis for developing an implementation strategy to promote the adoption of GBTs in developing countries such as Ghana.

Identification and selection of factors from literature

Comprehensive literature review could result in identifying a large number of factors, making which factors to include in the study a crucial issue. In this research, the identification of factors from the literature focused mainly on factors that have received substantial attention in previous studies carried out in different countries and contexts (Darko et al., 2017d; Chan et al., 2018). With regard to the barriers to GBTs adoption, for example, as cost, lack of awareness, and lack of information are commonly acknowledged in the literature as crucial barriers hindering GBTs and practices adoption, they were added to the potential barriers (Table 4.1). Rowlinson (1988) advised that in order to enable respondents to respond easily, well-known factors should be used for a research study.

2.2.1.2 Questionnaire survey

Questionnaire survey is a systematic method of collecting data based on a sample (Tan, 2011). It has several advantages that have made it popular within the green building area (Wong et al., 2016; Shen et al., 2017b; Olanipekun et al., 2018). For example, questionnaire survey has been argued to be an effective method to achieve “quantifiability and objectiveness” (Ackroyd and Hughes, 1981). Besides, questionnaire survey provides a cost-effective method for collecting quantitative data rapidly and with better anonymity of respondents (McQueen and Knussen, 2002; Cooper and Schindler, 2006). As stated previously, in this research, questionnaire survey was adopted as the main data collection method. Using questionnaire survey further helped to provide quantitative descriptions of the perceptions and attitudes of the whole study population through studying a sample of the population (Creswell, 2014). Despite certain issues associated with questionnaire survey, such as risk of bias and low response rate, questionnaire survey still affords a great opportunity for researchers to examine a large number of factors if measures are implemented to attain a representative and reasonable sample (Akadiri, 2011).

A survey questionnaire was designed based on factors identified from comprehensive literature reviews. The questionnaire development is explained within the next section. The questionnaire was used to solicit the professional views in this research. Specifically, the questionnaire survey was carried out in this study to:

i. identify the GBTs that are important to achieve sustainable housing development in Ghana (reported in Darko et al., 2018a).
ii. to identify the major drivers for GBTs adoption in Ghana (reported in Darko et al., 2017a).
iii. to investigate the critical barriers to GBTs adoption in Ghana (reported in Chan et al., 2018).

iv. to identify the important strategies to promote GBTs adoption in Ghana (reported in Darko and Chan, 2018).

It is worthy to note that following the recommendations of Cheng and Li (2002) and Wong and Li (2008), this study adopted two types of questionnaire surveys: a general survey and an AHP survey, as explained in later sections.

Questionnaire development

Structure of questionnaire

The questionnaire for the general survey consisted of eight sections. The first section presented the research aims and objectives, as well as contact details. The second section was designed to gather the respondents' background information, including their company and project types, professions, and industrial and green building experience. In the third section, the respondents were asked to assess the importance of the GBTs to achieve sustainable housing development. In the fourth section, the respondents were asked to assess some statements meant to measure the GBTs adoption activity. This was necessary for the PLS-SEM, and those statements were adapted from Lam et al. (2009) and Shi et al. (2013), who employed them to assess the state of green innovations adoption within Hong Kong and China, respectively. As well, the statements are presented in Table 9.1 as the 'GBTs adoption (GA)' measurement items. In the fifth section, the respondents were asked to assess the drivers for GBTs adoption. Within the sixth section, the respondents were requested to assess the criticalities of the barriers to GBTs adoption. Within the seventh section, the respondents were asked to evaluate the importance of the strategies to promote GBTs adoption. In the PLS-SEM, the factors assessed in the fourth to seventh sections of the questionnaire are referred to as measurement items (or observable variables). PLS-SEM and its relevant terms are explained in section 2.2.2.9. Finally, in the eighth section, definitions of the GBTs were provided to support the respondents' assessment of the GBTs within the third section of the questionnaire. To have a better understanding of the general survey, a sample of the questionnaire is provided in Appendix A. As for the AHP questionnaire, it consisted of two sections. The first section explained the decision-making problem – prioritization of GBTs for sustainable housing development – while the second section presented the pairwise comparison questions. A sample of the AHP questionnaire is shown in Appendix B.

Rating scales

In construction management research, many types of rating scales, e.g., five-point, seven-point, nine-point, and eleven-point rating scales, have been used for gathering professional opinions. However, in green building research, the five-point Likert scale has been widely used (Potbhare et al., 2009; Shi et al., 2013; Hwang et al., 2016; Hwang et al., 2017c). This study adopted five-point Likert scales for assessing the various items in the survey questionnaire. Table 2.2 shows the five-point Likert scales adopted in the various sections of the questionnaire. The preceding section explicates what each section of the questionnaire encompasses. This study applied the five-point Likert scales in accordance with the "seven plus or minus two" principle suggested by Miller (1956), which made it easy for the respondents to express their views. Moreover, the five-point Likert scale has been commonly recommended (Ekanayake and Ofori, 2004; Zhang et al. 2011b), as a result of its advantage to yield unambiguous results that are easy to interpret. It is also relatively easy to be used among busy industry professionals. This study also involves an AHP rating scale, which is presented in a later section.

Table 2.2 Five-point Likert scales used in the general survey questionnaire.

Assessment scores	Linguistic terms

1	Strongly disagree[a]	Not critical[b]	Not important[c]
2	Disagree[a]	Less critical[b]	Less important[c]
3	Neutral[a]	Neutral[b]	Neutral[c]
4	Agree[a]	Critical[b]	Important[c]
5	Strongly agree[a]	Very critical[b]	Very important[c]

Note: [a] The five-point Likert scale used within the fourth and fifth sections of the questionnaire; [b] The five-point Likert scale used within the sixth section of the questionnaire; [c] The five-point Likert scale used within the third and seventh sections of the questionnaire.

Experts' review of questionnaire

Besides the literature reviews that laid the foundation for developing the survey questionnaire, prior to the questionnaire survey, the questionnaire was piloted before it was accepted as final questionnaire. First, with a focus on question construction, the questionnaire was reviewed by an international expert – a professor who had more than 10 years' experience in green building. This ensured that the questionnaire was free of vague expressions and used appropriate technical terms. Second, interviews were performed with four industry professionals from Ghana, each of whom had above 10 years' working experience in the local construction industry and possessed relevant experience in green building (Darko and Chan, 2018). They were asked to consider the characteristics of the Ghanaian construction market and background of GBTs adoption within the market and assess whether the questionnaire covered all potential factors, and whether any factors can be added to, or removed from the survey. The professionals offered valuable feedback. For example, they advised that three potential strategies to promote the GBTs adoption – "acknowledging and rewarding GBTs adopters publicly", "support from executive management", and "more GBTs adoption advocacy by the Ghana Environmental Protection Agency" – were omitted by the questionnaire and should be added. Based upon the feedback, the questionnaire was modified to form the final questionnaire.

General survey

This study's population comprised all industry practitioners with knowledge and understanding of GBTs adoption in Ghana. As there was a lack of a sampling frame for this study, the sample was a nonprobability sample (Zhao et al., 2014). The nonprobability sampling method can be employed to achieve a representative sample (Patton, 2001). It is appropriate when a random sampling method cannot be used to select respondents from the population, but the respondents can rather be selected based upon their willingness to participate in the research study (Wilkins, 2011). Thus, a snowball sampling technique was used in this study to attain a valid and effective overall sample size. This technique 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 development of green building projects in Ghana were approached to identify the initial respondents. As stated earlier, within the Ghanaian context, this study defines green building projects as building projects that have either obtained the LEED certification or the Green Star SA certification (Darko et al., 2017a). The initially identified respondents were asked to share information regarding other knowledgeable participants. Using this approach, a total of 96 questionnaires were distributed to collect responses from contractor, consultant, and developer companies. Finally, 43 completed questionnaires with valid responses were returned, corresponding to a 44.8% response rate. This sample size satisfied the recommendation that a sample size ought to be above 30 for the central limit theorem to hold true (Ott and Longnecker, 2010; Zhao et al., 2016a). Hence, although the sample was a relatively small sample, statistical analyses could still be conducted. Similarly, as GBTs have not been widely adopted within the Ghanaian construction market, the number of experienced professionals is limited. Moreover, the sample size was high compared with the previous green building studies that used sample sizes of 31 (Zhao et al., 2016a, b) and 39 (Shen et al., 2017a). The background information of the respondents is presented in section 2.3.

AHP survey

The AHP survey aimed to prioritize the GBTs to achieve sustainable housing development on the basis of their importance. The general survey was helpful for conducting the AHP survey in at least two ways. First, the general survey helped in the selection of professionals befitting to enter into the AHP survey – an approach adopted from Cheng and Li (2002) and Wong and Li (2008). In this respect, those professionals with more than 6 years' experience in green building (Table 2.6) were invited to participate in the AHP survey. In terms of green building in Ghana, demographic information in this study shows that the most experienced professionals are those who have had more than 6 years' experience. In fact, the views of such professionals are highly valuable to an empirical inquiry since they can provide penetrating insights (Cheng and Li, 2002). Second, based upon the outcomes from the general survey, the important GBTs for entering into the AHP survey were identified. After identifying the professionals and GBTs to enter into the AHP survey, the AHP survey was carried out.

In the general survey, eight respondents indicated that they had more than 6 years' experience in green building. These respondents were invited to take part in the AHP survey via providing their views in filling out an AHP questionnaire. The reasons for using AHP are stated in section 2.2.2.8, where the AHP method is described in more detail. Five out of the eight respondents agreed they have time and were willing to participate in the AHP survey. As the application of AHP is novel in the Ghanaian context, it was necessary to ensure that the respondents have full understanding of the AHP concept and decision-making process. Thus, the AHP questionnaires were sent to the respondents via handing the questionnaires to them personally. Handing the questionnaires to the respondents personally provided opportunities for not only sharing the results from the general survey with them, but also explaining the AHP to them prior to the filling of the questionnaire. After receiving the five responses, the consistency test was carried out; results showed that four questionnaires had acceptable consistency and would be used for the AHP analysis. Despite being a small sample, it is acceptable for AHP. Darko et al. (2018b) conducted a comprehensive review of AHP application in construction, based upon 77 research articles published in eight high-quality peer-reviewed construction management journals, and found that small sample size is one of the most prominent justifications for using AHP. In this respect, they showed that there is no criterion on the sample size for AHP, and that some studies used only one respondent or expert; the majority of the studies used samples ranging from four to nine; whereas only a few used samples greater than 30. The four respondents in the present research had been involved in at least one green building project applying GBTs. Hence, these respondents could help address the research problem. The respondents were asked to undertake pairwise comparisons of the GBTs using a nine-point rating scale, as shown in Table 2.3.

Table 2.3 AHP pairwise comparison scale (Saaty, 1980).

Weight	Definition	Explanation
1	Equal importance	Two GBTs contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one GBT over another
5	Essential or strong importance	Experience and judgment strongly favor one GBT over another
7	Very strong importance	A GBT is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one GBT over another is the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is necessary
Reciprocals of previous values	If factor “*i*” has one of the previously mentioned numbers assigned to it when compared to factor “*j*”, then *j* has the reciprocal value when compared to *i*.	

2.2.2 Data Analysis Methods

Data collected from the questionnaire surveys were analyzed using different statistical analysis methods, which are described in the following sections.

2.2.2.1 Cronbach's alpha technique

Cronbach's alpha method remains one of the most popular methods for assessing the reliability of scales. It ascertains the average correlation or internal consistency among factors in a survey questionnaire to gauge the questionnaire's reliability. The Cronbach's alpha coefficient value ranges from 0 to 1 and could be employed in describing the reliability of factors extracted from multipoint and/or dichotomous formatted scales or questionnaires (Santos, 1999). The higher the Cronbach's alpha coefficient value, the more reliable is the adopted scale of measurement. Nevertheless, the general rule is that to conclude that the scale is reliable, the Cronbach's alpha coefficient value should not be lower than 0.70 (Nunnally, 1978). Using SPSS, the Cronbach's alpha coefficient value could be computed by (Li, 2003):

$$\alpha = \frac{k\,\overline{cov}/\overline{var}}{1 + (k-1)\overline{cov}/\overline{var}} \tag{2.1}$$

where α = Cronbach's alpha coefficient value; k = the number of scale items; $\overline{var}$ = the average variance of the scale items; and $\overline{cov}$ = the average covariance among the scale items. When the factors are standardized and have a common variance, the formula above can be simplified as:

$$\alpha = \frac{k\overline{r}}{1 + (k-1)\overline{r}} \tag{2.1.1}$$

where $\overline{r}$ = the average correlation among the scale items.

In this study, Cronbach's alpha coefficient test was used to evaluate the reliabilities of the five-point rating scales used to capture the survey responses. The Cronbach's alpha coefficient test results are presented and interpreted in later sections.

2.2.2.2 Data normality test – Shapiro-Wilk test

As numerous statistical tests require a normal distribution of the data (Kim, 2015), the Shapiro-Wilk test, which is a widely used method for testing data normality (Hsu et al., 2000; Ferretti et al., 2017), was used to test the data normality. The null hypothesis of the Shapiro-Wilk test is that "the data were normally distributed". The common alpha value for testing normality, 0.05, was used in conducting the Shapiro-Wilk test. If the *p*-value produced by the test is lower than the selected alpha value, then the null hypothesis must be rejected, and conclusion that the data are not normally distributed must be made. In this study, all the *p*-values produced by the Shapiro-Wilk test were less than 0.05, which indicated that the data collected were not normally distributed. This is an expected result as data collected from samples that are not very large are usually not normally distributed (Field, 2013; Shan et al., 2017a; Hwang et al., 2018). The non-normal distribution of the data influenced the selection of statistical tests for analyzing the data.

2.2.2.3 Mean score ranking technique

As a typical quantitative analysis technique for ranking the relative importance/criticality of factors, the mean score ranking technique has been widely used in green building research (Shi et al., 2013; Nguyen et al., 2017; Huo et al., 2018; Zhao et al., 2018). In this research, the mean score ranking technique was used to determine the relative rankings of the GBTs for sustainable housing development, GBTs adoption drivers, barriers, and promotion strategies in descending order of importance/criticality, as perceived by the respondents. A mean score is determined using equation 2.2. Following Mao et al.'s (2015) recommendation, where two or more factors had the same mean score, the factor with the smallest SD was given the highest rank. A smaller SD suggests that the differences in responses are not statistically large and thus the average is more likely to be valid for the majority (Staplehurst and Ragsdell, 2010). The one-sample *t*-test was used to test the significance of the mean scores. The null hypothesis of the one-sample *t*-test is that "the mean score is not statistically significant", while the alternative hypothesis 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 factor ought to be rejected if its *p*-value is lower than 0.05. Regarding the GBTs adoption barriers, the normalized values of the mean scores were calculated to identify the critical barriers amongst the 26 barriers (Xu et al., 2010; Zhao et al., 2014).

$$B_i = \frac{\sum_{j=1}^{n} \alpha_{ij}}{n} \qquad (2.2)$$

where n = the total number of respondents; α_{ij} = the importance/criticality of the factor i rated by the respondent j; and B_i = the mean score of the importance/criticality of the factor i.

2.2.2.4 Inter-group comparison – Kruskal-Wallis H test

As the respondents were from different companies (that is consultant, contractor, and developer companies) (see Table 2.6), it was essential to check whether there were significant differences between them, by conducting inter-group comparisons (Shan et al., 2017a; Hwang et al., 2018). To conduct the inter-group comparisons, two different statistical methods, analysis of variance (ANOVA) and Kruskal-Wallis H test, were considered. ANOVA is a widely used parametric test for checking differences among mean scores from at least three groups. The ANOVA test has an assumption that the population from which the sample was drawn is normally distributed

(Pallant, 2013). As the non-parametric alternative to ANOVA, the Kruskal-Wallis H test, on the contrary, does not have any stringent requirements; it does not also make any assumption about the underlying distribution of the population (Pallant, 2013; Field, 2013). Consequently, due to the non-normal distribution of the data collected, the Kruskal-Wallis H test was selected over ANOVA to conduct the inter-group comparisons in this research. In addition to the inter-group comparisons, the mean difference analysis was performed to determine the actual values of the differences in the mean scores from different groups (Hwang et al., 2016; Chan et al., 2017).

2.2.2.5 Concordance test – Kendall's coefficient of concordance

In order to analyze agreements among the respondents regarding the rankings of the GBTs for sustainable housing development, GBTs adoption drivers, barriers, and promotion strategies, Kendall's coefficient of concordance (Kendall's *W*) test was carried out. Kendall's *W* test is a non-parametric test widely used to determine the overall agreement among sets of rankings by different rankers (Chan et al., 2009a; Darko et al., 2017d). Kendall's *W* tests the null hypothesis that "no agreement exists among the rankings given by the respondents in a particular group". It ranges in value from 0 to 1, where when there is no agreement between the respondents, the value would be 0 and when there is a complete agreement, the value would be 1 (Siegel and Castellan, 1988). The null hypothesis must be rejected if the significance level of Kendall's *W* is low (p-value $\leq$ 0.001), otherwise the null hypothesis must be retained. With the respondents' ratings, Kendall's *W* could be computed by (Siegel and Castellan, 1988):

$$W = 12\sum\frac{R_i^2-3k^2N(N+1)^2}{k^2\,N(N^2-1)-k\sum T_j} \tag{2.3}$$

where $\sum R_i^2$ = the summation of the squared sum of ranks for the individual ranked N factors; k = the total number of respondents or rankings; and T_j = the factor for correction needed for the jth set of ranks for the tied ranks, defined as $T_j = \sum_{i=1}^{gj}(t_i^3 - t_i)$, where gj = the number of groups of ties in the jth set of ranks; and t_i = the number of tied ranks in the ith grouping of ties. The Kendall's W test results are presented and discussed in later sections.

2.2.2.6 Variable comparison – Wilcoxon's signed rank test

Roberts et al. (2016) mentioned that performing pairwise comparisons of matched variables is a useful strategy for identifying the key variables – the variables having the highest priority – amongst a set of variables. Accordingly, similar to Shan et al. (2017a) and Hwang et al. (2018), this research conducted detailed variable comparison to identify the most important strategies to promote GBTs adoption. The variable comparison was done to complement the descriptive analysis. To carry out the variable comparison, two separate statistical techniques, paired *t*-test and Wilcoxon's signed rank test, were considered. Paired *t*-test is a widely applied method for testing statistical difference between two matched variables (Shan et al., 2017a). As a parametric test, this method has a requirement that the tested data ought to be normally distributed (Lam et al., 2009). The non-parametric alternative to paired *t*-test is Wilcoxon's signed rank test (Pallant, 2013). Wilcoxon's signed rank test is an appropriate test to compare matched variables (Wu et al., 2014) without assuming any specific nature of data distribution or requiring equal variance of data (Field, 2013). As a result, Wilcoxon's signed rank test was used for the variable comparison in this study.

2.2.2.7 Exploratory factor analysis

Exploratory factor analysis (EFA) is a powerful statistical technique used for uncovering the underlying factor structure of a set of variables (Norusis, 2008; Field, 2013; McNeish, 2017). It helps to gain a deeper understanding of the number of factors underlying the variables, which variables are more closely linked to each other, and the strength of the relationships among the observable variables and the extracted latent factors. EFA can be applied when the underlying structure of the variables (1) is unknown, (2) has not been established in earlier research, and/or (3) has yet to be established with a particular subpopulation (McNeish, 2017). Establishing the underlying structure is essential for testing hypotheses and building theory. Consequently, EFA has been extensively used in construction management research (Zhao et al., 2013; Zhao et al., 2014). In the present study, EFA was applied to uncover the underlying structures of the GBTs adoption drivers, barriers, and promotion strategies, which created the base for further analysis, PLS-SEM. According to Chan et al. (2004), EFA comprises four basic steps, which are:

1. Identifying the relevant factors (e.g., GBTs adoption drivers) from the literature;
2. Computing the correlation matrix for all of the factors;
3. Extracting and rotating each factor; and
4. Interpreting and naming the principal (grouped) factors as underlying factors.

This study followed the aforesaid steps in conducting the EFA. However, the appropriateness of factor analysis for the factor extraction had to be examined before applying the EFA. Hence, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to determine the appropriateness of using factor analysis in this research. The KMO is a measure of sampling adequacy and it represents the ratio of the squared correlation amongst the variables to the squared partial correlation amongst the variables (Field, 2013). The KMO ranges in value 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, suggesting diffusion in the pattern of correlations and so factor analysis would be inappropriate (Norusis, 2008). Conversely, a value close to 1 is an indication that patterns of correlations are relatively compact and so factor analysis would yield reliable and distinct factors (Field, 2013). For a satisfactory factor analysis, the KMO value has to be above 0.50, an acceptable threshold, (Kaiser, 1974; Norusis, 2008; Field, 2009). However, the level of acceptance of KMO value varies depending on the KMO value, as shown in Table 2.4.

Table 2.4 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

Bartlett's test of sphericity is a statistical test that highlights the presence of correlations among variables (Chan et al., 2010). It can be used for assessing whether the original correlation matrix is an identity matrix, which would show that there are no relationships among the variables and so factor analysis 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 factor analysis would be appropriate (Pallant, 2013).

Factor extraction and rotation

EFA comprises factor extraction and factor rotation. Factor extraction is necessary to determine the number of factors underlying a set of variables, while factor rotation is necessary to improve the interpretability of the underlying factors (Norusis, 2008). The first extracted factor explains most of the variance in the sample, while the remaining factors explain relatively small portions of the variance. The extraction method of principal component analysis, with varimax rotation, was used in this study because it produces rotated component matrixes that are easy to interpret (Akintoye et al., 2000). It has been widely used in construction management research (Oyedele, 2010; Chan et al., 2011; Ameyaw, 2014). Eigenvalue represents the sum of the squared factor loadings of the variables, which represents the amount of variance a factor explains (Cheung et al., 2000). In this research, based on Kaiser's criterion (Kim and Mueller, 1994; Field, 2013), only factors with eigenvalues higher than 1.0 are retained.

2.2.2.8 Multi-criteria decision analysis: AHP method

Saaty (1980) created AHP, a mathematical tool for decision-making in multi-criteria situations. AHP is a framework of logic and problem solving through structuring judgements, perceptions, feelings, and memories into a hierarchy of factors that influence the results of decisions (Saaty, 2000). It is a structured technique via which preference opinions can be collected from decision makers. As a multi-criteria decision-making technique of choice and prioritization (Dyer and Forman, 1992), AHP outperforms conventional decision analysis methods via not necessitating numerical guesses. That is to say, AHP easily and effectively accommodates subjective expert judgements regarding the weights of decision factors (Saaty, 1990). The expert judgements are useful for establishing priorities amongst decision criteria, sub-criteria, and alternatives. These priorities might assist organizations in making effective resource allocation decisions. Through pairwise comparisons, AHP is able to establish the relative importance of decision factors and preferences for alternatives (Arroyo et al., 2014).

Since its introduction, AHP has seen wide use in the dealing with multi-criteria, complex, and unstructured decision-making problems. The method aids decision makers to model a complex decision-making problem as a hierarchy that covers the decision goal, the alternatives to reach the goal, and the criteria for evaluating the alternatives (Dyer and Forman, 1992; Arroyo et al., 2014). Construction decision-making problems have been characterized as being complex, ill-defined, and uncertain (Chan et al., 2009b). Al-Harbi (2001) also contented that elements of construction decision-making problems are plentiful and the interrelationships amongst these elements are complex and often nonlinear. Hence, the ability to make sound decisions is critical to the success of construction activities. AHP offers a powerful means of making strategic and sound construction decisions (Jato-Espino et al., 2014) – it allows decision makers to employ multiple criteria in both quantitative and qualitative manners to assess possible alternatives and then choose the best option.

AHP was used in this study to assess the comparability of GBTs to achieve sustainable housing development. While other multi-criteria decision-making techniques, such as analytic network process, could have been adopted for prioritizing the GBTs, AHP was selected due to its proven abilities in handling small sample sizes, ensuring high level of consistency among judgements, and due to its simplicity of application. The reader should see Darko et al. (2018b) for detailed discussions on these justifications. Although analytic network process is deemed a general form of the AHP method (Saaty, 1996), it is disapproved for being too stringent and time-consuming (compared to AHP) (Jato-Espino et al., 2014). This is because analytic network process allows interdependencies among factors.

AHP has been used in a broad range of areas of construction management. Darko et al. (2018b) found that green building is one of the most popular areas of AHP application in construction management. Green building researchers have used AHP to develop decision support models to deal with issues such as: lifecycle assessment of economic and environmental sustainability of highway designs (Lee et al., 2013); selection of sustainable building materials (Akadiri et al., 2013); management of sustainable technologies (Pan et al., 2012); analysis of influential location factors of sustainable industrial areas (Ruiz et al., 2012); exploration and prioritization of key performance indicators for assessing sustainable intelligent buildings (ALwaer et al., 2010); and development of green building rating systems (Ali and Al Nsairat, 2009). In the present study, AHP is used to prioritize GBTs for achieving sustainable housing development. The outcome can aid the identification and selection of suitable GBTs to realize sustainability goals in housing development. Though different studies have designed various AHP steps, this study employed a five-step AHP approach: (1) problem definition, (2) hierarchy formation, (3) pairwise comparison, (4) consistency test, (5) and weights calculation (Saaty 1980; Tam et al., 2007). These steps are described below.

Problem definition

The first step in AHP is to define the problem to be solved (Cheng and Li, 2002). A clear definition of the problem is very important to determine whether AHP is an appropriate method for solving the problem. Decision makers also need to understand the problem as well as the alternatives to solve it. In this research, the problem to be solved using AHP is "prioritization of GBTs for sustainable housing development".

Hierarchy formation

The second step in AHP is to decompose the problem into a hierarchy. Generally, the problem is modeled such that the first level of the hierarchy contains the decision goal/problem, whereas the subsequent lower levels represent the progressive breakdown of the criteria, sub-criteria, and the alternatives for reaching the decision goal. AHP is flexible and allows decision makers to form various varieties of hierarchies to suit the specifics of the problem. Hence, this research adopted a three-level hierarchy of the GBTs for sustainable housing development (see Fig. 5.1). The first level contains the prioritization goal, followed by five main categories of GBTs in the second level. The third level comprises the GBTs under each GBT category.

Pairwise comparison

Once the hierarchy is formed, the elements at the various levels of the hierarchy form matrixes. For example, a set of five elements forms a 5-by-5 matrix. These matrixes are used in designing the AHP questionnaire asking the decision makers to answer a series of pairwise comparison questions that are based upon the matrixes. Pairwise comparisons of elements at each level of the hierarchy are made, assuming the elements are independent of each other. Though pairwise comparison can be time-consuming, reducing the number of elements to be rated in each matrix may help to reduce the pairwise comparison time and elicit useful information for the decision-making (Saaty, 1980). That is, AHP sacrifices time for accuracy (Cheng and Li, 2002). In this study, when weighing the GBTs, the decision makers were asked to indicate the strength of the importance of one GBT over the other using the AHP pairwise comparison scale (Table 2.3). The judgements were quantified and translated into weights for the GBTs. Pairwise comparison data is usually presented in matrix form (Saaty, 1980). If there are "m" elements to be assessed within a matrix, then a total of $m(m-1)/2$ judgements would be made. A pairwise comparison matrix "A" could be derived for a given set of elements as:

$$A = \begin{bmatrix} a_{11} & a_{12} & .. & a_{1j} & .. & a_{1m} \\ a_{21} & a_{22} & .. & a_{2j} & .. & a_{2m} \\ . & . & .. & . & .. & . \\ . & . & .. & . & .. & . \\ a_{i1} & a_{i2} & .. & a_{ij} & .. & a_{im} \\ . & . & .. & . & .. & . \\ . & . & .. & . & .. & . \\ a_{m1} & a_{m2} & .. & a_{mj} & .. & a_{mm} \end{bmatrix} = (a_{ij})_{m \times m} \qquad (2.4)$$

where A = pairwise comparison matrix; a_{ij} = relative importance of element "i" when compared to element "j"; and m = number of elements in the matrix.

Consistency test

The consistency test represents an essential advantage of AHP over other basic linear weighting methods (Cheng and Li, 2001). This test is an advantage of the AHP method because it tests the consistency level of each pairwise comparison matrix and is central because as AHP allows subjective judgements, consistency is not naturally guaranteed (Darko et al., 2018b). Thus, this research conducted the consistency test to check the consistency of the judgements. In essence, the consistency test aids to ensure that only valid or consistent matrixes are included for further analysis. The maximum eigenvalue and the eigenvector of each pairwise comparison matrix can be computed by using the right eigenvector method (Saaty, 1990). The relative weights of elements are obtained by calculating the eigenvector of the matrix, whereas a measure of the consistency of the judgement is obtained by calculating the maximum eigenvalue. The right eigenvector method uses the following formula (Saaty, 1990):

$$\lambda_{max} = \sum_{j=1}^{m} \frac{AW}{mw_i} \ (i = 1, 2, \dots, m) \quad (2.5)$$

where λ_{max} = the largest eigenvalue of matrix A; A = pairwise comparison matrix; W = matrix of weights of elements; and w_i = weights of elements.

When the judgements are perfectly consistent, λ_{max} would be equal to m. However, AHP provides a measure of acceptable inconsistency, but does not require decision makers to be perfectly consistent. The consistency level of a judgement is determined using the consistency ratio (CR), which can be computed by (Saaty, 1980):

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = \frac{1}{\mathrm{RI}}\left(\frac{\lambda_{max} - m}{m-1}\right) \quad (2.6)$$

where CR = consistency ratio; CI = consistency index; and RI = average random consistency index (Table 2.5); m = number of elements in the matrix.

Table 2.5 Average random consistency index.

m	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

A CR value lower than 0.1 means that the matrix result has satisfactory consistency level and thus should be considered for further analysis. On the other hand, when the CR value is higher than 0.1, the matrix result is inconsistent and should not be considered for further analysis.

Weights calculation

AHP calculates the weights of the elements at each level of the hierarchy to establish priorities among the elements. The judgments are synthesized to yield a set of priorities for the hierarchy. The weights of elements can be obtained by following the following steps. From equation 2.4, for each row of elements, the product of relative importance must be computed by (Tam et al., 2007):

$$n_i = \prod_{j=1}^{m} a_{ij} \quad (i = 1, 2, \dots, m) \tag{2.7}$$

where n_i = product of relative importance for each row of elements; a_{ij} = relative importance of element "i" when compared to element "j"; and m = number of elements in the matrix.

Then, from equation 2.5, the vector $\overline{w_i}$ should be calculated by:

$$\overline{w_i} = \sqrt[m]{n_i} \quad (i = 1, 2, \dots, m) \tag{2.8}$$

where $\overline{w_i}$ = m^{th} power root of n_i.

Lastly, the weights of elements should be determined by normalizing vector $\overline{w_i}$ by:

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{m} \overline{w_i}} \quad (i = 1, 2, \dots, m) \tag{2.9}$$

where w_i = weights of elements and criteria.

Following these steps, this study calculated the weights of the GBTs to achieve sustainable housing development (Table 5.3).

2.2.2.9 Modeling: PLS-SEM method

This research investigated the influences of various types of GBTs adoption barriers, drivers, and promotion strategies on the GBTs adoption using structural equation modeling (SEM), a multivariate statistical analysis technique. SEM involves two kinds of variables – observable variables and latent variables. Whereas the observable variables (hereafter referred to as measurement items) are variables that can be directly measured, the latent variables (hereafter referred to as constructs) are variables that cannot be directly measured and hence are inferred from the measurement items. SEM not only tests hypotheses amongst measurement items and constructs, but it also uses a confirmatory approach to evaluate a structural hypothetical model based on a phenomenon (Byrne, 2013). That is, SEM evaluates direct and indirect relationships among one or several independent variables and one or several dependent variables. Since SEM goes beyond the conventional multiple regression, ANOVA, and factor analysis (Ozorhon and Oral, 2017), it was selected as the method of analysis in this study. Besides, different from the multivariate regression analysis and factor analysis, SEM can conduct both confirmatory factor analysis (CFA) and path analysis simultaneously in a single structural equation model (Lim et al., 2012; Xiong et al., 2015). A typical structural equation model contains a set of measurement models and a structural model. A measurement model evaluates the relationships amongst a construct and the measurement items in the domain of the construct, whereas a structural model displays the relationships amongst constructs (Hair et al., 2014a). SEM was used in this study for barriers modeling, drivers modeling, and promotion strategies modeling. Specifically, SEM was applied to:

i. model the influences of various types of GBTs adoption barriers on GBTs adoption;
ii. model the influences of various types of GBTs adoption drivers on GBTs adoption; and
iii. model the influences of various types of GBTs adoption promotion strategies on GBTs adoption.

There exist two approaches to SEM – the covariance-based SEM (CB-SEM) approach, and the variance-based PLS-SEM approach. Unlike the CB-SEM, PLS-SEM can handle small sample sizes and non-normal data (Hair et al., 2012a, b). This PLS-SEM advantage over CB-SEM has made PLS-SEM popular in construction management research lately. With a sample size of 35 professionals, Zhao and Singhaputtangkul (2016) used PLS-SEM to investigate the impacts of firm characteristics on enterprise risk management in Chinese construction firms; while Aibinu et al. (2011) used PLS-SEM to investigate the relationship amongst cooperative behavior and organizational justice in construction, with a sample of 41 contractors. Therefore, similarly, the present study adopted PLS-SEM, using SmartPLS 3.2.7 software, to test the study hypotheses and validate the hypothetical models. Based upon the EFA results, the research hypotheses and models are developed and presented in Chapter 9.

CFA can test the relationships amongst measurement items and their respective construct (Zhao et al., 2014). According to Hair et al. (2014a), after specifying the measurement and structural models, the reliability and validity of the measurement items within the measurement models ought to be evaluated. Evaluating the measurement models is vital as it helps to ensure that the constructs, which form the basis for evaluating the relationships hypothesized in the structural model, are accurately represented and measured, so verifying the adequacy of the measurement models for the path analysis. Reliability refers to the extent to which measurement of constructs with multi-item scale reflects the accurate scores of the constructs relative to the error (Hulland, 1999). Composite reliability score and Cronbach's alpha coefficient value were used to assess the internal consistency reliability of the measurement items representing and measuring each construct. In this respect, while composite reliability score and Cronbach's alpha coefficient value are similar and have the same interpretation (Aibinu and Al-Lawati, 2010), composite reliability scores should be above 0.70 (Hair et al., 1998) and Cronbach's alpha coefficient values should be 0.70 or higher (Nunnally, 1978). Once reliability has been assessed, validity, which covers convergent validity and discriminant validity of the constructs, must be assessed. Factor loadings represent the bivariate correlations amongst measurement items and their corresponding construct and are the means through which the measurement items are linked to the construct (Hair et al., 2014a). For a satisfactory level of convergent validity, each measurement item needs to have a factor loading of 0.50 or higher (Hulland, 1999) and the average variance extracted (AVE) of each construct should also be 0.50 or higher (Fornell and Larcker, 1981). AVE can be simply defined as the grand mean value of the squared loadings of a set of measurement items and is equivalent to a construct's communality (Hair et al., 2014a, b). Discriminant validity tests whether a construct measures what it is originally intended to measure; simply put, discriminant validity tests the extent to which a construct is different from other constructs. To assess discriminant validity, two techniques were used. First, Fornell and Larcker (1981) criterion, which states that the variance that a construct shares with its measurement items is higher than what it shares with any other construct, was used. In this respect, each construct's AVE should be more than the highest squared correlation with any other construct. Second, examination of the cross loadings of the measurement items was conducted to verify discriminant validity. In this respect, each measurement item's loading on its respective construct must be greater than the cross loadings on other constructs (Chin, 1998).

Path coefficients represent the hypothesized relationships linking constructs (Hair et al., 2014a). After verifying the reliability and validity of the measurement models, the significance of path coefficients must be estimated in order to test the hypotheses inside the structural model. To this end, the bootstrapping technique (Davison and Hinkley, 1997; Helm et al., 2009) was used. Bootstrapping is a versatile technique useful for estimating the distribution of any statistic for any kind of distribution (Jack et al., 2001). Following Hair et al.'s (2014b) recommendation, in this research, the number of bootstrap subsamples was 5,000, and the number of cases was equal to the number of responses (i.e., 43). Using such a large number of bootstrap subsamples is essential to ensure stability of the results. The critical *t*-values for a two-tailed test were 1.65 (significance level = 10%), 1.96 (significance level = 5%) and 2.58 (significance level = 1%) (Hair et al., 2014b). The PLS-SEM results are presented and discussed in Chapter 9.

2.3 BACKGROUND INFORMATION OF RESPONDENTS

The background information of the respondents is shown in Table 2.6. Of the total number of 43 respondents, 16 (37%), 14 (33%), and 13 (30%) were from consultant, contractor, and developer companies, respectively. It is noteworthy that the respondents were experienced in developing various building projects, with all of them experienced in developing residential projects. Additionally, the respondents were of different professional backgrounds, including engineers, quantity surveyors, architects, project managers, and a contracts manager. The great diversity and heterogeneity of the respondent panel helped to ensure the reliability and quality of the data collected (Harty, 2008; Shan et al., 2017a). According to the respondents' working experience in the construction industry, the majority of the respondents had more than 5 years' experience; just a few, 14%, had 1-5 years' experience. Furthermore, all of the respondents had experience in green building, with 24 (56%) having 1-3 years' experience, 11 (25%) having 4-

6 years' experience, and 8 (19%) having over 6 years' experience. Given the few green building projects launched in Ghana in recent years, this result can be deemed reasonable. In light of the respondents' industrial and green building experience along with their experience in residential building and development, their opinions were representative for this research to guarantee the reliability of the findings.

Table 2.6 Background information of the respondents.

Characteristics	Frequency	Percentage
Company types		
Consultant	16	37
Contractor	14	33
Developer	13	30
Project types		
Residential	43	100
Commercial/office	34	79
Industrial	24	56
Educational	23	53
Professions		
Engineer	13	30
Quantity surveyor	11	26
Architect	9	21
Project manager	9	21
Contracts manager	1	2
Years of experience in construction industry		
1-5 years	6	14
6-10 years	17	40
11-15 years	10	23
16-20 years	3	7
> 20 years	7	16
Years of experience in green building		
1-3 years	24	56
4-6 years	11	25
> 6 years	8	19

2.4 CHAPTER SUMMARY

This chapter offered a detailed description of the research methodology. The research methods used to achieve the research objectives were described and the background information of the respondents presented. This study adopted a quantitative approach where empirical data were collected from industry professionals mainly through questionnaire survey. After developing the survey questionnaire based upon comprehensive literature reviews, it was revised based on feedbacks from industry professionals. This chapter first described the data collection methods and then the data analysis methods were described. Statistical methods used in this study, such as mean analysis, reliability analysis, normality test, concordance test, factor analysis, and PLS-SEM, were described. The research aims and objectives were achieved through a combination of the methods described in the present chapter. The next chapter presents reviews of relevant literatures on the GBTs for sustainable housing development and GBTs adoption drivers.

CHAPTER 3 LITERATURE REVIEW – GBTs FOR SUSTAINABLE HOUSING DEVELOPMENT, AND DRIVERS FOR GBTs ADOPTION [3]

3.1 INTRODUCTION

The previous chapter describes the research methodology, whereas the present chapter reviews the literatures relating to the GBTs for sustainable housing development and the GBTs adoption drivers. The literature review on the GBTs for sustainable development forms the first part of this chapter. There exist several GBTs for developing different types of buildings projects. The reasons why this study focuses on those for sustainable housing development are provided in section 1.3.2. In addition, GBTs for sustainable housing development include technologies that could help save and even generate energy (Lockwood, 2006; Mokhtar Azizi et al., 2014), those that are water-efficient, and those that are environmentally friendly, providing improved indoor environmental quality and possessing features for enhancing the environmental, economic, and social sustainability and performance of a building (Building and Construction Authority of Singapore (BCA), 2016). A better understanding of the GBTs that are important for sustainable housing development is useful both conceptually and to inform sustainable housing design and development within the industry.

[3] As shown later in this chapter, this chapter is largely based upon:

Darko, A., Chan, A. P. C., and Owusu, E. K. (2018a). What are the green technologies for sustainable housing development? An empirical study in Ghana. *Business Strategy and Development*, 1(2), 140-153.

Darko, A., Zhang, C., and Chan, A. P. C. (2017c). Drivers for green building: A review of empirical studies. *Habitat International*, 60, 34-49.

Darko, A., Chan, A. P. C., Gyamfi, S., Olanipekun, A. O., He, B. J., and Yu, Y. (2017a). Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. *Building and Environment*, 125, 206-215.

GBTs adoption offers a wide variety of significant sustainability benefits that are not likely to be derived from traditional building technologies adoption. The UNEP (2009) showed that with the adoption of GBTs, a 30-80% reduction in building energy consumption is attainable. Many other scholars and organizations have also indicated that GBTs adoption provides several other environmental, economic, and social benefits, such as increased water efficiency, improved productivity, higher property values, and enhanced human health and well-being (WorldGBC, 2017c; Roufechaei et al., 2014; Darko et al., 2018c). These benefits play a huge role in pushing for the GBTs adoption (Chan et al., 2017) and are referred to as GBTs adoption drivers in this study. The second part of this chapter deals with the review of the literature related to the GBTs adoption drivers.

3.2 GBTs FOR SUSTAINABLE HOUSING DEVELOPMENT: A REVIEW [4]

Various GBTs have been introduced to achieve sustainability in housing development and can be found in the literature (Zhang et al., 2011a, b; Roufechaei et al., 2014; Koebel et al., 2015; Ahmad et al., 2016). Some researchers focused on GBTs in the design stage (Roufechaei et al., 2014; Ahmad et al., 2016), while others focused on those in the whole lifecycle (Zhang et al., 2011a, b). Moreover, the classifications of GBTs for sustainable housing development in the construction industry vary depending on the views taken by different researchers. For instance, whereas Zhang et al. (2011a) classified GBTs based upon various project objectives (energy efficiency, indoor environmental quality enhancement, materials efficiency, water efficiency, and operations and maintenance optimization), Roufechaei et al. (2014) classified them based upon designer responsibility (architectural, mechanical, and electrical). To identify the GBTs

[4] Reported in Darko, A., Chan, A. P. C., and Owusu, E. K. (2018a). What are the green technologies for sustainable housing development? An empirical study in Ghana. *Business Strategy and Development*, 1(2), 140-153.

for sustainable housing development, a comprehensive literature review was done. Scopus, Web of Science, and Google Scholar are powerful, highly recognized scholarly search engines that allow researchers to track the current progress in a particular research area (Tober, 2011; Shan and Hwang, 2018). While Google Scholar has an additional advantage of having a wider coverage (Jacsó, 2005; Xiong et al., 2015), all of these three search engines have been widely used in conducting literature reviews (Olanipekun et al., 2017; Khoshbakht et al., 2018). In this study, the literature review concerning the GBTs for sustainable housing development involved two steps. In the first step, relevant keywords, "green building", "sustainable building", "green construction", "sustainable construction", "green building technologies", "sustainable building technologies", "green construction technologies", "sustainable construction technologies", "green technologies", "sustainable technologies", and "housing development", were searched in the aforesaid search engines. In the second step, following Shan et al.'s (2017a) approach, a careful visual examination of the attained papers was conducted to assess their relevance to the subject matter. Eventually, only papers discussing/analyzing potential GBTs for sustainable housing development were retained and reviewed. Adopting relevant keywords, the literature reviews in later chapters/sections of this thesis followed the same approach as described above.

After a comprehensive literature review on the GBTs for sustainable housing development, this study identified 28 GBTs and, based mainly on Zhang et al.'s (2011a) and Ahmad et al.'s (2016) GBTs classifications, grouped them into five major GBT categories: energy efficiency technologies, water efficiency technologies, indoor environmental quality enhancement technologies, materials and resources efficiency technologies, and control systems, as summarized in Table 3.1. Even though all these identified GBTs are considered important in the literature, it is certain that relative importance differs (Wong and Li, 2006). A questionnaire survey is done in this study to collect professional opinions on the relative importance of these GBTs.

Table 3.1 Summary of GBTs in the design stage of housing development (see Darko et al., 2018a).

			Key references						
GBT categories	Code	List of GBTs	Zhang et al. (2011a)	Zhang et al. (2011b)	Ahmad et al. (2016)	Roufechaei et al. (2014)	Koebel et al. (2015)	Chen et al. (2015)	Lee et al. (2007)
Energy efficiency	EE1	Application of energy-efficient lighting systems	–	–	–	X	–	–	X
	EE2	Application of energy-efficient windows	–	X	X	–	X	X	–
	EE3	Application of energy-efficient HVAC system	–	–	X	–	–	–	X
	EE4	Use of energy-efficient appliances (e.g., energy-efficient refrigerators)	–	–	X	–	–	–	–
	EE5	Application of solar technology to generate electricity	X	X	X	X	–	–	–
	EE6	Application of rooftop wind turbines to generate electricity	–	–	–	X	–	–	–
	EE7	Integrative use of natural lighting with electric lighting technology	X	X	X	X	–	X	–
	EE8	Application of solar water heating technology	X	–	X	X	–	–	–
	EE9	Application of solar shading devices	–	–	X	–	–	X	–
	EE10	Application of ground source heat pump technology	X	X	–	X	–	X	X
	EE11	Use of wooden logs to provide structure and insulation	–	–	–	X	–	–	–
	EE12	Optimizing building orientation and configuration	–	X	X	X		X	–
	EE13	Application of natural ventilation	–	–	–	X	–	X	–
Water efficiency	WE1	Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	X	–	X	–	–	–	–
	WE2	Rainwater harvesting technology	X	X	X	–	–	–	–
	WE3	Grey water reclaiming and reuse technology	X	–	–	–	–	X	–
Indoor environmental quality enhancement	IQ1	Ample ventilation for pollutant and thermal control	X	X	X	X	–	–	–
	IQ2	Application of indoor CO_2 monitoring devices	–	–	X	–	–	–	–
	IQ3	Application of low emission (low-E) finishing materials	–	–	X	–	–	–	–
	IQ4	Optimizing building envelope thermal performance	–	X	X	X	–	X	–
	IQ5	Application of solar chimney for enhanced stack ventilation	–	–	X	–	–	–	–
	IQ6	Use of efficient type of lighting (lighting output and color)	–	–	X	X	–	–	–
Materials and resources efficiency	MR1	Underground space development technology	X	X	–	–	–	–	–
	MR2	Use of environmentally friendly materials for HVAC systems	X	X	–	X	–	–	–
Control systems	CS1	HVAC control	–	–	X	–	–	–	–
	CS2	Security control	–	–	X	–	–	–	–
	CS3	Audio visual control	–	–	X	–	–	–	–
	CS4	Occupancy/motion sensors	–	–	X	–	–	–	–

3.2.1 Energy Efficiency Technologies

Achieving energy efficiency is one of the key goals for implementing certain GBTs in housing development. Constructing, operating, and maintaining a building entail energy consumption, which can generally be minimized by adopting energy-efficient technologies. As Yang and Yu (2015) defined, "energy-efficient technologies refer to technologies that reduce the amount of energy required to provide goods and services". The comprehensive literature review revealed that the housing industry could achieve higher energy efficiency by applying technologies like energy-efficient lighting, household appliances (e.g., energy-efficient refrigerators, dryers, and washers), HVAC system, window, renewable energy systems (e.g., wind turbines, solar panels, and ground source (geothermal) heat pumps), natural ventilation, and building orientation and configuration. Zhang et al. (2011a) discovered that the use of low emissivity (low-E) insulation window technology and solar water heating technology allowed housing developers to achieve improvements in energy efficiency. The results from Roufechaei et al. (2014) indicated that the application of lighting sources to save energy, integrative use of natural lighting (daylighting) with electric lighting system, and the application of natural ventilation were technologies that contributed to reducing energy consumption in housing units. Chen et al. (2015) identified solar shading devices, the use of natural light and ventilation, and building orientation optimization as technologies that improve energy efficiency and so reduce building energy budgets. Doherty et al. (2004), Lee et al. (2007), and Yunna and Ruhang (2013) found ground source heat pump to be a technology for increasing building energy efficiency. Koebel et al. (2015) showed that high efficiency windows had a great impact on energy use in buildings.

3.2.2 Water Efficiency Technologies

It is known that green buildings offer reduced whole lifecycle costs (USGBC, 2003). This is most frequently attributed to their potential benefit in energy and water saving. Water-efficient technologies are important as they help reduce the amount of water used in operating a building. Zhang et al. (2011a), Zhang et al. (2013), and Zhang (2014) wrote that decentralized rainwater technology, water-saving appliances, and gray water systems (water reclamation and reuse) greatly helped to achieve water efficiency in buildings and in low-carbon communities. Ahmad et al. (2016) presented two key technologies for conserving water in green residential buildings, which were rainwater harvesting technology and water-efficient appliances and fixtures. Bond (2011a) studied the GBTs incorporated into the design and retrofitting of homes in Australia. The findings indicated that rainwater harvesting technology was one of the most common and client-preferred water-efficient technologies. Bond (2010) also identified that water-efficient fixtures and fittings were important in the design of green buildings in Australia. According to Millock and Nauges (2010), rainwater tanks and the installation of water-efficient appliances (such as dual flush toilets and water-efficient shower heads) are effective technologies for water conservation in households.

3.2.3 Indoor Environmental Quality Enhancement Technologies

Indoor environmental quality enhancement technologies presented in this research refer to the GBTs needed primarily to efficiently complete a housing project which provides a good indoor environment for occupants. As per the literature review, such GBTs include the application of indoor CO_2 monitoring devices, application of low emission (low-E) finishing materials, ample ventilation for pollutant and thermal control, application of solar chimney for enhanced stack ventilation, optimizing building envelope thermal performance, and use of efficient type of lighting (lighting output and color). The research findings from Zhang et al. (2011a, b) showed that optimizing building envelope thermal performance and ample ventilation for pollutant and thermal control were two of the key indoor environmental quality enhancement technologies applicable in the design stage of sustainable housing development. Likewise, in developing an approach for sustainable housing design, Ahmad et al. (2016) highlighted that the application of solar chimney for enhanced stack ventilation, thermal insulation, and ample ceiling heights for naturally ventilated zones were three of the essential technologies to maintain comfort zone temperatures. As well, they stressed that the application of low-E finishing materials and indoor CO_2 monitoring devices should also be considered in order to ensure better indoor air quality. According to Pacheco et al. (2012), the thermophysical and optical properties of the building envelope are important parameters of design that have significant impacts on the indoor thermal comfort; thus, to ensure occupants' comfort, the overall building envelope thermal performance ought to be evaluated and optimized. Pacheco et al.'s (2012) viewpoint was supported by Chen et al. (2015) who argued that the indoor thermal environment is largely affected by the building envelope's thermal properties. Hence, both Pacheco et al. (2012) and Chen et al. (2015) agreed that careful use of thermal insulation, reflective surfaces, and heat storage capacity can enhance passive building thermal performance. The use of efficient type of lighting (lighting output and color), which can enhance the indoor environmental quality with regard to lighting, was among the GBTs for sustainable housing development identified by Tenorio (2007) and Roufechaei et al. (2014).

3.2.4 Materials and Resources Efficiency Technologies

Materials and resources efficiency technologies help save scarce and non-renewable resources and materials. The materials and resources efficiency technologies for green projects identified by Zhang et al. (2011a) included underground space development technology and application of environmentally friendly materials for HVAC systems. Zhang et al. (2011b) reported similar results; they indicated that the application of underground space technology is useful for saving land. Via a questionnaire survey with 30 firms experienced in underground residential building projects, Shan et al. (2017a) found that space/land saving was the most significant advantage of underground residential buildings. Several other previous studies suggest that the employment of underground space development technology in housing construction can well constrain the ever-growing urban sprawl, and concurrently save space for the natural and heritage landscapes (Bobylev, 2009; Liu et al., 2015; Alkaff et al., 2016). Roufechaei et al. (2014) identified that the use of environmentally friendly materials for HVAC systems was among the top six GBTs for sustainable housing development. Other researchers who identified use of environmentally friendly materials for HVAC systems as a technology for green property development include Zhang et al. (2013) and Zhang (2014).

3.2.5 Control Systems

Control systems refer to those technologies for the management of occupants' preferences of aspects in a building environment, such as indoor air quality, thermal and illuminance comfort, and energy conservation (Dounis and Caraiscos, 2009). Typically, these control systems are integrated, centralized, software, and hardware networks that are in charge of monitoring and controlling the indoor climatic conditions of a building. With these control systems in place, the building's operational performance together with the occupants' security and comfort could be ensured. Ahmad et al. (2016) gave six control systems for designing sustainable residential buildings: HVAC control, occupancy sensors, shading control, audio visual control, intercoms, and security control. After conducting a review on advanced building control systems, Dounis and Caraiscos (2009) identified that shading control is important for controlling the incoming natural light and solar radiation, and for reducing glare. As a technology for sustainable housing development, the goal of HVAC control is primarily to maintain the comfort of occupants with minimal energy use (Guo and Zhou, 2009; Afram and Janabi-Sharifi, 2014). Lu et al. (2010) and Garg and Bansal (2000) also identified the use of smart occupancy sensors as an important technology for sustainable housing development.

3.3 GAPS IN KNOWLEDGE

The above literature review indicates that numerous studies have addressed the GBTs that are important to achieve sustainable housing development. Nevertheless, most of these were case studies that are restricted in their limited generalizability (Koebel et al., 2015), or provided descriptive descriptions of the importance of the GBTs and lack quantitative research/evidence based upon industrial professionals' opinions. Accordingly, a compressive quantitative survey is necessary. Likewise, because the green building approach varies across countries and regions (WorldGBC, 2017a), most of the previous studies were country/region-specific, identifying the GBTs to achieve sustainable housing development within specific regions, or cities, of different countries (e.g., Roufechaei et al., 2014; Ahmad et al., 2016). However, research on the GBTs to achieve sustainable housing development within the context of Ghana is lacking. The present study addresses this lack. As part of the present research, an empirical questionnaire survey is performed to identify the GBTs that are important to achieve sustainability goals in the design phase of housing developments, particularly in Accra, Ghana. The reasons for focusing on the design phase are presented in section 1.3.2.

As Koebel et al. (2015) indicated, climate has the greatest influence on decisions regarding the identification and selection of GBTs for sustainable housing development in a specific region.

That is to say, builders build to the local climate. Accordingly, given the differences in climatic conditions in different geographical areas of Ghana (Dickson and Essah, 1988; VIGS-GHANA, 2011), focusing on Accra helps validate the findings of this study, as suggested by Roufechaei et al. (2014). Accra remains the capital city of Ghana as well as the capital of the Greater Accra Region. The region was selected particularly because vast parts of Ghana have tropical climates (as indicated in section 1.3.1), owing to their location in the Dahomey Gap and Accra also has a year-round tropical climate. The tropical climate of Accra means plentiful sunshine (Chan et al., 2009a), which causes hot-humid weather, which results in increased energy use in the city. Additionally, the Greater Accra region is the most urbanized region in Ghana (Songsore, 2016). Furthermore, as a coastal city, Accra is vulnerable to the impacts of climate change, and rapid population growth exerts more and more pressure on ecological systems and scarce resources (Steynor and Jack, 2015). Also, Accra represents one of the largest cities of Ghana in terms of housing, infrastructure, and population (Central Intelligence Agency, 2017). Hence, improving the sustainability of housing in Accra would have a significant impact upon national sustainable development. The sustainability of housing in Accra can be improved by incorporating suitable GBTs into housing design (Assari and Mahesh, 2011). It is therefore important to help industry practitioners and stakeholders to better understand how or what technologies can be applied to achieve sustainability in housing development. This research also enriches the extant literature by further prioritizing the GBTs for sustainable housing development using the AHP method, which helps in differentiating in general the more important GBTs from the less important ones (Cheng and Li, 2002).

3.4 LITERATURE REVIEW ON GBTs ADOPTION DRIVERS [5]

Darko et al. (2017c) presented a comprehensive review of the literature about the drivers for GBTs and practices adoption. Since the previous studies reviewed considered both the benefits of GBTs and practices adoption and actions outside the benefits (e.g., government regulations) as drivers for GBTs and practices adoption, Darko et al. (2017c) stated that drivers for GBTs and practices adoption are "the persuasions that encourage the adoption of GBTs and practices, and comprise the benefits of GBTs and practices adoption and actions outside the benefits that lead or motivate people to engage in GBTs and practices adoption". With such a broad definition in mind, Darko et al. (2017c) reviewed 42 relevant peer-reviewed journal papers. As a result, they identified a total of 64 drivers for the GBTs and practices adoption (Table 3.2). These 64 drivers were then grouped into five major categories: external drivers, corporate-level drivers, property-level drivers, project-level drivers, and individual-level drivers (Fig. 3.1). Falkenbach et al. (2010) reviewed previous research relating to environmental sustainability in the field of real estate investing and hence identified 10 drivers from just a real estate investor's viewpoint. They found that a three-level classification of these 10 drivers exists in the literature, namely, external drivers, corporate-level drivers, and property-level drivers. Through a careful examination of the previous literature, Darko et al. (2017c) determined that Falkenbach et al.'s (2010) classification framework could be adopted to categorize GB drivers in general, with the introduction of additional drivers and categories of drivers, as shown in Fig. 3.1.

Table 3.2 GBTs and practices adoption drivers identified from the literature (see Darko et al., 2017c).

Label	GBTs and practices adoption drivers	References
dr1	Government regulations and policies	[1, 2, 3, 5, 6, 7, 8, 11, 12, 14, 15, 16, 19, 23, 24, 25, 26, 28, 30, 32, 35, 41, 42]
dr2	Energy conservation (or rising energy costs)	[1, 2, 3, 6, 7, 9, 11, 12, 13, 17, 20, 23, 28, 30, 33, 36, 40, 41, 42]
dr3	Reduced whole lifecycle costs	[3, 4, 5, 8, 9, 10, 11, 12, 19, 21, 22, 23, 24, 28, 29, 34, 41, 42]
dr4	Environmental protection	[1, 2, 3, 4, 6, 8, 11, 14, 16, 18, 23, 26, 28, 30, 34, 39, 40, 41]
dr5	Incentive schemes	[1, 2, 3, 6, 8, 13, 15, 17, 19, 24, 25, 31, 35, 37, 40, 41]
dr6	Marketing benefits	[4, 5, 6, 7, 8, 11, 12, 16, 17, 18, 19, 23, 29, 30, 34]

[5] Published in Darko, A., Zhang, C., and Chan, A. P. C. (2017c). Drivers for green building: A review of empirical studies. *Habitat International*, 60, 34-49.

dr7	Knowledge and awareness, and information	[1, 3, 5, 8, 9, 11, 14, 15, 16, 18, 24, 25, 35, 42]
dr8	Corporate social responsibility	[6, 7, 8, 9, 11, 17, 19, 21, 22, 27, 30, 32, 41]
dr9	Demand from clients/tenants	[5, 11, 12, 14, 17, 18, 24, 25, 28, 32, 39, 41]
dr10	GB rating systems	[1, 11, 12, 14, 17, 24, 25, 27, 28, 32, 34, 35]
dr11	Competitive advantage	[7, 10, 11, 12, 16, 18, 23, 27, 28, 30, 38]
dr12	Improved occupants' health, well-being, and satisfaction	[3, 4, 6, 7, 9, 11, 12, 20, 30, 36, 40]
dr13	Improved occupants' productivity	[1, 6, 10, 11, 28, 29, 30, 34, 36, 38]
dr14	High return on investment	[7, 8, 11, 18, 19, 20, 23, 24, 29, 41]
dr15	Corporate image, culture, and vision	[3, 5, 8, 9, 10, 11, 12, 17, 30, 34]
dr16	Attract premium clients and high rental returns	[4, 6, 11, 12, 18, 19, 20, 31]
dr17	Education and training	[1, 2, 9, 15, 24, 28, 35, 42]
dr18	Increased property values	[11, 21, 22, 23, 29, 33, 41]
dr19	Improved indoor environmental quality	[1, 2, 9, 12, 21, 22, 30]
dr20	Waste reduction (materials and construction wastes)	[1, 2, 9, 23, 30, 32]
dr21	Recognition within the industry	[10, 15, 27, 28, 41]
dr22	Water conservation	[1, 9, 11, 20, 30]
dr23	Attraction and retention of quality staff	[28, 29, 30, 34]
dr24	Company policy	[3, 9, 18, 34]
dr25	Resource conservation	[1, 2, 3, 30]
dr26	Moral imperative or social conscience	[14, 18, 28]
dr27	Promotion and communication	[16, 23, 37]
dr28	Ease in resale and high resale value	[6, 19, 34]
dr29	Lower vacancy rates (or higher occupancy rates)	[6, 19, 20]
dr30	Personal commitment (e.g., owner's commitment)	[9, 14, 36]
dr31	Reduced construction costs	[1, 23, 32]
dr32	Integrated design approach or deign quality	[1, 2, 14]
dr33	Better ways to measure and account for costs	[1, 2, 23]
dr34	Product and material innovation and/or certification	[1, 2, 11]
dr35	Reduced liability and risks	[29, 31]
dr36	Decreased obsolescence	[21, 22]
dr37	Decreased construction time	[23, 32]
dr38	Meeting contract and developer's requirements	[27, 36]
dr39	Attitudes and traditions	[16, 24]
dr40	Performance-based standards and contracts	[1, 2]
dr41	Proactive role of materials manufacturers	[1, 2]
dr42	New kinds of partnerships and project stakeholders	[1, 2]
dr43	Self-identity	[14]
dr44	Impress regulators	[18]
dr45	Reduced depreciation in rent and price	[19]
dr46	Increased probability of lease renewal	[20]
dr47	Decreased tenant rent concessions	[20]
dr48	Increased construction time certainty	[23]
dr49	Improved project constructability	[23]
dr50	Reduced on-site worker health and safety risks	[23]
dr51	Achieve high quality building	[23]
dr52	Well controlled design and construction	[23]
dr53	Improve reusable and recycle building elements	[23]
dr54	Superior performance of green materials	[28]
dr55	Structural conditions	[28]
dr56	Helps to transform the market	[29]
dr57	Reduced payback period	[34]
dr58	Familiarity with green products/processes	[39]
dr59	Public perception	[39]
dr60	Increased longevity of building	[41]
dr61	Availability of green suppliers	[5]
dr62	Competent team members	[7]
dr63	Creation of better future opportunities	[8]
dr64	Reduced insurance cost	[9]

References: 1. Ahn et al. (2013); 2. Manoliadis et al. (2006); 3. Arif et al. (2009a); 4. Love et al. (2012); 5. Serpell et al. (2013); 6. Gou et al. (2013); 7. Low et al. (2014a); 8. Abidin and Powmya (2014); 9. Aktas and Ozorhon (2015); 10. Windapo and Goulding (2015); 11. Andelin et al. (2015); 12. Windapo (2014); 13. Brotman (2016); 14. Murtagh et al. (2016); 15. Khoshnava et al. (2014); 16. Wang et al. (2014); 17. Mulligan et al. (2014); 18. Potbhare et al. (2009); 19. Zhang (2014); 20. Devine and Kok (2015); 21. Bond (2011a); 22. Bond (2011b); 23. Zhai et al. (2014); 24. Udawatta et al. (2015); 25. Häkkinen and Belloni (2011); 26. Qi et al. (2010); 27. Low et al. (2014b); 28. Niroumand et al. (2013); 29. Chan et al. (2009a); 30. Boyle and McGuirk (2012); 31. Sayce et al. (2007); 32. Arif et al. (2012); 33. Popescu et al. (2012); 34. Bond (2010); 35. Arif et al. (2009b); 36. Bhavani and Khan (2008); 37. Richardson and Lynes (2007); 38. Edwards (2006); 39. Tinker et al. (2006); 40. Tan (2014); 41. Wong and Abe (2014); 42. DuBose et al. (2007).

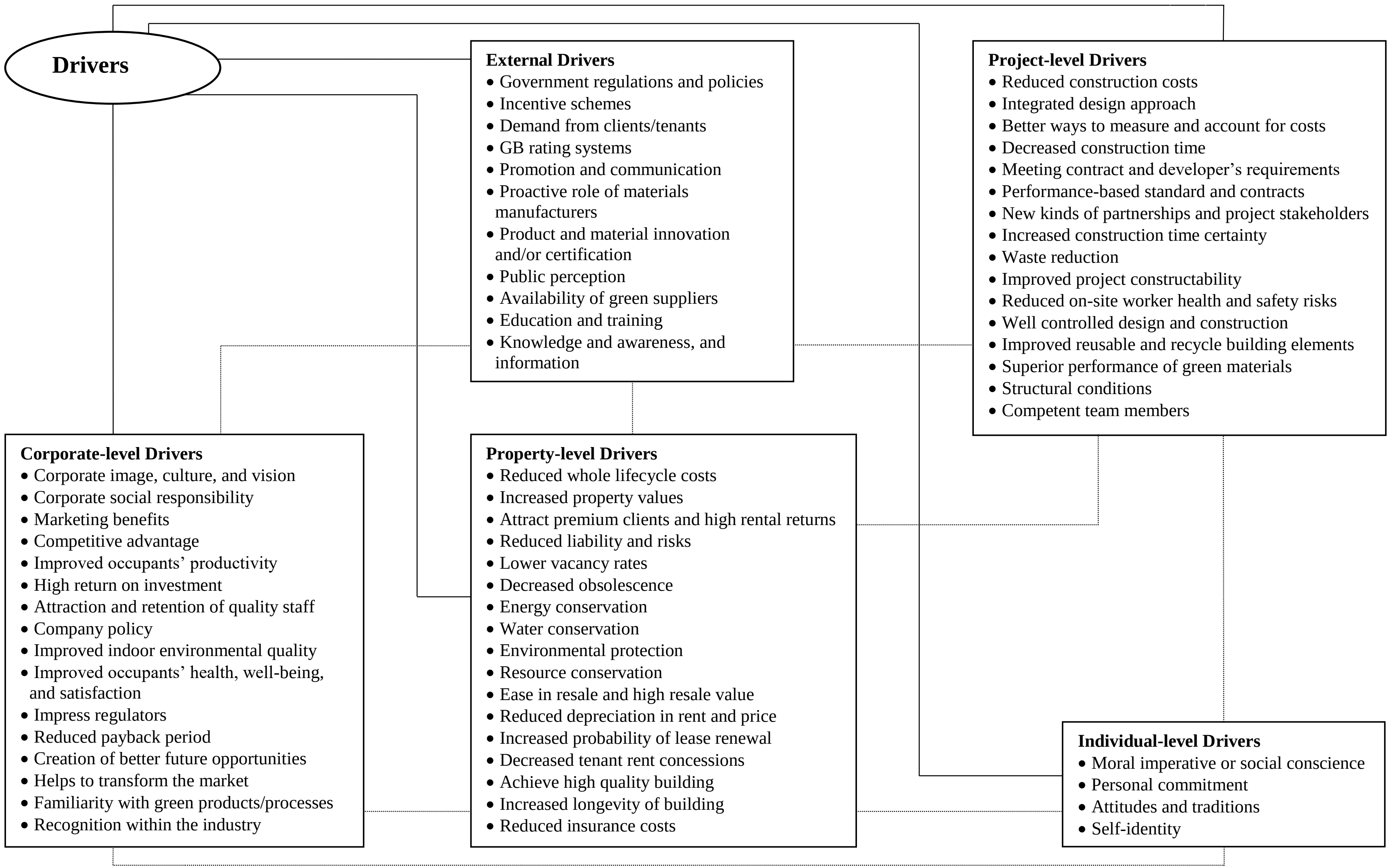

Fig. 3.1 Conceptual framework of GBTs and practices adoption drivers (see Darko et al., 2017c).

3.4.1 External Drivers

External drivers are drivers that are mainly set by external parties, e.g., the government, United Nations, European Union, and clients, to companies/organizations that building green. In other words, external drivers refer to activities that occur outside of the company that develops green buildings. Recently, several governments around the world have intensified their involvement with the green building market, and research has shown that the government's role is important to driving the adoption of GBTs and practices (Qian and Chan, 2010; Wang et al., 2014). Thus, governments have adopted a number of policies aimed at incentivizing and/or mandating GBTs and practices adoption (DuBose et al., 2007). The number of regulatory requirements increases each year and expected to continue to increase in the future as well, since green practice in the construction industry is becoming a more common phenomenon in many countries (Andelin et al., 2015).

In Europe, the Scandinavian countries were the first to launch regulations that mandate building energy efficiency improvement (Allouhi et al., 2015). For other European countries, one of the major motivations for setting building regulation was the need to reduce the energy dependency which became apparent following the oil crisis in the 1970s (Pérez-Lombard et al., 2011). The European Union requires all its member states to meet higher efficiency standards and acquire energy performance certificates for all new construction and renovations, through the European Union Energy Performance of Buildings Directive of 2002 (EPBD, 2002). Within the US, there are many legislations, executive orders, and national policies that motivate GBTs and practices adoption within different states. These are typically directed toward building energy-efficiency, waste management, and carbon emissions reduction. Mulligan et al. (2014) summarized recent policies for driving GBTs and practices adoption in the state of Michigan, such as the Customer

Choice and Electricity Reliability Act and the Clean, Renewable, and Efficient Energy Act. It is argued that these policies could help to overcome the psychological barriers (e.g., perceived higher costs) for stakeholders to adopt GBTs and practices. In other states like Washington and California, owners and developers submitted that they implement GBTs and practices because of strict local codes and regulations regarding site selection, energy consumption, and recycling (Korkmaz, 2007). Similar policy initiatives can be found in Asia where countries such as China, Singapore, Hong Kong, and India are rapidly embracing the green building concept (Ye et al., 2013; Gou and Lau, 2014). China was a pioneer to introduce green building standards in Asia. The Chinese government, within the 1980s, took the initiative to set the first building regulation for the northern residential industry, which spread to all other regions by 2000 (Ye et al., 2013). A lot of studies have addressed government policies and national programs in promoting GBTs and practices adoption in China (Ye et al., 2013; Zhang, 2014).

The regulatory requirements affect and exert pressure upon all major construction stakeholder groups, and while they can be deemed external or top-down drivers, they can also be considered bottom-up or market-led corporate drivers, basically because firms may seek opportunities to mitigate the down-side risks of future regulatory changes (Sayce et al., 2007). Green building policies and regulations have been proved to be effective and influential in both leading change and raising awareness within the construction industry (Arif et al., 2012). Andelin et al. (2015) mentioned that companies could gain competitive advantage if they react proactively to green building regulations. However, when considering legislation as a primary driver, one must note that the regulations themselves usually vary according to country or region, and hence the role that international organizations play in regulating international laws is core to providing equal operational environment for companies irrespective of the countries within which they operate (Carroll, 2004). Therefore, international regulatory requirements that act as vehicles for change towards sustainability have been established. Among the most salient initiatives are the Kyoto Protocol, which principally sets targets to reduce greenhouse gas emissions worldwide, and the UN's Principles of Responsible Investment (Parnell, 2005).

Several previous studies found strong evidence that government regulations and policies are key drivers that compel stakeholders to go green (Arif et al., 2009a, b; Boyle and McGuirk, 2012; Gou et al., 2013; Serpell et al., 2013; Low et al., 2014a; Khoshnava et al., 2014; Murtagh et al., 2016). In Murtagh et al.'s (2016) research which aimed to understand what motivations drive architectural designers in the UK to pursue green design, most of the interviewees viewed regulations positively and agreed that "legislative drivers are a good thing" and that when green building is a regulation, architects are able to help their clients in adopting green building practices. The questionnaire survey and interviews study that investigated the drivers for greening new and existing buildings in Singapore reported that all the respondents confirmed the importance of government legislations and policies in promoting green building (Low et al., 2014a). The respondents ranked legislation as the most significant driver for green building in the construction industry. This finding supports that of the Indian studies (Arif et al., 2009a, b), where the views of experts from academia, private and public sectors, and regulatory bodies on the major drivers for green building were analyzed. Boyle and McGuirk (2012) aimed at understanding the motivations of professional service firms for adopting green office space within Australia. Interviews with management professionals of the firms revealed that market positioning via compliance was a main motivation for adopting green office spaces. That is, the respondents were of the view that green office spaces were adopted to meet regulatory requirements. The research emphasized the fact that when green building becomes a regulation, stakeholders tend to comply. The finding of Boyle and McGuirk's (2012) study was similar to that of the case studies and interviews conducted among developers in Hong Kong (Gou et al., 2013). The Hong Kong developers ranked legislation as the most effective means to stimulate interest in green building and stated that "if you don't legislate people won't start to do it". In Malaysia, Khoshnava et al. (2014) conducted a questionnaire survey with clients, consultants, contractors, designers, suppliers, and manufacturers to identify the major drivers for implementing green practices in industrialized building system construction. The majority of the respondents pointed out that the influence of legislation was higher than that of the other drivers.

In addition to legislative initiatives, local authorities in several countries and cities offer incentive programs to make green building attractive. For more comprehensive reviews and descriptions of different types of green building incentives, the reader is referred to Olubunmi et al. (2016) and Shazmin et al. (2016). Green building incentive schemes have also been proven to encourage the development of green buildings at various national levels. In the US, for example, incentives such as direct monetary payment, state income tax credit, and density bonus have been adopted by many states to drive demand from stakeholders (Yudelson, 2008). While these are financial incentives, nonfinancial incentives also exist. An example is the gross floor area (GFA) concession scheme. This incentive scheme motivates stakeholders to commit to green building investment and meet higher standards, through the granting of additional GFA bonus to stakeholders who meet certain green standards. The GFA concession scheme has been adopted by governments such as the Hong Kong and Singapore governments (Qian et al., 2016). Through a survey with 436 green accredited professionals in Japan, Wong and Abe (2014) indicated that market incentives can motivate project stakeholders to adopt green building and that two of the most desired types of incentives were preferential interest rates and financial incentives. The possibility of receiving these incentive awards has further been widely cited in the literature as a driver for stakeholders in many countries to move towards green building (Abidin and Powmya, 2014; Tan, 2014). Government incentives help drive green building practices as they might compensate stakeholders for the extra costs and efforts that may be required to build green.

There is growing evidence that client/tenant demand and awareness play an essential role in driving green building. Arif et al. (2012) investigated the major drivers for the implementation of effective waste management practices in building projects. They found that client demand/preference and regulations were the top drivers. A similar study also found support that clients' interest is a crucial driver for engaging in construction waste minimization (Udawatta et al., 2015). Moreover, in the UK study, the first driver to which most of the architectural designers referred for implementing sustainability was client demand (Murtagh et al., 2016). The demand and willingness of clients in the end determine the extent of green building development. Customer's demand is closely related to issues like knowledge, supply, method, value, and cost (Häkkinen and Belloni, 2011). Despite the cost implications, clients and the public are likely to be motivated to embrace green building practices if they are better informed and educated about the "big picture" benefits of such actions. Increased education and training has become a key driving force for green building development (Niroumand et al., 2013). Education via better information and communication flow has significant influence on the level of knowledge and awareness of clients and the general public. Researchers have highlighted the relevance of increased knowledge, awareness, and information in the process of changing the attitude and behavior of construction stakeholders toward green building (Potbhare et al., 2009; Abidin and Powmya, 2014). Wang et al. (2014) found promotion and communication strategies, such as generic marketing, television programs, and education and training programs, to be significant drivers for the use of wood as a sustainable solution for green building in the UK building sector. For more effective market penetration of green building, it is essential to increase the knowledge and environmental awareness of all stakeholders, and more specifically, to better disseminate information to the demand side, i.e., clients, investment and financial institutions, etc. (Wong and Abe, 2014).

As mentioned earlier, several green building rating systems have been created to help boost green building in many countries. Green building rating systems consist of various requirements (e.g., sustainable energy and water use) conforming to the triple bottom line of sustainable development. Zhang (2015) summarized the most essential green building rating systems in the world, including the UK's Building Research Establishment Environmental Assessment Method (BREEAM) and the US's LEED. Green rating or certification has been found to be one of the important external drivers for green building. It is commonly acknowledged that most of the green building decisions and actions in the construction industry are based on financial returns, thus stakeholders only use green options if they are financially viable. Therefore, unless there is a requirement to comply with a green building rating system, stakeholders do not always consider green practices (Windapo, 2014; Udawatta et al., 2015). Aside from green building rating systems, many companies offer benchmarking and sustainability management services, e.g., the Jones Lang LaSalle/Upstream and IPD (IPD Environment Code) (Falkenbach et al., 2010). Although there is not much empirical evidence supporting them, other external drivers identified in the literature include proactive roles of materials manufacturers and availability of green suppliers (Manoliadis et al., 2006; Serpell et al., 2013).

3.4.2 Corporate-level Drivers

It is important to understand the internal drivers that enhance business in terms of sustainability. As discussed in the previous section, external drivers such as regulatory incentives and mandates continue to pressure stakeholders to improve the sustainability of their portfolios. Then again, the prospect of future and more burdensome legislation vis-à-vis building design and construction has led some stakeholders and companies to adopt a "beyond compliance" culture either to reduce down-side risk or attain higher returns (Sayce et al., 2006). These proactive actions can be viewed as ways to gain certain competitive advantages, such as differentiating oneself from competitors. One study that demonstrates the potential of green building in providing a competitive advantage to the property company is the study by Zhang et al. (2011b).

The modern competitive and complex business environment has affected the manner in which companies operate. With the level of technological advancement, information on abuses and irresponsible actions easily spread nowadays, making it difficult for companies to take the risk of compromising their reputation (Niskala et al., 2009). Consequently, establishing a good image and reputation has become necessary for organizations to survive in their industries. Corporate image reflects a company's values and defines the attractiveness of the company as well as of its products in the market (Andelin et al., 2015). The desire for good image and reputation could impact a company's commitment to green building. Developers who wish to build up their reputation and gain competitive advantage have started incorporating green strategy into their business (Zhang et al., 2011b). Perceptions of a company's reputation are shaped by a myriad of attributes, including the quality and range of its services, its identify, values, and culture (Boyle and McGuirk, 2012). The review of literature has pointed out that "corporate image, culture, and vision" is one of the biggest drivers for pursuing green building practices. By conducting two separate questionnaire surveys, Andelin et al. (2015) established mutual sustainability drivers for tenants and investors in Nordic countries. They detected that the most remarkable driver for these two major groups of stakeholders was corporate image and culture. A recent study in South Africa also demonstrated that good public image was the topmost driver for construction companies to consider green practices (Windapo and Goulding, 2015). Other studies also found evidence that "corporate image, culture, and vision" influences the decisions of stakeholders to implement green building practices (Serpell et al., 2013; Mulligan et al., 2014). By publicizing their green image, companies could be more competitive in the market and enjoy greater product demand, and potential for higher profits.

Building green can further show a company's commitment to social responsibility, and by assuming this social responsibility, the company can enhance its publicity and image. It is recognized that corporate social responsibility (CSR) is a major issue affecting business competitiveness and image. An increasing number of housing developers have begun to grow CSR culture in efforts to build up their reputation and remain competitive in the industry (Zitzler et al., 2000). CSR offers a property company an opportunity to communicate its commitment to sustainability and thereby gain strong customer trust and good publicity (Newell, 2008). Many leading property companies are active in promoting their impressive environmental performance, helping them gain substantial media exposure, resulting in notable corporate branding and differentiation opportunities (Falkenbach et al., 2010). Research has shown that investing in green building can help in achieving not only high environmental performance standards, but also social performance, which can be helpful to attract customers. Hence, CSR culture is now a key driver for organizations to adopt green building (Gou et al., 2013; Low et al., 2014a).

Another major driver for green building is "marketing benefits". The existing body of knowledge emphasizes that building green could serve as a powerful sales and marketing tool for property companies (Chan et al., 2009a; Love et al., 2012). An opportunity of enhanced marketability that could help companies to increase their market shares as an integral part of the business strategy encourages green building adoption. Through application of green elements (such as solar panels), the property developer would be able to develop unique green products that have good potential to easily penetrate the market when customers demand for more sustainable products. Greening can therefore be a good opportunity to satisfy the expectations of today's and future customers on green living environments.

Some companies have strong environmental policies that force the adoption of greener market and industry standards. Potbhare et al. (2009) demonstrated that company policy is the most important motivation for organizations to adopt green building guidelines. This attitude has been backed by other works. For example, Aktas and Ozorhon (2015) examined the green building certification process of existing buildings in Turkey and established that a number of companies decided to retrofit their buildings to receive green certificates, because of strict environmental policies of the companies. In certain cases, developing a green environment that can be comfortable for occupants was a vision of the companies. Having an environmental policy may shape the company's greening process and help enhance its corporate image to gain recognition within the industry (Aktas and Ozorhon, 2015).

If stakeholders' business logic has to be considered, it is clear that financial or economic aspects, such as rental yields and investment returns, are crucial because they can be considered as the main sources of income. The investment's future income stream and the risk-adjusted attained during the period in which it is held are primarily of interest to the stakeholder

(WorldGBC, 2013). Chan et al. (2009a) suggested that economic benefits should be the most essential issues for the business survival of every stakeholder. Adopting green building practices has been found to generate higher return on investment (Abidin and Powmya, 2014; Low et al., 2014a), which could be linked to higher occupancy rates, higher rental returns, etc. And this merit helps push stakeholders to take part in green building development. A key challenge for the green building stakeholder or company is to balance the need to consider green building solutions with the need for financial returns on the investment (Baker and Chinloy, 2014). As Collett et al. (2003) noted, there has been a variation in the median holding period of properties over time, and the median holding period of UK properties, for instance, generally fell from about 12 years in the early 1980s to below 8 years in the late 1990s. The payback period of investments in green properties depends on two main factors, the added value to the property and the potential energy savings (Popescu et al., 2012). Numerous stakeholders, especially those with only a short-term interest in a property, would only consider investments having payback periods significantly shorter than the intended holding period, partly because of the desire to raise short-term returns (Bond, 2010).

According to the USGBC (2003), design features that boost indoor air quality and energy efficiency are salient and cost-effective strategies to enhance the productivity of employees and product quality. The Rocky Mountain Institute (1994) stressed that a 1% increase in productivity (measured by absenteeism, production quality, or production rate) can deliver savings to a building that exceeds its entire energy bill. Hence, it is understandable to note that the productivity aspect or gains of green building influence the interests of stakeholders in green building practices. A growing body of evidence suggests that improved worker productivity helps drive the green building market forward (Bhavani and Khan, 2008; Bond 2010). There are some interesting statistics supporting this. For example, it was discovered that worker productivity in green offices is 2 to 3% higher and that pays for the annual energy costs of lighting and heating a typical big company building (Edwards et al., 2006).

These productivity gains could be linked to the healthy, natural, and stimulating work environment that green building could offer. Green buildings typically offer more satisfying and healthier work environments for occupants (USGBC, 2003), which in turn increases personal well-being, reduces sick leaves and staff absenteeism, and increases commitment to the company that provides the building. Devine and Kok (2015) compared the differences between the average level of tenant satisfaction for green and non-green buildings and identified that there is a clear difference of 4% higher tenant satisfaction for green buildings in general and, more specifically, 20% higher for BOMA BESt buildings and 10% higher for LEED buildings.

The use of green building as a strategic means to attract and retain in-demand knowledge workers has also garnered attention in the literature as a central part of companies' decisions (Boyle and McGuirk, 2012). Because personal expenses constitute an essential part of a company's operating costs, companies regard their corporate values and identity as critical for attracting and retaining the necessary labor to drive their businesses. As the younger generations coming through appear to be keener on CSR and environmental issues (Nelson et al., 2010), the companies that provide greener work environments are more likely to attract quality employees. Employee turnover could be very costly to companies, especially in terms of knowledge where the "product" is human brainpower, which naturally goes with the employee when he or she leaves (Heerwagen, 2000). Other corporate-level drivers include impress regulators and market transformation (Potbhare et al., 2009).

3.4.3 Property-level Drivers

From the viewpoint of stakeholders, the benefits of green buildings are beyond dispute. Green buildings provide distinct benefits through environmental protection to high energy efficiency. Thus, stakeholders are increasingly demanding green buildings to reduce both their environmental impact and occupancy cost. Many stakeholders at most times focus on maximization of the capital value of the building, which Reed and Wilkinson (2005) believe can be achieved by decreasing costs, capitalization rates, and increasing income. In fact, the recognition that high operation and maintenance costs of buildings could be reduced through green design has over the years driven the green building market far. Evidence indicates that green buildings may have reduced whole lifecycle costs than non-green ones. Homeowners, architects, builders, and developers in Australia and New Zealand agreed in two different studies that reduced whole lifecycle costs was the most important driver for engaging in green building (Bond, 2011a, b). Both studies identified that cost savings greater than $1,000 per annum was the impetus behind the decisions to build green. The questionnaire surveys conducted among building designers in Hong Kong and Singapore also revealed that the top business reasons that make green building attractive include lower operation costs and lower lifetime costs (Chan et al., 2009a).

The reduced lifecycle cost of green buildings can directly be linked to issues such as reduced water use and energy savings. As with the adoption of most green building practices, even in the midst of opposition, circumstances can engender a climate in which the practices can be accepted. The presence of commonly known crisis cannot be undermined as an impetus for garnering support for green building practices. Brotman (2016) observed that when utility bills are high, stakeholders are driven towards the adoption of energy saving technologies. This echoes with several other investigations, including Windapo (2014) who discovered in South Africa that rising energy costs has been a key driver for stakeholders to incorporate green building principles into their projects, and this driver has not changed significantly over time. Even in fast growing states like Arizona, extremely high energy costs were identified as helping make green building more attractive (DuBose et al., 2007). The literature suggests that stakeholders have recognized the importance of implementing GBTs to conserve energy and, in turn, reduce their utility bills. In many countries, such as the US, Greece, Malaysia, Iran, UK, India, and Australia, the most important driver for adopting green building practices is energy conservation (Manoliadis et al., 2006; Ahn et al., 2013; Niroumand et al., 2013).

The contribution of the construction industry to the world's environmental woes is most often discussed in relation to resource consumption and emissions. The construction industry is regarded as a major contributor of CO_2 emissions primarily because of its significant role in energy consumption (Low et al., 2014a). The potential of green building practices in ensuring that the buildings that stakeholders add to their inventory are well designed and more energy-efficient, therefore, helps to reduce the environmental impact of buildings. There is a large body of literature corroborating the idea that environmental protection is a vital issue promoting green building. It has been reported that reduced environmental impact provide an impetus for stakeholders to be involved in green building (Love et al., 2012; Abidin and Powmya, 2014). Also, the possibility of conserving limited resources has made green building more popular (Manoliadis et al., 2006). There are no doubts that the application of, for instance, renewable energy sources (such as solar and wind energy generation systems) can help to reduce the burden on energy sources that are nonrenewable and also costly to produce and use.

Stakeholders define value as the potential market value of their property, which is, in turn, influenced by the attractiveness of the property to potential customers (Andelin et al., 2015). According to the WorldGBC (2013), the market value of a property is directly linked to the occupancy and rental rates. Therefore, the fact that sustainability issues have significant impacts on rents, occupancy rates, and operation costs, exert influence on property values. There are real studies providing convincing evidences that sustainability issues improve the value of properties. For example, Devine and Kok (2015) documented the findings of a research which analyzed the relationship between various proxies for green building, including LEED, BOMA BESt, and ENERGY STAR, and both nonfinancial and financial outcomes. The study involved data collected over a 10-year period for 291 buildings in the US and Canada. The nonfinancial performance measures included lease renewal rates, tenant satisfaction (gleaned through detailed tenant surveys), and resource consumption data. Their findings presented some interesting statistics, confirming differences between green and non-green buildings on various performance measures. It was found that rental returns are 3.7% and 2.7% higher for LEED-and ENERGY STAR-certified buildings, respectively. The largest premium of 14% for rental rates was found to be associated with LEED Core and Shell certifications. They also identified that LEED certification alone results in an 8.5% increase in occupancy rate, whereas having both LEED and BOMA BESt certifications results in an 18.7% increase in occupancy rate. Furthermore, it was demonstrated that there is an increased probability of lease renewal in green buildings than non-green buildings. Thus, a 5.6% marginal increase in the likelihood of lease renewal in a green building over the likelihood of renewal in a comparable non-green building was observed. Regarding utility consumption, the energy and water consumption for the buildings were examined. It was identified that LEED-certified buildings use notably less energy, by about 28%, than their noncertified counterparts, and green buildings use less water than non-green buildings. A significant decrease in tenant rent concessions and higher levels of tenant satisfaction for green buildings were also found. It was concluded that these findings provide useful insight into the value drivers for green building. While decreased water and energy usage leads to lower expenses for both tenants and owners, greater rental returns are also achieved through decreased rent concessions. Moreover, there is a clear relationship between higher re-leasing probability, better-off-tenants, and higher occupancy rates, and all these three relative improvements essentially lead to a more stable rental returns and less costly building operations. Both the reduced variability in the building's turnover and operations, and the cost savings should, therefore, lead to higher value for green buildings (Devine and Kok, 2015).

Still, it is argued that the business case for investing in green buildings currently rests more on risk reduction than the proven financial returns (Sayce et al., 2007). Scholars have provided evidence that consideration of green practices can reduce the risk of an investment (Sayce et al., 2007; Chan et al., 2009a). The perceived risk of an investment can arise from numerous factors, however, the discussion of decreased liability and risks in investing in green buildings typically builds on either the lower risk of vacancy or lower risk of future obsolescence (Falkenbach et al., 2010; Bond, 2011a, b).

3.4.4 Project-level Drivers

Decisions at the project level have significant impact on the overall or final cost of the building. Making the right design decisions is therefore required to keep cost within an acceptable range. There are compelling arguments about the cost premium associated with green building. However, when it comes to the question of whether or not building green costs more than the non-green approach, a recent study has shown that there is not yet a conclusive answer

(Dwaikat and Ali, 2016). While some studies argue that it costs more to build green (Chan et al., 2009a; Shi et al., 2013), other evidences support that green building can be achieved with little or no added cost to that of the non-green approach (Kats et al., 2003; Matthiessen and Morris, 2004). Through a review of 33 green-certified buildings and comparing their costs with that of similar non-green buildings, Kats et al. (2003) noted a widespread public misconception that green buildings are prohibitively more expensive. They also noted that the majority of the extra cost of green buildings is not in "hard costs" (i.e., costs associated with the installation of major green components and materials), but is instead in "soft costs" (i.e., costs associated with extra time for planning, design, and construction). Matthiessen and Morris (2004) also compared the actual construction cost of 45 buildings seeking green certification with similar non-green buildings and discovered that there is no statistically significant difference between the budgets of non-green buildings and those seeking some level of green certification.

The green building cost has been declining because of more common use of integrated design approaches. Bond (2010) showed that in designing and constructing green buildings that work well in both nonfinancial and financial terms, the most successful results are achieved by using an integrated approach, whereby all parties are engaged in the early design phase, and the design team is allowed to collaboratively innovate solutions. The USGBC (2003) asserted that many green buildings cost no more to build, or may even cost less than non-green alternatives, because resource-efficient strategies and integrated design often allow downsizing of more expensive electrical, structural, and mechanical systems. Integrated design is an essential component of green building (Yudelson, 2009) and with its potential to improve the design quality as well as reduce costs, stakeholders could be motivated to implement green building principles on their projects (Manoliadis et al., 2006; Ahn et al., 2013). There are books discussing how the integrated design approach reduces the cost of green building (Yudelson, 2009, 2008).

One main study on the project-level drivers for green building is the study by Zhai et al. (2014). Increasing the level of uptake of off-site production approaches is important to address the mounting challenges of green building. Zhai et al. (2014) investigated the attitudes and motivation levels of the Chinese construction industry towards the adoption of off-site production approaches and improved green building practices. Through a questionnaire survey with 110 construction professionals in China, including architects, engineers, contractors, manufacturers, suppliers, and developers, the authors found 21 drivers for the implementation of off-site production in green projects. The top ranked drivers included reduced construction waste, decreased construction time, reduced materials waste, increased construction time certainty, reduced labor demand and construction cost, improved project constructability, ensure project cost certainty, reduced on-site worker health and safety risks, and achieve high building quality. Other project-level drivers identified in the literature include competent team members, superior performance of green materials, meeting contract requirements, and new kinds of partnerships and project stakeholders (Niroumand et al., 2013; Low et al., 2014a, b).

3.4.5 Individual-level Drivers

Motivation is understood, in psychological theory, as the forces behind most human behaviors (Murtagh et al., 2016). It does not only determine what behavior may be enacted, but also its duration and persistence (Wiener, 1992). People are proposed to be intrinsically driven to mastery their operational environment; that is to control their own lives or desire a sense of competence, and to a sense of self-regulation, personal volition, and autonomy in their behavior

(Murtagh et al., 2016). The contexts within which people operate may either frustrate or support these basic drives – the market or industry sector, the work organization, and the national economy are examples of these contexts. It is clear that individuals operate with multiple motivations that can range from controlled or extrinsic motivations to intrinsic or autonomous motivations. Extrinsic motivations come from outside the individual, such as regulations and financial reward from increased profit as discussed in previous sections. In contrast, intrinsic motivations are relatively independent of outside controls, are volitional, and more flexible, allowing people to act in their own ways. Individual-level drivers are relatively intrinsic and describe what internally drives people to want to move towards sustainability goals or try green building practices on their own projects. Four main individual-level drivers for green building were identified following the literature review: moral imperative or social conscience, personal commitment, attitudes and traditions, and self-identity. While these drivers can be effective in driving the adoption of green building practices, the amount of empirical studies on them are still quite low.

Self-identity, for example, was identified in only one study, that is the interviews study by Murtagh et al. (2016). The architectural designers opined that who they saw themselves as being motivated them to implement sustainability in their works. It was established that when individuals personally wish to improve their professional identity by doing “high quality work” or “very nice job”, they tend to be more committed to green design. The respondents felt that there is a strong link between their self-identify and their designs, and their self-identity is an essential part of their profession. Moral imperative and personal commitment were also major drivers indicated by the architectural designers. With moral imperative, the architects felt green construction is an ethical way to build, and this has been supported by Potbhare et al. (2009) who found that social conscience is an individual’s motivation to adopt green building guidelines. Aktas and Ozorhon (2015) also identified that personal commitment to sustainability has driven some owners in developing countries to green retrofit their buildings. Individuals' attitudes and traditions also have a key role to play in driving the green building concept (Wang at al., 2014).

The many GBTs and practices adoption drivers identified and discussed by Darko et al. (2017c) are presented above. As earlier stated, the present research considers only the benefits of GBTs adoption as the drivers for GBTs adoption. Therefore, based mainly upon Darko et al.'s (2017c) review, the present study selected 21 potential drivers for GBTs adoption, which were used for the questionnaire survey in Ghana. Table 3.3 displays these 21 drivers and the number of times each of the drivers was cited within the literature to show the attention each has attracted. These drivers can motivate the adoption of GBTs and therefore a better understanding of them would play a pivotal role in promoting the wider adoption of GBTs in Ghana.

Table 3.3 List of selected drivers for GBTs adoption (see Darko et al., 2017a).

		References																				
Code	Drivers for GBTs adoption	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total number of references for a certain driver
DR01	Greater energy efficiency		x	x	x	x	x	x	x		x			x					x		x	11
DR02	Reduced whole lifecycle costs	x	x	x	x					x	x	x	x	x	x	x			x	x	x	14
DR03	Company image and reputation		x	x	x				x	x	x	x		x	x	x		x	x		x	13
DR04	Improved occupants' health and well-being	x	x	x	x			x			x			x					x		x	9
DR05	Improved occupants' productivity		x	x	x	x		x							x		x			x	x	9
DR06	Non-renewable resources conservation		x	x	x	x	x												x			6
DR07	Reduced environmental impact	x	x	x	x	x	x	x		x						x			x		x	11
DR08	Improved indoor environmental quality		x	x	x	x	x				x			x								7
DR09	Greater water efficiency		x	x	x	x					x										x	6
DR10	Commitment to social responsibility		x	x				x	x	x	x					x		x			x	9
DR11	Waste reduction		x	x		x	x				x											5
DR12	High return on investment			x					x							x				x	x	5
DR13	Reduced use of construction materials in the economy		x																			1
DR14	Attraction and retention of quality employees		x	x																x		3
DR15	Enhanced marketability	x		x				x	x			x		x	x	x		x		x	x	11
DR16	High rental income	x	x	x	x			x						x							x	7
DR17	Better workplace environment		x		x												x					3
DR18	Increased building value		x	x	x			x												x	x	6
DR19	Setting a standard for future design and construction		x		x								x									3
DR20	Job creation opportunity		x																	x		2
DR21	Facilitating a culture of best practice sharing		x										x									2

References: 1. Love et al. (2012); 2. Darko et al. (2017b); 3. Darko et al. (2017c); 4. Darko et al. (2017d); 5. Ahn et al. (2013); 6. Manoliadis et al. (2006); 7. Gou et al. (2013); 8. Low et al. (2014a); 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. (2009a); 19. Chan et al. (2009a); 20. Andelin et al. (2015).

3.5 GAPS IN KNOWLEDGE

After a comprehensive review of the literature on GBTs and practices adoption drivers, Darko et al. (2017c) identified that research on the drivers for GBTs and practices adoption within the context of developing countries is limited. In particular, in the context of Ghana, it is missing. This study aims at addressing this lack by examining the drivers for GBTs adoption in Ghana through a comprehensive empirical questionnaire survey with industry professionals to identify the major drivers. The findings may help the industry practitioners and policy makers promote the GBTs adoption. As well, the previous global studies did not empirically test how the various GBTs adoption drivers influenced GBTs adoption in the industry. Hence, this study contributes to the body of knowledge by showing the quantitative influences of various types of drivers on GBTs adoption.

3.6 CHAPTER SUMMARY

GBTs are increasingly important to sustainable housing development and several GBTs have been introduced in sustainable housing projects and then studied in the literature. The adoption of GBTs also provides a wide range of benefits that play a key role in driving GBTs adoption. This chapter is divided into two parts. The first part reviewed the literature related to the GBTs for sustainable housing development. Through the review of the literature, a number of GBTs were identified, classified, and discussed. Based upon Darko et al.'s (2017c) work, the second part of this chapter presented a comprehensive literature review about the drivers for adopting GBTs and practices. Eventually, 21 relevant drivers were selected from the literature and used for the present study. This chapter is important as it provided a foundation for the development of the survey questionnaire used for this research. The chapter also identified gaps in the body of knowledge that this research aims to address. The following chapter reviews the literatures concerning the barriers to GBTs adoption and strategies to promote the GBTs adoption.

CHAPTER 4 LITERATURE REVIEW – BARRIERS AND PROMOTION STRATEGIES OF GBTs ADOPTION

4.1 INTRODUCTION

Despite GBTs adoption offering numerous sustainability benefits that drive the GBTs adoption, the GBTs adoption is still hindered by a number of barriers. It is necessary to better understand the barriers to the GBTs adoption to help find ways and means to overcome them. Many studies have been conducted on the barriers that hinder GBTs and practices adoption. This chapter first reviews the literature on the barriers to the adoption of GBTs and practices, in order to identify the barriers. In order to successfully promote GBTs adoption, strategies are needed to overcome the barriers. Therefore, strategies to promote GBTs and practices adoption have been discussed within the existing literature. This chapter also reviews the literature regarding the strategies to promote GBTs adoption. As a result of the reviews of the literatures, this chapter provides lists of potential GBTs adoption barriers and promotion strategies that are crucial to developing the survey questionnaire for this study.

4.2 LITERATURE REVIEW ON GBTs ADOPTION BARRIERS [6]

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[6] Reported in Chan, A. P. C., Darko, A., Olanipekun, A. O., and Ameyaw, E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production*, 172, 1067-1079. Also, see:

Darko, A., and Chan, A. P. C. (2017). Review of barriers to green building adoption. *Sustainable Development*, 25(3), 167-179.

Chan, A. P. C., Darko, A., Ameyaw, E. E., and Owusu-Manu, D. G. (2016). Barriers affecting the adoption of green building technologies. *Journal of Management in Engineering*, 10.1061/(ASCE)ME.1943-5479.0000507, 04016057.

Darko, A., Chan, A. P. C., Ameyaw, E. E., He, B. J., and Olanipekun, A. O. (2017b). Examining issues influencing green building technologies adoption: The United States green building experts' perspectives. *Energy and Buildings*, 144, 320-332.

The numerous barriers hindering the adoption of GBTs and practices in construction have been investigated by several green building researchers and practitioners. Earlier studies have shown that barriers to GBTs and practices adoption exist in both developed and developing countries. With regard to developed countries, Ahn et al. (2013) identified the top five barriers to green building within 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 to be the most critical barriers affecting GBTs adoption within the US. There are several other US researches on the green building barriers (Meryman and Silman, 2004; Mulligan et al., 2014; Rodriguez-Nikl et al., 2015; Darko et al., 2017b).

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

Within Kong Hong, Lam et al. (2009) showed that additional 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 within Hong Kong include Gou et al. (2013) and Qian et al. (2015). As for Chan et al. (2009a), they studied 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 (2011b) 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 major barriers to implementing GBTs inside Australia. Tagaza and Wilson (2004) also highlighted the main barriers to green building in Australia: higher costs of green materials, unfamiliarity with GBTs, lengthy planning and approval process for inventive GBTs within a firm, lengthy GBTs implementation time, and risks and uncertainties involved. Williams and Dair (2007) presented 12 barriers impeding sustainable building within England. Amongst these 12 barriers 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 within the literature that primarily focused on green building barriers within the context of developed countries, for example, Finland (Häkkinen and Belloni, 2011), Sweden (Persson and Grönkvist, 2015), and Brazil (Kasai and Jabbour, 2014).

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 market demand, lack of knowledge and expertise, lack of incentives, lack of green building policies and regulations, and lack of databases and information. Other green building barriers studies done in the context of developing countries include the studies by Potbhare et al. (2009) and Luthra et al. (2015) in India, Aktas and Ozorhon (2015) in Turkey, Djokoto et al. (2014) in Ghana, Nguyen et al. (2017) in Vietnam, and Durdyev et al. (2018) in Cambodia. After a comprehensive review of the literature in both developed and developing countries, this research identified 26 potential barriers to GBTs adoption, which are shown in Table 4.1.

Table 4.1 List of potential GBTs adoption barriers (see Chan et al., 2018).

Code	Barrier factors	References
B01	Higher costs of GBTs	Williams and Dair (2007), Lam et al. (2009), Chan et al. (2009a), Zhang et al. (2011a, b, c), Hwang and Tang (2012), Shi et al. (2013), Chan et al. (2016), Darko et al. (2017b), Nguyen et al. (2017), Durdyev et al. (2018)
B02	Lack of GBTs databases and information	Williams and Dair (2007), Bond (2011b), 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), Durdyev et al. (2018)
B04	Lack of awareness of GBTs and their benefits	Williams and Dair (2007), Chan et al. (2009a), Zhang et al. (2011b, c), Bin Esa et al. (2011), AlSanad (2015), Chan et al. (2016), Darko et al. (2017b), Durdyev et al. (2018)
B05	Lack of government incentives	Chan et al. (2009a), Potbhare et al. (2009), Zhang et al. (2012), Love et al. (2012), Darko and Chan (2017), Darko et al. (2017b), Shen et al. (2017b), Nguyen et al. (2017), Durdyev et al. (2018)
B06	Lack of local institutes and facilities for GBTs research and development (R&D)	USGBC (2003), Hwang and Tang (2012)
B07	Lack of green building policies and regulations	Winston (2010), Zhang et al. (2011b, c), Love et al. (2012), Samari et al. (2013), Luthra et al. (2015), AlSanad (2015), Nguyen et al. (2017)
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. (2017b)
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 (2017), Durdyev et al. (2018)
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 (2017), Chan et al. (2016), Darko et al. (2017b)
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 (2017)
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), Durdyev et al. (2018)
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, Nguyen et al. (2017)
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 (2017)
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. (2017b)
B26	Limited experience with the use of nontraditional procurement methods	Love at al. (2012), Chan et al. (2016)

4.2.1 Gaps in Knowledge

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. Darko and Chan (2016) also identified that 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 green building barriers is essential for formulating proper strategies to overcome the barriers and consequently promote green building. This is even more critical in developing countries such as Ghana wherein green building is fairly new to the construction market. Because different regulations and conditions exist in different countries, it is necessary to have a better understanding of the barriers facing GBTs adoption in specific countries (Aktas and Ozorhon, 2015). That would help in efforts to address the barriers and promote the GBTs adoption. However, comprehensive investigations and surveys about 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. Hence, a comprehensive analysis of the GBTs adoption barriers within Ghana, combining the views of different stakeholders, is worthwhile. Similarly, the previous studies did not empirically test how the various types of GBTs adoption barriers influenced GBTs adoption in the construction industry. The present study addresses this limitation via developing a quantitative model that elucidates how different types of GBTs adoption barriers influence GBTs adoption.

4.3 LITERATURE REVIEW ON STRATEGIES TO PROMOTE GBTs ADOPTION [7]

How to promote the successful and widespread adoption of GBTs and practices has been a priority issue in the construction industry recently. Accordingly, researchers and practitioners have investigated and discussed strategies to promote GBTs and practices adoption. In order to identify these strategies, a comprehensive literature review was conducted.

Hwang et al. (2017b) identified the three most feasible solutions to promote the adoption of green business parks within Singapore – co-funding and incentives from government, green development policies and regulations, and collaborating with research institutions to study the green business parks benefits. Another Singapore-based study by Hwang and Tan (2012) identified the strategies to encourage green building adoption, including widening the coverage

[7] Reported in Chan, A. P. C., Darko, A., and Ameyaw, E. E. (2017). Strategies for promoting green building technologies adoption in the construction industry—An international study. *Sustainability*, 9(6), 969. Also see:

Darko, A., and Chan, A. P. C. (2018). Strategies to promote green building technologies adoption in developing countries: The case of Ghana. *Building and Environment*, 130, 74-84.

Darko, A., Chan, A. P. C., Ameyaw, E. E., He, B. J., and Olanipekun, A. O. (2017b). Examining issues influencing green building technologies adoption: The United States green building experts' perspectives. *Energy and Buildings*, 144, 320-332.

of governmental incentives to include GBTs adoption, educating clients on the green building benefits, creating a green building framework, organization of construction tours for educating the public about the green building benefits, and government funding for green building R&D. Inside Hong Kong, Wong et al. (2016) studied a set of factors for facilitating green procurement adoption within the construction industry. They identified the top three factors from 35 factors: government's mandatory environmental regulations, requirements of clients in tendering, and governmental and nongovernmental organizations' requirements. Moreover, they identified 10 underlying facilitator groups. At least, they found government regulations and standards, green technology and lifecycle considerations, and commitment from executive management to be the most important facilitator groups. Darko et al. (2017b) discovered that providing relevant incentives, making better information about the GBTs costs and benefits available, and green labeling and rating were the most important promotion strategies of GBTs adoption in the US. Qian and Chan (2010) did a comparative analysis of the building energy efficiency promotion measures existing in the UK, US, Canada, and China, and developed a conceptual model of the measures. Several promotion measures were presented in their model, examples of which were funding from the government for building energy efficiency technologies R&D, financial and nonfinancial incentives, low-cost loans for building energy efficiency implementation, product labeling and rating, and better enforcement of existing standards. In Utrecht of the Netherlands and Valencia of Spain, Van Doren et al. (2016) identified the local strategies to facilitate the scaling up of energy conservation initiatives. They identified strategies such as developing and enforcing regulations, developing private and public funding mechanisms, communicating the financial and co-benefits of energy conservation initiatives, establishing offline and online information points for energy conservation initiatives, and educating and training stakeholders about energy conservation initiatives. Potbhare et al. (2009) created an implementation strategy to promote green building guidelines adoption in India; availability of institutional framework, availability of better costs and benefits information, enhancing the environmental awareness of the public via seminars, conferences, and workshops, and educational programs for contractors, policy makers, and developers were highlighted as crucial promotion strategies. Li et al. (2014) tackled the problem of how to promote green building within the Chinese context, arguing that enhancing stakeholders' environmental awareness, strengthening green technology R&D and communication, and formulating green building policies were the three fundamental measures to promote green building. In Malaysia, Esa et al. (2017) identified the key strategies for driving construction and demolition waste minimization practices adoption: regulations enhancement, awareness and awards, and effective management procedures. As for Li et al. (2017), Doan et al. (2017), and Shan and Hwang (2018), they studied the literature about green building rating systems and concluded that developing green building rating systems plays an important part in nurturing green building development internationally.

Following a very careful review of the literature, this research identified 12 potential strategies to promote GBTs adoption. As stated previously, three other potential strategies were identified through the presurvey interviews with industry professionals. These were used to complement those identified from the literature. Table 4.2 shows the 15 potential strategies to promote the GBTs adoption used in designing the survey questionnaire.

Table 4.2 List of potential strategies to promote GBTs adoption (see Darko and Chan, 2018).

		References																						
Code	Promotion strategies	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
ST01	Financial and further market-based incentives for GBTs adoption	√	√	√	√			√	√				√	√	√	√	√	√	√		√			
ST02	Mandatory green building policies and regulations	√		√	√	√	√	√	√	√			√	√			√	√	√	√	√		√	
ST03	Green rating and labeling programs			√	√	√		√			√	√	√	√				√			√	√		
ST04	Better enforcement of green building policies after they have been developed							√													√		√	√
ST05	Low-cost loans and subsidies from government and financial institutions		√					√						√			√				√			√
ST06	Public environmental awareness creation through workshops, seminars, and conferences			√					√					√			√	√			√		√	
ST07	More publicity through media (e.g., print media, radio, television, and internet)			√										√			√							
ST08	GBTs-related educational and training programs for developers, contractors, and policy makers	√		√					√					√			√						√	
ST09	Availability of better information on cost and benefits of GBTs	√	√	√		√			√	√							√				√			
ST10	Availability of competent and proactive GBTs promotion teams and local authorities			√					√								√							
ST11	Availability of institutional framework for effective GBTs implementation	√	√	√													√							
ST12	A strengthened GBTs R&D	√	√	√										√							√			
ST13	Acknowledging and rewarding GBTs adopters publicly[a]																							
ST14	Support from executive management[a]																							
ST15	More GBTs adoption advocacy by the Ghana Environmental Protection Agency[a]																							

References: 1. Hwang et al. (2017b); 2. Hwang and Tan (2012); 3. Darko et al. (2017b); 4. Darko et al. (2017c); 5. Wong et al. (2016); 6. Yang and Zhang (2012); 7. Qian and Chan (2010); 8. Chan et al. (2009a); 9. Lam et al. (2009); 10. Windapo (2014); 11. Li et al. (2017); 12. Shi et al. (2013); 13. Zhang (2015); 14. Olubunmi et al. (2016); 15. Qian et al. (2016); 16. Potbhare et al. (2009); 17. Gou et al. (2013); 18. Mulligan et al. (2014); 19. Shen et al. (2017a); 20. Li et al. (2014); 21. Murtagh et al. (2016); 22. Gan et al. (2015); 23. Van Doren et al. (2016). [a] The strategy was added after interviews.

4.3.1 Gaps in Knowledge

This study adopts Mintzberg's (1987) definition of strategy: "strategy is a plan, some sort of consciously intended course of action, a guideline (or set of guidelines) to deal with a situation". This definition reflects that strategies have two main features: they are developed purposefully and consciously, and they are developed in advance of the actions to which they apply (Mintzberg, 1987). Hence, at this initial stage of GBTs adoption in developing countries such as Ghana, it is necessary to develop strategies to promote GBTs adoption. However, only limited attempts have been made to better understand the strategies to promote GBTs adoption within developing countries. Over the past few years, researchers have investigated strategies to promote GBTs and practices adoption. Much of this research has been focused on developed countries. Moreover, as Chan et al. (2017) indicated, most of the previous studies recommend strategies to promote GBTs and practices adoption without empirical evidence/support. Given the limitations of previous research, it is of interest to carry out an empirical investigation on the strategies to promote GBTs adoption in the context of a developing country. Also, although the literature documents a broad variety of strategies to promote GBTs and practices adoption, these strategies existing in various other countries might not be applicable to Ghana due to the cultural, economic, and regulatory differences between countries. Accordingly, carrying out a study specifically focused on the developing country of Ghana is worthwhile. In addition, this study adds to the green building body of knowledge by establishing the underlying structure of the strategies to promote GBTs adoption and analyzing and modeling the likely influences of the strategies on the GBTs adoption.

4.4 A BRIEF OVERVIEW OF THE CURRENT SITUATION OF GBTs ADOPTION IN GHANA [8]

This section provides the reader with an understanding of the context within which this research was done, by presenting a brief overview of the current situation of GBTs adoption in Ghana. As mentioned before, the adoption of GBTs in Ghana is slow and still in its infancy. The Ghana Green Building Council (GHGBC), which is the main organization to assist in advancing GBTs adoption in Ghana, was only recently established in 2009 (GHGBC, 2010). Nonetheless, Ghana is among the few developing countries that are attempting to achieve major progresses in GBTs adoption and development. For example, Ghana has successfully launched the first LEED-certified green hospital in Africa, which is the Ridge Hospital (Bubbs, 2017), and the first green commercial office building in West Africa, which is the One Airport Square (ArchDaily, 2015). Various GBTs, such as solar water heating technology, rainwater harvesting technology, and natural ventilation technology, were adopted in these projects, suggesting that Ghana provides a good context for research to understand the typical GBTs adoption issues within a typical developing country.

In terms of policy, although 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 the use of GBTs. In 2007, for example, based on the Energy Commission of Ghana's advice, the government took the initiative to buy and distribute six million energy-efficient compact fluorescent lamps for free as a direct replacement of six million traditional incandescent lamps (Energy Commission of Ghana, 2009). This was an action to deal with the

[8] Reported in Darko, A., Chan, A. P. C., Gyamfi, S., Olanipekun, A. O., He, B. J., and Yu, Y. (2017a). Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. *Building and Environment*, 125, 206-215.

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). This Sustainable Development Action Plan focuses on sustainable production and consumption programs that would 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 research study might assist relevant Ghanaian government departments in their efforts to further motivate GBTs adoption. Regarding green building rating systems, as stated previously, currently, there are two primary rating systems applied in Ghana, which are the Green Star SA and the LEED. The GHGBC is now 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 adoption activities. That is, GBTs have been adopted in commercial office building projects 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 to mandate GBTs adoption on government-funded projects. In the Ghanaian residential sector, although some buildings have adopted some GBTs, until they have obtained a green certification, they may not be viewed as green buildings. Furthermore, it is worth noting that the health sector has also made good efforts toward GBTs adoption and development inside Ghana. It is hoped that the findings of this study would help policy makers and practitioners to promote the widespread adoption of GBTs in the Ghanaian construction industry.

4.5 CHAPTER SUMMARY

Through comprehensive literature reviews, this chapter has revealed that GBTs adoption faces numerous barriers that require in-depth understanding to help policy makers and practitioners devise proper policies and strategies to promote GBTs adoption. The chapter reviewed previous works identifying GBTs and practices adoption barriers and promotion strategies. As a result, it identified 26 potential barriers and 12 potential promotion strategies of GBTs adoption for the purpose of this research study. Following the comprehensive literature reviews, this chapter pointed out the gaps in the body of knowledge that the present research aims to address. Lastly, this chapter gave a brief overview of the current GBTs adoption situation in Ghana, the country of the research. The following chapter presents the results from the questionnaire survey about the GBTs to achieve sustainable housing development in Ghana and a model of the GBTs based upon the AHP method.

CHAPTER 5 DATA ANALYSIS AND RESULTS – GBTs TO ACHIEVE SUSTAINABLE HOUSING DEVELOPMENT IN GHANA [9]

5.1 INTRODUCTION

The previous chapters introduced this study, described the research methodology, and reviewed the relevant literatures. The present chapter reports upon partial findings from the questionnaire surveys done inside Ghana. Explicitly, it reports upon the GBTs to achieve sustainable housing development in Ghana. This chapter's objectives are to identify the important GBTs to achieve sustainable housing development, in particular Accra, Ghana and to contextualize the GBTs as a model to assist sustainable housing development. See section 3.3 for why it was reasonable to focus on Accra herein. In order to achieve the objectives, two types of questionnaire surveys – a general and an AHP survey – were conducted, which have been thoroughly described within Chapter 2. The present chapter presents and discusses the findings from these two surveys. The results from the general survey, based upon which an initial conceptual model of the GBTs for sustainable housing development is built, are first presented. The AHP survey results, based on which a final, modified model of the GBTs to attain sustainable housing development, are then presented and discussed. The findings from this chapter can be useful for industry professionals responsible for decision-making within the design stage of housing projects. Theoretically, this chapter adds to the green building body of knowledge via presenting one of the first studies in its kind focusing on GBTs for sustainable housing development within the Ghanaian context.

[9] This chapter has been partially published in Darko, A., Chan, A. P. C., and Owusu, E. K. (2018a). What are the green technologies for sustainable housing development? An empirical study in Ghana. *Business Strategy and Development*, 1(2), 140-153.

5.2 TESTING IMPORTANCE OF PROPOSED GBTs

In the general survey, the respondents were asked to indicate the importance of each of the 28 proposed GBTs to achieve sustainable housing development (Table 3.1) with a five-point rating scale (1 = not important, 2 = less important, 3 = neutral, 4 = important, and 5 = very important). Prior to the analysis of the data collected, the data reliability and normality were tested using Cronbach's alpha coefficient test and the Shapiro-Wilk test, respectively. The computed Cronbach's alpha value for the 28 GBTs was 0.910. This is much higher than the threshold of 0.70, suggesting that the five-point scale measurement and hence the data collected are highly reliable for further analyses. The Shapiro-Wilk test results indicated that the data collected are not normally distributed, as all the *p*-values produced by the test were less than 0.05. So as to test the importance of the GBTs, their mean scores were computed. The higher the mean scores, the more important the GBTs would be, as advocated by Cheng and Li (2002). To ascertain whether the data collected from respondents with different views and experience can be treated as a whole for presenting a general view of the GBTs for sustainable housing development, the Kruskal-Wallis H test was conducted. This test tests whether any significant differences existed among the respondents from consultant, contractor, and developer companies, as explained in section 2.2.2.4. The Kruskal-Wallis H test results indicated that there were no significant differences among the respondents from different companies in rating the importance of any of the proposed GBTs, because the significance values of all the GBTs were greater than 0.05. Moreover, the Kendall's *W* test result of 0.171 with the small associated level of significance of 0.000 implied that there was a significant degree of agreement between the respondents in a particular group regarding the assessment of the importance of the GBTs to achieve sustainable housing development. The results of these two tests indicated that the importance assessments from the panel of respondents could be aggregated for analyses.

Table 5.1 shows the mean ranks of the GBTs to achieve sustainable housing development. For a research rigor, only GBTs with mean scores higher than 4.00 were considered to be important. This approach was adopted from Cheng and Li (2002) and does not only ensure that GBTs that are actually crucial to achieving sustainable housing development are identified in this study, but also helps to reduce the large number of GBTs to a reasonable number to allow reliable and effective pairwise comparisons during the AHP survey. In addition, yet, three GBTs with mean scores greater than 3.90 but less than 4.00 were deemed to be marginally important and were also included for further analysis. These three GBTs were HVAC control (CS1) (mean = 3.98), security control (CS2) (mean = 3.93), and occupancy/motion sensors (CS4) (mean = 3.91).

Table 5.1 Mean ranks of GBTs to achieve sustainable housing development.

GBT categories	Code	List of GBTs	Mean
Energy efficiency	EE13	Application of natural ventilation	4.53
	EE1	Application of energy-efficient lighting systems	4.53
	EE12	Optimizing building orientation and configuration	4.49
	EE3	Application of energy-efficient HVAC system	4.42
	EE4	Use of energy-efficient appliances (e.g., energy-efficient refrigerators)	4.35
	EE5	Application of solar technology to generate electricity	4.35
	EE7	Integrative use of natural lighting with electric lighting technology	4.28
	EE2	Application of energy-efficient windows	4.23
	EE9	Application of solar shading devices	4.09
	EE8	Application of solar water heating technology	3.81
	EE6	Application of rooftop wind turbines to generate electricity	3.72
	EE11	Use of wooden logs to provide structure and insulation	3.42
	EE10	Application of ground source heat pump technology	2.51
Water efficiency	WE1	Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	4.40
	WE2	Rainwater harvesting technology	4.28
	WE3	Grey water reclaiming and reuse technology	4.01
Indoor environmental quality enhancement	IQ3	Application of low emission (low-E) finishing materials	4.14
	IQ1	Ample ventilation for pollutant and thermal control	4.12
	IQ6	Use of efficient type of lighting (lighting output and color)	4.07
	IQ4	Optimizing building envelope thermal performance	3.88
	IQ2	Application of indoor CO_2 monitoring devices	3.56
	IQ5	Application of solar chimney for enhanced stack ventilation	3.51
Materials and resources efficiency	MR2	Use of environmentally friendly materials for HVAC systems	4.23
	MR1	Underground space development technology	3.67
Control systems	CS1	HVAC control	3.98
	CS2	Security control	3.93
	CS4	Occupancy/motion sensors	3.91
	CS3	Audio visual control	3.65

Note: Mean ranks in descending order; For a research rigor, only GBTs with mean scores greater than 4.00 were deemed important; HVAC control (CS1) (mean = 3.98), security control (CS2) (mean = 3.93), and occupancy/motion sensors (CS4) (mean = 3.91) were marginally important.

From Table 5.1, certain patterns were identified:

- Application of natural ventilation, application of energy-efficient lighting systems, optimizing building orientation and configuration, and application of energy-efficient HVAC system were the most important energy efficiency technologies. Installation of water-efficient appliances and fixtures (e.g., low-flow toilets), and rainwater harvesting technology were the most important water efficiency technologies. Application of low emission (low-E) finishing materials, and ample ventilation for pollutant and thermal control are the most important indoor environmental quality enhancement technologies. Use of environmentally friendly materials for HVAC systems was the most important materials and resources efficiency technology. And HVAC control and security control were the most important control systems.
- The mean ranks of the GBTs suggest that the GBTs had different degrees of influences on the process of achieving sustainable housing development; that is, some GBTs were more important than others. Ranking of the GBTs will also be done in the AHP survey.
- Expectedly, not only was “application of ground source heat pump technology” (EE10) (mean = 2.51) not important, but it also had the lowest level of importance amongst all the GBTs. The negation of the importance of ground source heat pump technology in sustainable housing development could be accredited to the hot and humid weather conditions of Ghana that do not make the heating of households an important issue. The finding is consistent with existing empirical research by Roufechaei et al. (2014), who found that application of ground source heat pump was one of the three least important GBTs to achieve sustainable housing development in Esfahan, Iran.

Overall, from Table 5.1, the top five GBTs (mean ≥ 4.40) that are of high importance to the achievement of sustainable housing development were "application of natural ventilation" "application of energy-efficient lighting systems", "optimizing building orientation and configuration", "application of energy-efficient HVAC system", and "installation of water-efficient appliances and fixtures (e.g., low-flow toilets)". These five GBTs are discussed below.

5.2.1 Application of Natural Ventilation

The GBT "application of natural ventilation" was ranked first (mean = 4.53). This suggests that the practitioners within the current housing industry of Accra, Ghana, attach great importance to the adoption of natural ventilation in housing development as an effective means to reap sustainability benefits. The importance of natural ventilation application was also demonstrated in Roufechaei et al.'s (2014) research in which one of the top five GBTs to achieve sustainable housing development was the application of natural ventilation. Zhang et al. (2011b) also found the application of natural ventilation as one of the most effective GBTs for sustainable housing development in China. First, as a passive design technology, natural ventilation is much more inexpensive to apply than active design technologies, such as ground source heat pumps (Zhang et al., 2011a). Hence, as cost remains a primary obstacle to taking up sustainable construction projects in developing countries such as Ghana (Djokoto et al., 2014), the importance of natural ventilation application for sustainable housing development is high. Moreover, because of the utilization of natural means, natural ventilation technologies have long been instrumental in increasing the sustainability of buildings. For example, the application of natural ventilation is a helpful method for reducing the energy consumption and cost associated with mechanical cooling and fan operation while also providing the expected level of building performance

(Axley, 2001). Thus, the application of natural ventilation is highly important for the industrial practitioners in developing housing projects in terms of sustainability during the design stage.

5.2.2 Application of Energy-Efficient Lighting Systems

"Application of energy-efficient lighting systems" received the second position (mean = 4.53). This confirms the finding of Roufechaei et al. (2014) that the application of lighting choices to save energy was the second most important or effective green technology to achieve sustainable housing development. As electricity consumption for lighting accounts for a substantial part of global energy consumption (Yang and Yu, 2015), the application of lighting systems that are more energy efficient to boost the efficiency of electricity consumption in lighting is highly important for sustainable housing development. Energy-efficient lighting systems have great potential for reducing the energy consumption for lighting and greenhouse gas emissions. For instance, fluorescent lamps are capable of reducing the amount of energy needed for attaining the same level of illumination compared to when traditional incandescent lamps are used. Also, solid-state lighting technology helps a building to consume only 10% of the energy consumed by incandescent lamps for reaching the same level of illumination and even lasts 10 times longer (Yang and Yu, 2015). These advantages may explain the reason why the application of energy-efficient lighting systems was deemed to be one of the most important GBTs to achieve sustainable housing development. As per the Energy Commission of Ghana (2009), lighting is responsible for the largest share of the total residential electricity load in Ghana, with the total lighting load estimated to be between 60 and 65%. A Ghanaian household survey of energy use by lighting types conducted by the Energy Foundation in 1999 discovered that incandescent light bulbs accounted for 79%, linear fluorescent light bulbs 20%, and compact fluorescent light bulbs (more energy-efficient) only 1% (Energy Commission of Ghana, 2009). This further supports why the application of energy-efficient lighting systems was ranked very high.

5.2.3 Optimizing Building Orientation and Configuration

"Optimizing building orientation and configuration" was ranked third (mean = 4.49), indicating that the importance of optimizing building orientation and configuration to achieve sustainable housing development was confirmed by most of the respondents in the survey. Optimizing the orientation and configuration of the building is another very vital and effective passive design technology to attain better sustainable housing development through increasing the building's energy saving potential. It is known that in the passive design of a building, the most important of the intervening parameters is orientation (Morrissey et al., 2011). The world over, there is a growing consensus that the southern orientation is the best and optimal option, with a general rule being: orient the longest wall sections toward the south (Littlefair, 2001; Mingfang, 2002). In line with this, the Passive Solar Handbook Volume 1 revealed that the building could obtain the greatest energy saving by optimizing its orientation through rotating the longest walls 30° to the south. Likewise, a research study substantiated that, especially in countries such as Ghana with hot and humid weather, if maximum energy saving is to be reached, then it is critical to orient the main glazing surface of the building to face south (Shaviv, 1981). Other specific benefits derived from optimizing building orientation and configuration, that make it highly important for sustainable housing development, include the following:

- it is not only applicable in the early stages of design, but it is also a comparatively low-cost technology;
- energy demand reduction;
- it prevents extensive application of sophisticated passive technologies;

- it improves the performance of other passive design approaches/technologies; and
- increment in the amount of daylight (Pacheco et al., 2012).

5.2.4 Application of Energy-Efficient HVAC System

"Application of energy-efficient HVAC system" was ranked fourth (mean = 4.42). This finding was also supported by the viewpoints of previous studies (Wong and Li, 2006; Guo and Zhou, 2009; Ahmad et al., 2016), where the importance of energy-efficient HVAC was also stressed. With the growth in the demand for thermal comfort, HVAC system has nowadays become the largest energy end use in the residential sector. Pérez-Lombard et al. (2008) pointed out that in residential buildings, HVAC system consumes around 50% of the total electricity energy consumption and plays a crucial role in fine controlling the indoor environment to fulfil occupants' comfort requirements. Hence, the application of energy-efficient HVAC system in sustainable housing development is very important to use less energy to arrive at a reasonable level of thermal comfort for occupants. In Ghana, HVAC system accounts for about 6.5% of the total energy use in households (Gyamfi et al., 2018). The finding of this study suggests that adopting more energy-efficient HVAC systems in housing development can be helpful for reducing this percentage.

5.2.5 Installation of Water-Efficient Appliances and Fixtures

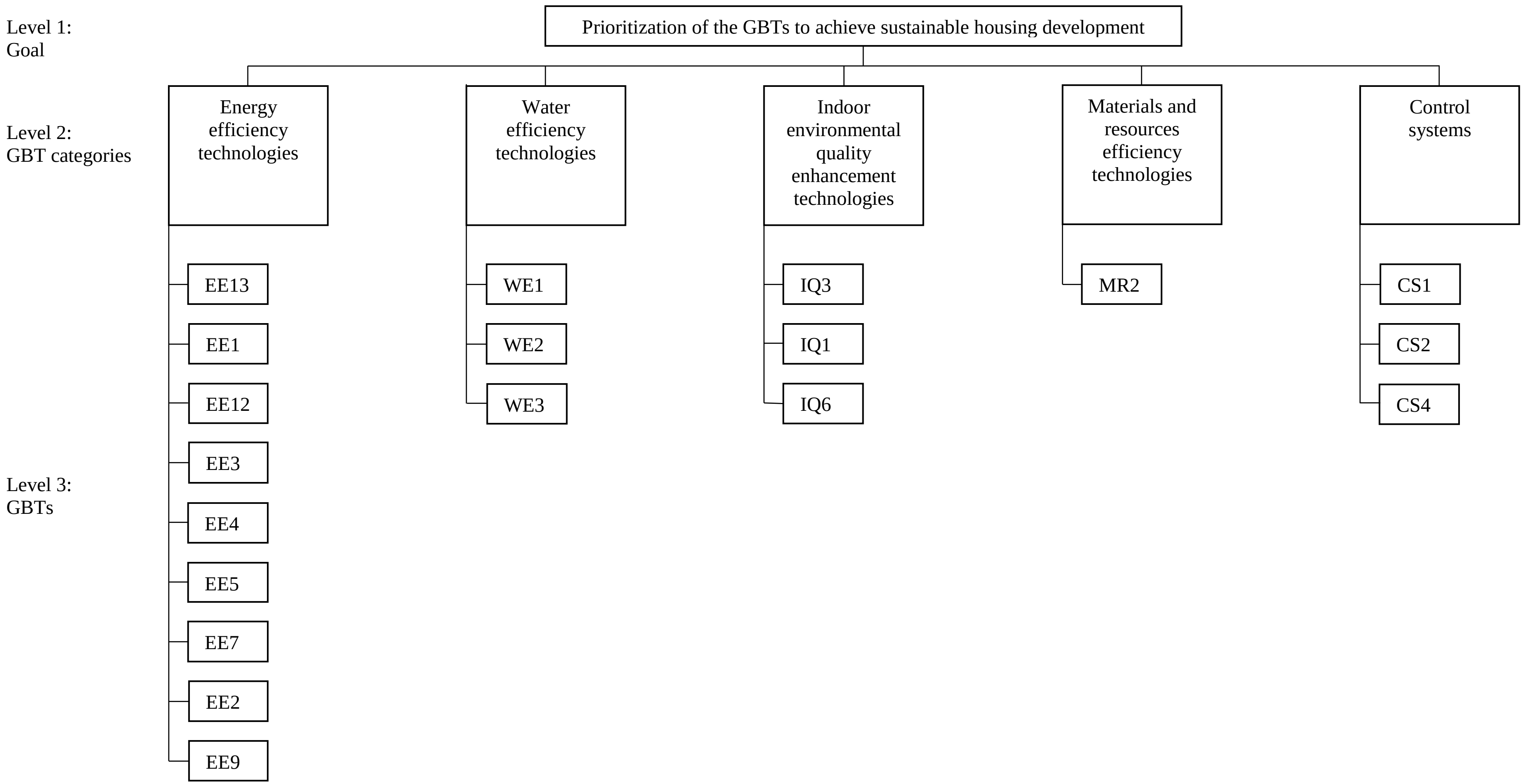
"Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)" was the fifth most important GBT (mean = 4.40). Water scarcity is a global environmental problem. Owing to the contamination of water by pollutants, even water-abundant countries, such as Norway and Canada, face challenges in providing potable water. In a water-scarce country like Ghana, the installation of water-efficient appliances and fixtures, such as dual flush or low-flow toilets, water-efficient washing machines, and low-flow shower heads or water flow restrictor taps, has been considered an important GBT to develop housing projects that are sustainable in terms of water use. The installation of water-efficient appliances and fixtures is an important green technology for sustainable housing development for two main reasons (Millock and Nauges, 2010). First, a significant proportion of daily water use in households is accounted for by water consumed by outdoor as well as indoor appliances. Second, presently, there has been a growing recognition of the reduction potential of water-efficient appliances and fixtures. As examples, a water-efficient washing machine can use only one-third of the water used by a traditional model; while a traditional single-flush toilet can use up to 12l of water per flush, a dual flush toilet can use just a quarter of this; and whereas a traditional shower head could use up to 25l of water per minute, a water-efficient shower head may use as little as 7l per minute (Millock and Nauges, 2010).

In the light of the above discussion, it can be summarized from the overall perception of various practitioners that the most important GBTs to achieve sustainable housing development mostly belong to energy efficiency category. However, all the GBTs identified to be important demonstrate that the housing industry could achieve sustainable development through adopting these GBTs. Policy makers should take the initiative to design and implement good policies to promote the widespread adoption of these GBTs in the housing industry. If one computes the average of the mean scores of the GBTs to obtain a mean score for each GBT category, then it could be stated that water efficiency technologies (mean, 4.23) and energy efficiency technologies (4.06) are the most important GBT categories for achieving sustainable housing development, which are followed by materials and resources efficiency technologies (3.95), indoor environmental quality enhancement technologies (3.88), and control systems (3.81).

The fact that water efficiency and energy efficiency are the most significant criteria for assessing sustainable building performance around the world (Shad et al., 2017; Illankoon et al., 2017) might explain this finding. The energy crises that make energy saving a high priority in Ghana might also support why energy efficiency technologies were considered as amongst the most important GBTs in sustainable housing development.

5.3 TESTING COMPARABILITY OF GBTs IN INDIVIDUAL GBT CATEGORIES

This study has practical implications for the development of sustainable housing projects. Thus, based upon the results in Table 5.1, a three-level hierarchical conceptual model for identifying GBTs to achieve sustainable housing development is proposed and illustrated in Fig. 5.1. This proposed model comprises only the GBTs that were found to be important in this study (Table 5.1), ensuring that the model can indeed assist sustainable housing development in the industry, as the importance of those 19 GBTs were confirmed and agreed on by the industry practitioners. The top level of the model is occupied by the prioritization goal. The second level is occupied by five main GBT categories. The third level comprises the GBTs expanding from the GBT categories. In this level, the various GBTs in each GBT category are given in descending order of importance, according to the results in Table 5.1. Confronted with the problem of identifying and selecting the most apt combination of GBTs to achieve sustainable housing development, decision makers may focus and act on the GBTs with higher importance within individual GBT categories. Based upon the AHP results, this proposed initial conceptual model is modified to develop the final model of the GBTs to achieve sustainable housing development in this study.



Note: The codes at the Level 3 correspond to the codes in Table 5.1.

Fig. 5.1 Initial conceptual model of GBTs to achieve sustainable housing development (see Darko et al., 2018a).

In order to assess the comparability of the GBTs, the mean weights of the GBTs were computed by means of AHP, which was helpful for prioritizing or ranking the GBTs and differentiating in general the more important GBTs from the less important ones (Cheng and Li, 2002). In this respect, the GBTs in Fig. 5.1 formed various matrixes that were rated by the respondents using the AHP rating scale (Table 2.3). For example, the nine GBTs in the energy efficiency category formed a 9-by-9 matrix. It should be noted that the GBT category of 'materials and resources efficiency technologies' was excluded from the AHP analysis since it contained only one GBT that was identified to be important in this study (Fig. 5.1). As explained earlier, the consistency test was carried out for measuring the consistency of the judgment matrixes. Saaty (1994) has laid out the acceptable consistency ratio (CR) values for various sizes of matrixes – the CR value for a 3-by-3 matrix is 0.05 or below; that for a 4-by-4 matrix is 0.08 or below; and that for larger matrixes is 0.1 or below. As mentioned hitherto, four responses having passed the consistency test were entered into the analysis. Vis-à-vis these four responses, one matrix had its CR value greater than the acceptable value (Table 5.2) and hence was excluded.

Table 5.2 CR values for the judgment matrixes.

Number	CR (matrix 1) 9-by-9	CR (matrix 2) 3-by-3	CR (matrix 3) 3-by-3	CR (matrix 4) 3-by-3
R1	0.056	0.016	0.000	0.006
R2	0.023	0.000	0.033	0.012
R3	0.009	0.000	**0.081**	0.000
R4	0.045	0.021	0.001	0.008

Note: The four respondents are represented with R1-R4. Acceptable CR values (Saaty, 1994): 0.05 or less for a 3-by-3 matrix; 0.08 or less for a 4-by-4 matrix; 0.1 or less for larger matrixes. Bolded when the CR value is above the acceptable value.

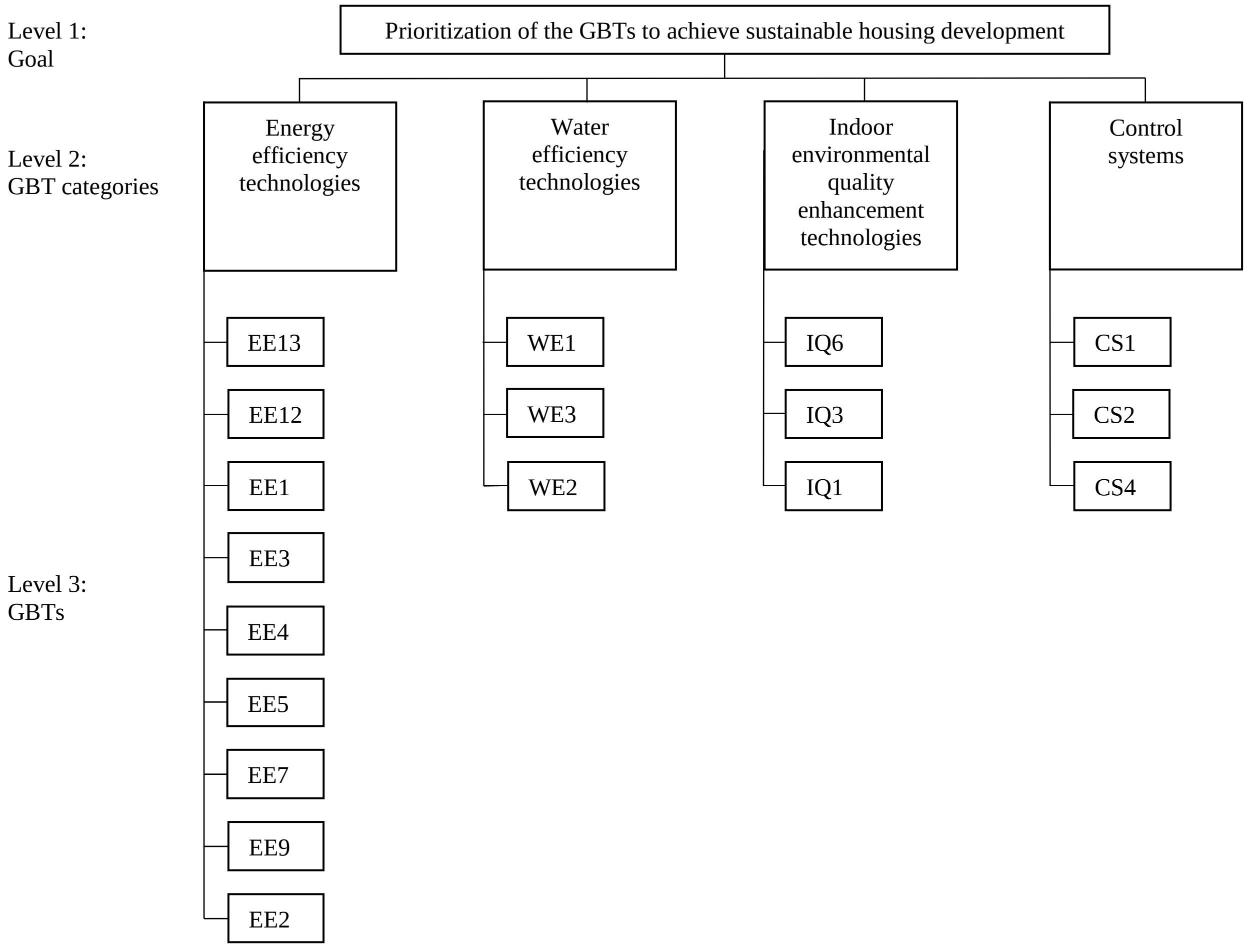
Table 5.3 indicates the mean weights (or relative priorities) of the GBTs to achieve sustainable housing development. The results reveal different GBTs having different priorities/rankings in accordance with the mean weights assigned by the respondents. In general, the mean weights ranged from 0.012 to 0.436, establishing priorities amongst the GBTs. In each GBT category, the GBTs are disparate in their relative priorities, and the AHP findings are slightly dissimilar from the findings of the general survey. For instance, while optimizing building orientation and configuration was prioritized second amongst the energy efficiency technologies according to the AHP findings, it was prioritized third in the general survey. Although there are only slight differences amongst the priorities of the GBTs established within the general and AHP surveys, statistical test of these differences might not be appropriate, because of the dissimilar sample sizes and GBTs used for the two surveys. On the basis of the AHP findings, Fig. 5.1 is modified to develop the final model depicting the hierarchy of the GBTs to achieve sustainable housing development (Fig. 5.2). This model has implications for sustainable housing development. The priorities established amongst the GBTs might help practitioners when developing sustainable housing projects with limited resources, and when it is not possible or necessary to implement all GBTs in a single project. In such situations, the priorities can be relied upon to identify and select the most appropriate combination of GBTs to eventually achieve the sustainable project. For example, using the model of GBTs in Fig. 5.2, practitioners seeking to implement a proper mixture of energy efficiency technologies, water efficiency technologies, indoor environmental quality enhancement technologies, and control systems in order to achieve sustainable housing development might first consider the following combination: application of natural ventilation (EE13), installation of water-efficient appliances and fixtures (e.g., low-flow toilets) (WE1), use of efficient type of lighting (lighting output and color) (IQ6), and HVAC control (CS1). Based on the model, many other combinations of GBTs can be made and implemented to help achieve sustainable housing development.

Table 5.3 Mean weights of GBTs to achieve sustainable housing development.

GBT categories	Code	List of GBTs	Mean weight
Energy efficiency	EE13	Application of natural ventilation	0.254
	EE12	Optimizing building orientation and configuration	0.238
	EE1	Application of energy-efficient lighting systems	0.207
	EE3	Application of energy-efficient HVAC system	0.108
	EE4	Use of energy-efficient appliances (e.g., energy-efficient refrigerators)	0.102
	EE5	Application of solar technology to generate electricity	0.031
	EE7	Integrative use of natural lighting with electric lighting technology	0.027
	EE9	Application of solar shading devices	0.021
	EE2	Application of energy-efficient windows	0.012
Water efficiency	WE1	Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	0.356
	WE3	Grey water reclaiming and reuse technology	0.348
	WE2	Rainwater harvesting technology	0.296

Indoor environmental quality enhancement	IQ6	Use of efficient type of lighting (lighting output and color)	0.399
	IQ3	Application of low emission (low-E) finishing materials	0.374
	IQ1	Ample ventilation for pollutant and thermal control	0.227
Control systems	CS1	HVAC control	0.436
	CS2	Security control	0.380
	CS4	Occupancy/motion sensors	0.184

Note: Mean weights in descending order.



Note: The codes at the Level 3 correspond to the codes in Table 5.3.

Fig. 5.2 Final model of GBTs to achieve sustainable housing development.

5.4 CHAPTER SUMMARY, CONTRIBUTIONS, AND LIMITATIONS

Sustainable housing development is attracting much attention from the industrial practitioners and academics, since it is a way of implementing sustainability in the construction industry and particularly in the housing industry. GBTs are increasingly important to achieving sustainable housing development. This chapter analyzed the GBTs that are important to achieve sustainable housing development in Accra of Ghana. It did so by adopting a combination of research methods including literature review and questionnaire surveys to collect professional views of the importance of GBTs. The data was first analyzed descriptively and the results showed that 19 out of the 28 GBTs examined were considered to be important GBTs to achieve sustainable housing development, with application of natural ventilation, application of energy-efficient lighting systems, optimizing building orientation and configuration, application of energy-efficient HVAC system, and installation of water-efficient appliances and fixtures (e.g., low-flow toilets) identified as the five most important GBTs. The results of the descriptive analysis were based on to create an initial conceptual model of the GBTs to achieve sustainable housing development, which was then modified based on AHP to develop the final model of the GBTs.

The contributions of this study are in at least two ways. First, the research findings help industry professionals who are responsible for decision-making in the design stage of housing projects hone their understanding of the important GBTs to achieve sustainable housing development, representing a good starting point to successfully implement sustainable housing development. Second, the model of GBTs resulting from this research can be used to guide the identification and selection of appropriate GBTs for sustainable housing development. Practitioners should use the priorities of the GBTs within each GBT category in their identification and selection of the right combination of GBTs for sustainable housing development. The implication of this study for policy makers is that, due to the potential sustainability benefits, they should establish and implement policies aimed at promoting the widespread adoption of the identified GBTs in the housing industry. This is also important as these GBTs have yet to see widespread adoption in Ghana. For example, incentives could be offered to practitioners who incorporate the GBTs in their housing projects. Similarly, the government of Ghana has launched a national housing policy that aims at creating an enabling environment for housing development (Government of Ghana, 2017). To ensure the sustainable housing development, it may be necessary to promote the adoption of the identified GBTs by incorporating them in this national housing policy, alongside incorporating them in other housing programs. Moreover, businesses might consider the GBTs in their strategic business plans and adopt them in their construction projects, as adopting GBTs can aid them to show their commitment to sustainable development and social responsibility.

Even though the objectives of this chapter were achieved, some limitations still exist. First, the respondents' experience and attitudes could influence the importance assessment made in this study as it was subjective. Aside from that, because the sample sizes for both the general survey and AHP survey were relatively small, one must be cautious when interpreting and generalizing the analysis results. Moreover, the implementation of AHP in this chapter has some limitations that need to be mentioned. AHP could be more rigorous and comprehensive when it involves a list of alternatives (e.g., the GBTs analyzed in this chapter) and criteria to evaluate them. This study analyzed a large number of 18 different GBTs using the AHP, hence it was difficult to establish a set of criteria that could be common to all the GBTs. Nevertheless, as the first study focusing on GBTs to achieve sustainable housing development in Ghana, the primary aim was to identify the important GBTs. Having identified these GBTs, future research could focus on a specific GBT, establish relevant criteria for the selection of that GBT, and apply the AHP to evaluate the GBT and the criteria to develop a decision support system to support the selection of that GBT in the industry. This could be done for any of the important GBTs identified in the present study. Thus, this study forms a solid foundation for advancing the knowledge about the GBTs to achieve sustainable housing development in both Ghana and other countries. Besides, this research focused on the GBTs to achieve sustainable housing development in Accra; future study can extend the investigation to other cities of Ghana. Lastly, future research could employ larger samples and compare between the GBTs to achieve sustainable housing development in Ghana and other countries.

CHAPTER 6 DATA ANALYSIS AND RESULTS – DRIVERS FOR GBTs ADOPTION IN THE CONSTRUCTION INDUSTRY: GHANAIAN PERSPECTIVE [10]

6.1 INTRODUCTION

The previous chapter analyzed the GBTs to achieve sustainable housing development in Ghana. The present chapter reports on the drivers for adopting GBTs in Ghana, with the objectives of identifying the major drivers and uncovering the underlying structure of the drivers. Thus, this chapter forms the base for modeling the influences of the drivers on the GBTs adoption activity and establishing the implementation strategy to promote the GBTs adoption (Chapter 9). To achieve the objectives of this chapter, 21 drivers, as indicated in Table 3.3, were identified from a comprehensive literature review. A questionnaire survey was then done with 43 professionals with green building experience. The profiles of the respondents are shown in Table 2.6. In the questionnaire, the 21 drivers were presented and the respondents were asked to rate their degree of agreement on each driver using a five-point rating scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). The data collected were subjected to various statistical analyses using the SPSS 20.0 statistical package. The analysis results are thoroughly discussed in this chapter, and a comparison of results between the developing country of Ghana and the developed country of the US is made. This results comparison is instructive, offering significant information for international policy makers, advocates, and industry practitioners interested in the GBTs adoption and promotion.

[10] This chapter has been fully published in Darko, A., Chan, A. P. C., Gyamfi, S., Olanipekun, A. O., He, B. J., and Yu, Y. (2017a). Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. *Building and Environment*, 125, 206-215.

Since this research study aimed to conduct empirical comparisons between the GBTs adoption drivers, barriers, and promotion strategies in Ghana and other (especially developed) countries, prior to the empirical questionnaire survey within Ghana, an international survey on the GBTs adoption drivers, barriers, and promotion strategies was carried out. This international survey involved 104 green building experts from 20 different countries around the globe; none of these experts was from Ghana. For more details about this international survey, one may refer to the publications made from it (Chan et al., 2016, concerning the barriers; Chan et al., 2017, on the promotion strategies; and Darko et al., 2017d, regarding the drivers). In addition, based on this international survey, Darko et al. (2017b) analyzed the GBTs adoption drivers, barriers, and promotion strategies in the US, the country where the majority of the responses were received. In essence, the comparisons of results between Ghana and other (developed) countries conducted in this Chapter 6, Chapter 7, and Chapter 8 are based upon publications from the international survey, and the Ghanaian results. The fact that the same questionnaire (with slight modifications to suit each context) was applied for both the international survey and Ghanaian survey made the results comparisons possible and appropriate (Chan et al., 2010). An example of the aforesaid modifications to the questionnaire is that a GBTs adoption barrier "insufficient green building rating systems and labeling programs" in the international context was modified to "lack of green building rating systems and labeling programs" within the Ghanaian context. This was reasonable and necessary as Ghana currently do not have its own green building rating systems. Additionally, the number of drivers, barriers, and promotion strategies used for both the international survey and Ghanaian survey remained the same, except that in the Ghanaian context, professionals suggested three additional strategies to promote the GBTs adoption, as indicated earlier in Chapter 2.

This chapter improves understanding of the major drivers for GBTs adoption and could assist policy makers, advocates, and practitioners in encouraging the widespread adoption of GBTs.

6.2 STATISTICAL ANALYSES

Before analyzing the data, the data reliability and normality were tested using Cronbach's alpha coefficient test and the Shapiro-Wilk test, respectively. The computed Cronbach's alpha value for the 21 GBTs adoption drivers was 0.909. This value is much greater than the threshold of 0.70, suggesting that the five-point scale measurement and hence the data collected are highly reliable for further analyses. The Shapiro-Wilk test results indicated that the data collected are not normally distributed because all of the *p*-values produced by the test were 0.000 (i.e., below 0.05). After finding the data reliable, various statistical analyses, including mean analysis, one sample *t*-test, mean difference analysis, Kruskal-Wallis H test, Kendall's *W*, and factor analysis were performed on the data. These methods are described in detail and justified in section 2.2.2. The mean analysis was employed to determine the relative ranking of the 21 drivers for GBTs adoption. As explained inside section 2.2.2.3, if two or more drivers happened to have the same mean score, the highest rank was given to the driver with the lowest SD. The one-sample *t*-test was then used to test the significance of the mean scores of the drivers against a test value of 3.50 (Darko et al., 2017d). Kendall's *W* was employed to test the agreement between different respondents' rankings of the drivers. The mean difference analysis was performed to ascertain the actual values of the differences in the mean scores of the drivers from the three respondent groups according to company types (see Table 2.6). The Kruskal-Wallis H test was carried out to check whether the differences in means from the three groups were statistically significant. Lastly, factor analysis was implemented to establish the underlying structure of the significant drivers for the GBTs adoption. The factor analysis outcome is used as the constructs (and their measurement items) for the GBTs adoption drivers for the PLS-SEM (Chapter 9).

6.3 ANALYSIS RESULTS AND DISCUSSION

The summary of the survey results on the drivers for GBTs adoption is shown in Table 6.1 (the driver codes conform to those in Table 3.3). The mean scores of the importance of the drivers range from 3.51 to 4.47. It is worthy to note that the mean scores of all of the 21 drivers were above the test value of 3.50. However, from the results of one-sample *t*-test, 16 drivers were considered statistically significant since the *p*-values of these drivers were less than 0.05. The result indicates that these drivers are significantly important in driving and shaping the GBTs adoption in Ghana. As for the drivers “high rental income” (DR16), “waste reduction” (DR11), “enhanced marketability” (DR15), “commitment to social responsibility” (DR10), and “attraction and retention of quality employees” (DR14), they were deemed insignificant. The reason why “high rental income” (DR16) and “enhanced marketability” (DR15) were not perceived to be significant drivers might 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 drivers behind the GBTs adoption (mean $\geq$ 4.21) were “setting a standard for future design and construction” (DR19), “greater energy efficiency” (DR01), “improved occupants’ health and well-being” (DR04), “non-renewable resources conservation” (DR06), and “reduced whole lifecycle costs” (DR02), all of which were statistically significant, implying that these drivers were perceived to be the most important drivers for the GBTs adoption. These five drivers are discussed below.

Table 6.1 Summary of the survey results on the drivers 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)	*p*-value
DR19	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	0.52[b]
DR01	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	0.61[b]
DR04	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	0.82[b]
DR06	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	0.49[b]
DR02	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	0.72[b]
DR07	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	0.52[b]
DR09	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	0.62[b]
DR08	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]
DR18	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	0.73[b]
DR21	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	0.61[b]
DR20	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	0.09[b]
DR17	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	0.89[b]
DR13	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	0.46[b]
DR05	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	0.53[b]
DR12	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	0.72[b]
DR03	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	0.48[b]
DR16	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	0.62[b]
DR11	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	0.91[b]
DR15	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	0.62[b]
DR10	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	0.73[b]
DR14	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*	0.52[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 Kruskal-Wallis H test result is insignificant at the 0.05 significance level (p-value > 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 drivers was 0.056 with a significance level of 0.000. All the p-values produced by the Shapiro-Wilk test were 0.000, suggesting that the data collected are not normally distributed.

6.3.1 Setting a Standard for Future Design and Construction

Unexpectedly, "setting a standard for future design and construction" (DR19) was ranked first with a very high mean score (mean = 4.47). The highest rank of this driver was unexpected because "setting a standard for future design and construction" was ranked low and considered an insignificant driver for GBTs adoption in previous studies done by Darko et al. (2017b, d). However, this result is in line with the viewpoint of Mondor et al. (2013) that "high performing projects can affect their industry standards by setting a standard for future design and construction". The study finding suggests that Ghanaian practitioners think that adopting GBTs today could 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 particular technology within the construction industry, the less risky it would be to implement it (Ozorhon and Karahan, 2016), and this could influence the interest the industrial practitioners have in the technology. Thus, when stakeholders have a vision for green building development, the desire to set the pace for other professionals to follow can greatly drive them to adopt GBTs. The stakeholders and policy makers in the present construction industry of Ghana are working with the vision to "transform the built environment in Ghana towards sustainability" (GHGBC, 2010), and this vision can be realized through the adoption and implementation of GBTs.

6.3.2 Greater Energy Efficiency

The driver "greater energy efficiency" (DR01) was ranked second (mean = 4.42). As a green building development practice, the GBTs adoption in Ghana has been overwhelmingly driven by greater energy efficiency, which is associated with a reduction in greenhouse gas emissions. This is an unsurprising finding because Ghana has over the last four decades (1984, 1994, 1998, 2007, and 2012) experienced major energy crises and thus the Ghanaian electricity sector has been burdened with difficulties about power quality and supply security from the beginning of 2013 till now (Gyamfi et al., 2018), as noted earlier. This creates an urgency for stakeholders to explore ways for improving the efficiency of energy use in Ghana. Therefore, the importance of greater energy efficiency as a driver behind the 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). As a result, 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 can 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). Besides, the employment of light emitting diode (LED) bulbs could 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), wherein energy conservation was found as a key driver for implementing sustainable construction practices. The result is also reinforced by Luo et al. (2017), who found that "green energy was the most preferred attribute of green buildings, exerting an even stronger overall effect on consumer choice than price".

6.3.3 Improved Occupants' Health and Well-being

The driver "improved occupants' health and well-being" (DR04) obtained the third rank (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 application of natural lighting and ventilation and technologies for enhancing air quality, green buildings typically contribute toward improving and protecting the health and comfort of occupants. Poor health conditions inside a building can pose serious problems, such as frequent sick leave and absenteeism, increased risk of illness, and decreased job satisfaction, for occupants. This is because people spend up to 90% of their time indoors, and the levels of pollutants indoors are usually higher than those outdoor (USEPA, 2017). Accordingly, building technologies that can assist in improving 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 people (World Health Organization, 2015). This might explain why "improved occupants' health and well-being" was ranked as the third major driver for adopting GBTs.

6.3.4 Non-renewable Resources Conservation

The driver "non-renewable resources conservation" (DR06) occupied the fourth position (mean = 4.21). The conservation of non-renewable resources is increasingly vital 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 preserved. Manoliadis et al. (2006) also identified that resource conservation was amongst the top five drivers for adopting sustainable construction practices. It could be inferred from the research finding that GBTs adoption offers a promising way to ensure the sustainable use of natural and non-renewable resources, such as fossil fuels, natural gas, minerals, and land. For example, 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 yield large amounts of greenhouse gases and contribute to environmental pollution can be significantly minimized (Love et al., 2012). Zhang et al. (2011a) 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 as such the GBTs adoption has been deemed highly important for the country.

6.3.5 Reduced Whole Lifecycle Costs

The driver "reduced whole lifecycle costs" (DR02) received the fifth rank (mean = 4.21). The adoption of GBTs contributes toward lessening the lifetime costs of operating and maintaining a building facility. A similar situation was also found by Darko et al. (2017c), wherein reduced whole lifecycle costs was a major driver for pursuing GBTs and practices. The reduced whole lifecycle costs from GBTs adoption may be credited to the cost savings from lower utility bills resulting from the greater energy efficiency and the reduced healthcare costs resulting from the superior health and well-being of occupants. Kats (2003) claimed that "green buildings provide financial benefits that conventional buildings do not" and these financial benefits include lower operation and maintenance costs and reduced healthcare costs. She indicated that owing to the greater energy efficiency of green buildings, an amount of US$60,000 could be saved annually. This financial benefit can be well received by Ghanaian construction stakeholders and thus can significantly drive them to take relevant voluntary actions for the GBTs adoption.

In the light of the above discussion, it can be summarized from the overall perception of various practitioners that even though 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. They could apply the GBTs adoption promotion strategies identified in this study.

6.4 AGREEMENT AND MEAN DIFFERENCE ANALYSES RESULTS

In addition to the overall ranking of the drivers, this study also analyzed the agreement between the respondents and the differences in opinions among respondents from consultant, contractor, and developer companies (Table 6.1). As mentioned earlier, Kendall's *W* test was used for the agreement analysis. Section 2.2.2.5 describes the Kendall's *W* test. In this study, the value of Kendall's *W* for ranking the 21 drivers was 0.056, and the significance level of *W* was at 0.000, indicating that a significant degree of agreement exists among all of the respondents in a certain group regarding the ranking of drivers for GBTs adoption. From the results of mean difference, generally, the opinions of the importance of the drivers from the contractors and developers were higher than those from the consultants. This finding might imply that the identified drivers encouraged the contractors and developers more to adopt GBTs. Moreover, the consultants and contractors had the largest difference in the opinion of the importance of the driver "job creation opportunity" (DR20, Diff. (CS – CT) = 0.58). Again, the consultants and developers had the largest difference in the opinion of the importance of the same DR20 (Diff. (CS – DP) = 0.75). For all of these differences in opinions, the contractors and developers ranked the driver "job creation opportunity" (DR20) higher than the consultants: while the contractors and developers ranked it sixth and third, respectively, the consultants ranked it (seventeenth) lower. This can be because the contractor and developer companies are more responsible for the actual construction works and so 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 opinion of the importance of "attraction and retention of quality employees" (DR14, Diff. (CT – DP) = 0.49). But, this mean difference was not statistically large since it was not above 0.50. In addition, from the Kruskal-Wallis H test results, it could be inferred that all the differences in opinions were not statistically significant as the *p*-values of all the drivers were more than 0.05 (Table 6.1). 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 drivers for the GBTs adoption.

6.5 COMPARISON OF RESULTS WITH THE UNITED STATES

After discussing the results obtained by analyzing the top five drivers for GBTs adoption in the construction industry of Ghana, based upon the results from this research and those from Darko et al. (2017b), a comparison was made of the top five most important GBTs adoption drivers in Ghana (a developing country) and those in the US (a developed country), as shown in Table 6.2. Darko et al.'s (2017b) study is a study that analyzed a list of GBTs adoption drivers, similar to that analyzed in the present study, within the context of the US. Comparison of results among countries has gained scholarly attention in the construction management domain. For example, Chan et al., (2010) compared their results vis-à-vis the critical success factors for public-private partnership projects in China with those of a previous study in the UK; while Bagaya and Song (2016) compared their results concerning the causes of schedule delays in construction projects in Burkina Faso with those of past researches in other countries (e.g., Hong Kong). The present study however is one of the first to compare between the GBTs adoption drivers in a developing country (Ghana) and those in a developed country (the US). Future research could expand and improve this comparison through including many other countries. In addition, in future studies where cross-country empirical data on the GBTs adoption drivers would be collected and used, the Spearman rank correlation test can be used to measure the correlation between the ranks of the drivers among every two countries. As shown in Table 6.2, the drivers that appeared in the top five highest ranked GBTs adoption drivers in both Ghana and the US are marked with the symbol "√", and those that did not appear in the top five drivers in the US are marked with the symbol "–". In all cases, the respective ranks of a driver are indicated in bracket.

Table 6.2 Occurrence of Ghana's top five GBTs adoption drivers in the US.

Top five drivers for GBTs adoption in Ghana	Ghana[a] (this research)	US[b] (Darko et al., 2017b)
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 6.2 indicate that while setting a standard for future design and construction was the highest ranked driver for GBTs adoption within Ghana's construction industry, it did not appear in the top five highest ranked drivers in the US; it was ranked as low as sixteenth in the US. Based upon this finding, it could be stated that setting a standard for future design and construction is the most important driver for GBTs adoption in only the developing country of Ghana, not in the developed country of the US, wherein the green building industry is relatively better developed. This finding is reasonable as Ghana seeks ways and means to improve and transform its construction industry to match up with the level of green building development in developed countries like the US (GHGBC, 2010). As well, it could be noted that contrary to the Ghanaian situation, non-renewable resources conservation is not a highly important driver for adopting GBTs in the US. Additionally, it is worth noting that two drivers, "greater energy efficiency" and "improved occupants' health and well-being", appeared in the top five drivers 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 within Ghana and the US, respectively. For the driver "reduced whole lifecycle costs", albeit it did not appear in the top five drivers in the US, it can still be regarded as a highly important driver for the 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 drivers can be attributed to the different conditions and regulations in different countries. However, the results of this study suggest that these three drivers, "greater energy efficiency", "improved occupants' health and well-being", and "reduced whole lifecycle costs", could be highly important for driving all GBTs adoption activities regardless of geographical locations. It is therefore recommended 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 the GBTs adoption and promotion a high priority.

6.6 FACTOR ANALYSIS RESULTS

The previous empirical studies did not group the drivers for GBTs and practices adoption based on the study results. As a result, as a supplement to the analysis conducted in the present study to identify the significant drivers for GBTs adoption, because of the large number of significant drivers identified, this study also briefly applied EFA to explore the underlying dimensions of the significant drivers for future research endeavor and for the PLS-SEM in Chapter 9. Prior to applying the EFA, the appropriateness of the data was examined. The KMO value of 0.717 was higher than the acceptable threshold of 0.50 (Table 2.4), indicating that the sample is acceptable for factor analysis. The Bartlett's test of sphericity result of 313.036 with an associated level of significance of 0.000 suggested that the population correlation matrix is not an identity matrix (SPSS, 1997; Pallant, 2013). The results of these two tests indicate that factor analysis is applicable. Additionally, despite criticisms of factor analysis with small samples, Lingard and Rowlinson (2006) identified that the majority (70%) of the factor analysis-based studies in the construction management domain still used samples below 100, with some using samples ranging from 20 to 42 (Dainty et al., 2003; Ng, 2004; Ramírez et al., 2004). Accordingly, it is considered appropriate to use factor analysis to process the data collected from the sample of 43 respondents in the present study. Furthermore, because all factor loadings were higher than or equal to 0.50 (Table 6.3), each variable is regarded significant in contributing to interpreting its respective factor (Chan et al., 2010), hence all the variables were retained.

Table 6.3 Results of EFA on drivers for GBTs adoption (rotated component matrix).

		Driver groupings				
Code	Drivers for GBTs adoption	1	2	3	4	5
Grouping 1: Environment-related drivers						
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	–	–	–	–
Grouping 2: Company-related drivers						
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	–	–	–
Grouping 3: Economy and health-related drivers						
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	–	–
Grouping 4: Cost and energy-related drivers						
DF02	Reduced whole lifecycle costs	–	–	–	0.867	–
DF01	Greater energy efficiency	–	–	–	0.789	–
Grouping 5: Industry-related drivers						
DF21	Facilitating a culture of best practice sharing	–	–	–	–	0.826
DF19	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.

For factor extraction, principal component factor analysis method was implemented to identify underlying grouped drivers. The results of factor analysis after varimax rotation are displayed in Table 6.3. Five underlying grouped drivers with eigenvalues higher than 1 were extracted in this research. With these five underlying grouped drivers, 71.16% of the variance is explained by GBTs adoption drivers (Table 6.4). This variance explained is higher than the guideline of 60% (Malhotra, 2006; Zhao et al., 2013). As shown in Table 6.3, the 16 significant drivers are split into five meaningful groupings and considering the variables with high loadings within each grouping and their common features, these five groupings could be labelled as follows: environment-related drivers, company-related drivers, economy and health-related drivers, cost and energy-related drivers, and industry-related drivers. The primary purpose of performing factor analysis on the GBTs adoption drivers is not to identify and thoroughly discuss an unconfirmed factor structure, but to establish a factor structure to allow this research to conduct the PLS-SEM for investigating the influences of the different types of GBTs adoption drivers on GBTs adoption (Chapter 9). The established factor structure could also be useful for future research to expand the knowledge base.

Table 6.4 Total variance explained.

	Initial eigenvalues			Rotation sums of squared loadings		
Groupings	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

6.7 CHAPTER SUMMARY, CONTRIBUTIONS, AND LIMITATIONS

To promote the wider adoption of GBTs to ultimately achieve the sustainable development of buildings, this chapter aimed to identify the main drivers for GBTs adoption in the construction industry within the context of the developing country of Ghana. To this end, a comprehensive literature review was performed to identify 21 drivers. Through a questionnaire survey with 43 professionals with green building experience, the results first revealed 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 drivers that greatly drive the GBTs adoption. Moreover, the importance of 16 GBTs adoption drivers were statistically significant, and there were no statistically significant differences in the opinions of the importance of all the drivers. As well, a comparative analysis showed 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. However, it was found that these three drivers, "greater energy efficiency", "improved occupants' health and well-being", and "reduced whole lifecycle costs", could be highly pivotal for driving all GBTs adoption activities irrespective of geographical locations. Additionally, a factor analysis was done upon the data, and the results indicated that the 16 significant drivers could be grouped into five underlying drivers: environment-related drivers, company-related drivers, economy and health-related drivers, cost and energy-related drivers, and industry-related drivers. These are used in examining and modeling the influences of the drivers on the GBTs adoption (Chapter 9).

Given the few empirical studies investigating the key drivers for GBTs adoption in developing countries (Darko et al., 2017c), the findings of this research make a significant contribution to the green building body of knowledge. Moreover, having an in-depth understanding of the key 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 research 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 drivers. In this respect, the policy makers and advocates are advised to offer special attention to the formulation and implementation of good strategies to educate and increase the knowledge and awareness of the general public about these drivers, for the reason that they are benefits that can naturally stimulate interest in the GBTs adoption.

Although the objectives of this chapter were achieved, certain limitations still exist. First, the respondents' experiences and attitudes could have an influence on the evaluation of the drivers made in this research since it was subjective. Aside from that, because the sample size was not very large, caution ought to be taken when interpreting and generalizing the research outcomes. Future study could increase the sample size by including policy makers or government agencies in the study, as the present study included only contractors, developers, and consultants.

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

The following chapter focuses on analyzing the barriers to GBTs adoption within Ghana.

CHAPTER 7 DATA ANALYSIS AND RESULTS – BARRIERS TO GBTs ADOPTION IN THE CONSTRUCTION INDUSTRY: GHANAIAN PERSPECTIVE [11]

7.1 INTRODUCTION

Chapter 6 analyzes the drivers for GBTs adoption in Ghana, while the present chapter analyzes the barriers inhibiting the GBTs adoption. Both chapters are based on the questionnaire survey conducted inside Ghana. As explained earlier, the questionnaire survey was conducted with 43 professionals with green building experience (Table 2.6). The objectives of this chapter are to investigate the critical barriers to GBTs adoption and to establish the underlying factor structure of the critical barriers. To this end, the 26 barriers that were identified from the comprehensive literature review (Table 4.1) were presented in the survey questionnaire and the respondents were requested to rate the criticalities of these in GBTs adoption using a five-point rating scale (1 = not critical, 2 = less critical, 3 = neutral, 4 = critical, and 5 = very critical).

Like the previous chapter, the data regarding the barriers were subjected to dissimilar statistical analyses using the SPSS 20.0. The Cronbach's alpha coefficient value of 0.867 indicated that the data collected are reliable for further statistical analyses. The results of the Shapiro-Wilk test indicated that the data are not normally distributed since all the *p*-values were lower than 0.05. The mean score ranking method and SD were applied to rank the GBTs adoption barriers, followed by normalization for identifying the critical barriers among the 26 barriers. Kendall's *W* test was conducted to measure the agreement among the respondents regarding the rankings of the barriers. The Kruskal-Wallis H test was applied to check whether the differences in mean

[11] This chapter has been fully published in Chan, A. P. C., Darko, A., Olanipekun, A. O., and Ameyaw, E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production*, 172, 1067-1079.

scores from three respondent groups according to company types (Table 2.6) were statistically significant. The findings of the ranking analysis, from Ghana, are compared with findings from developed countries, US, Canada, and Australia. This comparison of findings offers invaluable insights for the global audience, i.e., those from developed and developing countries, interested in promoting the GBTs adoption and development.

Factor analysis was conducted to identify the underlying grouped barriers for the critical GBTs adoption barriers. The outcome is used for the PLS-SEM, Chapter 9, to investigate and model the influences of the barriers on GBTs adoption, and the PLS-SEM outcomes are fed into the development of the implementation strategy to promote the GBTs adoption. This chapter adds to the existing green building body of knowledge via analyzing GBTs adoption barriers in the context of a developing country. Practically, it helps policy makers, industry practitioners and stakeholders, and advocates take appropriate measures to address the barriers and consequently promote the GBTs adoption.

7.2 RANKING OF GBTs ADOPTION BARRIERS

The summary of the ranking analysis results on the barriers that hinder GBTs adoption is shown in Table 7.1 (the barrier codes conform to those in Table 4.1). The mean scores of the criticality of the barriers range from 2.93 to 4.51. Barriers with normalized values higher than or equal to 0.50 are considered critical barriers hindering the adoption of GBTs within Ghana.

Table 7.1 shows that 20 out of the initial 26 barriers had normalized values not less than 0.50, and hence are considered critical barriers. Expectedly, “higher costs of GBTs” was ranked first with the highest mean score (mean = 4.51). This outcome indicates that cost is the most critical barrier impeding GBTs adoption in the Ghanaian construction market. The finding agrees with the findings of previous studies carried out in the context of developing countries (Zhang et al., 2011a, b; Samari et al., 2013). The second, as the respondents ranked, was “lack of government incentives” (mean = 4.26), followed by “lack of financing schemes (e.g., bank loans)” as third (mean = 4.12), “unavailability of GBTs suppliers”, as fourth (mean = 4.07), and “lack of local institutes and facilities for GBTs R&D” (mean = 4.02) as the fifth most critical barrier.

The value of Kendall’s *W* for ranking the 26 barriers was 0.097, and the level of significance of Kendall’s *W* was at 0.000. This result indicates that there is a significant degree of agreement among all of the respondents in a certain group vis-à-vis the ranking of GBTs adoption barriers. From the Kruskal-Wallis H test results, the *p*-values of 25 barriers were greater than 0.05 (Table 7.1). The result indicates that there are no statistically significant differences in the opinions of the criticality of these barriers from consultants, contractors, and developers. As for the barrier “lack of GBTs promotion by government”, the results of the Kruskal-Wallis H test show that the differences in opinions are statistically significant. The opinion of the criticality of this barrier from the developers (mean = 4.46, rank 1) was higher than those from the consultants (mean = 3.81, rank 13) and contractors (mean = 3.57, rank 20). The result might imply that the lack of promotion by government impeded the developers’ adoption of GBTs more. In fact, the government’s role is known to be a factor that usually has a significant influence on developers’ green building adoption (Shen et al., 2017a).

Table 7.1 Ranking of GBTs adoption barriers.

	All respondents				Consultant			Contractor			Developer						
Code	Mean	SD	Rank	Normalization[a]	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Diff. (CS–CT)	Diff. (CS–DP)	Diff. (CT–DP)	*p*-value
B01	4.51	0.668	1	1.00[b]	4.56	0.629	1	4.57	0.514	1	4.38	0.870	2	–0.01	0.18	0.19	0.821[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	–0.37	–0.02	0.35	0.576[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	0.12	0.11	–0.01	0.843[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	0.25	0.33	0.08	0.723[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	0.20	–0.09	–0.29	0.881[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	0.56	–0.18	–0.74	0.110[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	–0.12	–0.50	–0.38	0.423[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	0.02	–0.43	–0.45	0.357[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	0.13	0.21	0.08	0.798[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	–0.13	0.17	0.30	0.721[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	–0.51	–0.45	0.06	0.395[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	0.24	–0.65	–0.89	0.032
B18	3.88	1.074	13	0.60[b]	4.00	0.966	9	3.79	1.051	13	3.85	1.281	17	0.21	0.15	–0.06	0.901[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	–0.51	–0.22	0.29	0.243[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	0.10	–0.19	–0.29	0.873[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	0.56	0.43	–0.13	0.332[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	0.23	0.17	–0.06	0.899[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	–0.32	0.21	0.53	0.612[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	–0.08	–0.52	–0.44	0.367[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	0.04	–0.02	–0.06	0.987[c]
B24	3.60	1.094	21	0.42	3.50	1.317	22	3.71	1.139	17	3.62	0.768	22	–0.21	–0.12	0.09	0.921[c]
B23	3.58	1.220	22	0.41	3.38	1.310	23	3.36	1.216	23	4.08	1.038	9	0.02	–0.70	–0.72	0.317[c]
B16	3.47	1.386	23	0.34	3.19	1.559	25	3.21	1.369	25	4.08	1.038	9	–0.02	–0.89	–0.87	0.213[c]
B11	3.42	1.096	24	0.31	3.50	1.265	21	3.29	1.139	24	3.46	0.877	24	0.21	0.04	–0.17	0.832[c]
B10	3.42	1.118	25	0.31	3.25	1.291	24	3.71	0.914	14	3.31	1.109	25	–0.46	–0.06	0.40	0.519[c]
B14	2.93	1.121	26	0.00	3.00	1.155	26	2.71	1.204	26	3.08	1.038	26	0.29	–0.08	–0.37	0.706[c]

Note: SD = Standard deviation; [a] Normalized value = (mean – minimum mean) / (maximum mean – minimum mean); [b] The normalized value shows that the barrier is a critical barrier (normalized value ≥ 0.50); [c] The Kruskal-Wallis H test result is insignificant at the 0.05 significance level (p-value > 0.05). The Kendall's W value for ranking the 26 barriers was 0.097 with a significance level of 0.000. All of the p-values produced by the Shapiro-Wilk test were lower than 0.05, representing that the data collected are not normally distributed.

7.2.1 Comparison of Results Between Ghana and Developed Countries

After identifying the top five barriers to GBTs adoption in Ghana's construction industry, based on the results from this study and those from Chan et al. (2016), the top five most critical GBTs adoption barriers within the developing country of Ghana and those in three selected developed countries, the US, Canada, and Australia, are compared in this study, as indicated in Table 7.2. Though other studies could have been selected for this results comparison, Chan et al.'s (2016) study was selected because it studied a set of GBTs adoption barriers similar to what has been studied in the present study. In Chan et al.'s (2016) study, 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 within developed and developing countries to promote GBTs adoption. Therefore, the present study compares the views among Ghana, the US, Canada, and Australia. As Table 7.2 shows, the barriers that appeared in the top five ranked GBTs adoption barriers within Ghana as well as in any of the three selected developed countries are marked with the symbol "√"; while those that did not appear in the top five ranked barriers in any of the three selected developed countries are marked with the symbol "–". In all cases, Table 7.2 also shows the respective rank (in bracket) of a certain barrier in a particular country.

Table 7.2 Occurrence of Ghana's top five GBTs adoption barriers in selected developed countries.

Top five GBTs adoption barriers 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 GBTs R&D	√ (rank 5)	– (rank 11)	– (rank 13)	– (rank 23)

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

It is interesting noting that “higher costs of GBTs” is the only barrier appearing in the top five GBTs adoption barriers within Ghana and in all the three selected developed countries, with its ranks across all the countries being very close (Table 7.2). This implies that the higher costs of GBTs represents a top barrier affecting GBTs adoption in not only the construction market of Ghana, but also the construction market of several developed countries (e.g., the US, Canada, and Australia). Nguyen et al. (2017) also noted that higher cost is the most cited barrier to green building adoption in both developed and developing countries. The finding of the present study suggests that developing cheaper yet efficient GBTs can help further the adoption of GBTs in the global construction market.

On the other hand, it is worthy to note that “lack of government incentives” appeared in the top five GBTs adoption barriers in only Ghana and the US and is rather close to becoming one of the top five barriers in Canada and Australia. Moreover, it can be noted that these three barriers, “lack of financing schemes (e.g., bank loans)”, “unavailability of GBTs suppliers”, and “lack of local institutes and facilities for GBTs R&D”, did not appear in the top five barriers within the US, Canada, and Australia, and their ranks within these countries seem to be very dissimilar from their ranks in Ghana. For instance, whereas ‘unavailability of GBTs suppliers’ was ranked fourth in Ghana, it was ranked fourteenth, twenty-fifth, and thirteenth within the US, Canada, and Australia, respectively. The results indicate that the most critical GBTs adoption barriers in the developing country of Ghana generally vary from those in the developed countries of the US, Canada, and Australia. The reason for the differences may be attributed to the maturity of the GBTs adoption activity within Ghana in comparison with that within developed countries; the Ghanaian GBTs adoption activity is less mature compared to the GBTs adoption activities in developed countries such as the US, Canada, and Australia (Darko et al., 2017a). This finding further explains why it is crucial to better understand the critical barriers facing GBTs adoption within specific countries so that proper measures could be formulated for promoting the GBTs adoption. To conclude, the above results comparison has indicated that though the most critical GBTs adoption barriers within the developing country of Ghana generally 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. So, removing this barrier would play a huge role in promoting GBTs adoption throughout the world.

7.3 FACTOR ANALYSIS OF GBTs ADOPTION BARRIERS

Since it is part of the objectives of this study to model the influences of GBTs adoption barriers on GBTs adoption, the underlying factor structure of the barriers needs to be firstly established. As mentioned before, factor analysis was conducted to achieve this. This section presents and thoroughly discusses the results of the factor analysis.

To better understand the GBTs adoption barriers in Ghana, the 20 critical barriers identified in section 7.2 (variables) were subjected to factor analysis. The KMO value was 0.562, which is acceptable as it satisfies the threshold of 0.50 (Table 2.4). Even though the KMO value of 0.562 is nevertheless relatively small, it is values below 0.50 that should lead the researcher "to either collect more data or rethink which variables to include" (Field, 2013). The KMO value might easily be increased through excluding some of the variables for the factor analysis, based upon certain exclusion criteria. However, several factors, e.g., the contribution of the variable to the interpretation of the factor group, must be taken into account in making any decision to exclude a variable. It is suggested that variables having factor loadings higher than or close to 0.50 must be retained because they are significant in contributing to the interpretation of the factor group (Akintoye, 2000; Matsunaga, 2010). Table 7.3 shows that all factor loadings were higher than or close to 0.50, with 18 (90%) of them higher than 0.50; hence, all the variables were included in the factor analysis. The chi-square value in the Bartlett's sphericity test statistics (383.730) was large and the associated significance level (0.000) was small. This result suggests that the population correlation matrix is not an identity matrix. Thus, it is appropriate to conduct factor analysis on the GBTs adoption barriers data.

Table 7.3 Results of EFA on GBTs adoption barriers (rotated component matrix).

		Barrier groupings				
Code	GBTs adoption barriers	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 policies 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 GBTs R&D	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

Principal component analysis technique was employed to identify underlying grouped barriers. Table 7.3 shows the results of factor analysis after varimax rotation. Five underlying groupings with eigenvalues greater than 1 were extracted. These explained 62.82% of the variance, and the remaining 15 groupings altogether explained only 37.18% of the total variance, suggesting that a model with the five extracted underlying groupings could adequately be used to represent the data (Li et al., 2011; Chan et al., 2016). As indicated in Table 7.3, the 20 variables are split into five meaningful groupings, with seven variables loaded onto grouping 1, five variables loaded onto grouping 2, three variables each loaded onto groupings 3 and 4, and two variables loaded onto grouping 5. To facilitate further discussion, based on the analysis results, the five extracted groupings need to be renamed (Chan et al., 2004). 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.

7.3.1 Grouping 1: Government-Related Barriers

This underlying group highlights the government's role in the promotion of GBTs adoption in Ghana, and is represented by seven critical barriers: (1) lack of green building rating systems and labeling programs, (2) lack of green building policies 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 GBTs R&D, and (7) lack of government incentives. The seven critical barriers in this group cover issues that fall within the purview of government. This group is the most dominant amongst all the five groups and explains the greatest variance (27.03%), from a statistical viewpoint (Table 7.3).

Although lack of government incentives had the least factor loading in this group, it is the most critical barrier in this group, as per the results of this study (Table 7.1). At the current stage of the GBTs adoption and development within Ghana, lack of government incentives represents a major barrier to the GBTs adoption. Ozdemir (2000) defined an incentive as "something that influences people to act in certain ways". In essence, in the context of green building, incentives influence people to adopt GBTs in their building projects. Hence, without incentives from the government, industry practitioners and stakeholders might not adopt GBTs. As stated earlier, because the GBTs adoption in Ghana is still in its infancy, currently, there exist no government incentives to stimulate the GBTs adoption in the country. This situation may explain why lack of government incentives is considered a critical barrier hindering the GBTs adoption in Ghana. The research finding infers that to promote the GBTs adoption, the government has to establish effective incentive schemes. For example, the government may offer financial incentives (e.g., tax credits) and nonfinancial incentives (e.g., expedited permitting) to GBTs adopters. Similar to the finding of this research, Shen et al. (2017b) identified that lack of government incentives was a significant barrier inhibiting the green procurement adoption within China.

Another critical barrier is the lack of local institutes and facilities for GBTs R&D. Prior studies highly emphasize the importance of R&D in driving the GBTs and practices adoption (Hwang and Tan, 2012; Zhang, 2015). However, a huge gap exists between funding for building related R&D and that for R&D in other industries. As the USGBC (2003) argued, by any conventional yardstick, public and private sectors typically make minimal R&D or innovation investment in the construction industry. Compared to developed countries, developing countries have much smaller portion of government's R&D budget allocated to the construction industry. In China, for example, only 0.4-0.6% of the government's R&D budget was allocated to the construction industry (Shen, 2008). This lagged behind the 0.6-1% allocated by developed countries like the UK (Shen, 2008). The study finding suggests that there is an absence of accredited institutions that conduct credible scientific research regarding GBTs and their benefits in Ghana, resulting in poor market demand for GBTs. It would, hence, be useful if the Ghanaian government could provide necessary funding for establishing and operating green technology research institutes and centers.

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

Lack of green building policies and regulations hampers the adoption and implementation of GBTs. Government policies and regulations are vitally important to promoting GBTs adoption. Government should be aware that in the initial stages of the GBTs adoption and development, its guidance and support are crucial for the successful and widespread adoption. That is to say, the promotion of GBTs adoption in the construction industry is to a large extent dependent on government policies and regulations (DuBose et al., 2007; Gou et al., 2013; Mulligan et al., 2014; Zhang, 2015). If expectations from the GBTs adoption are clearly defined in the form of regulatory requirements, then stakeholders might comply. In developing countries where the GBTs adoption is relatively new to the construction industry, without relevant regulations in place, organizations and individuals may dither to take relevant actions for the GBTs adoption. Thus, a lack of green building policies and regulations impedes GBTs adoption in Ghana at the moment. This result agrees with findings of studies done in Malaysia (Samari et al., 2013) and India (Luthra et al., 2015), and it implies that the Ghanaian government should assume a more active role in the pursuit of implementing sustainability in the construction industry by creating policies and regulations to promote the GBTs adoption. This can even be a more efficient and preferred way to promote the 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 (Nguyen et al., 2017).

Training staff is highly essential for the success of implementing new technology and software (Succar et al., 2013). The green building projects implementation varies from the traditional building projects implementation not only in terms of the processes, design, and materials, but also the technologies used. Whereas the use of GBTs is a key component of the implementation of green building projects, implementing traditional building projects does not require the use of GBTs. Consequently, 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 may significantly assist in facilitating the use of GBTs in the construction industry (Hwang et al., 2017b).

Government's endorsement and promotion of a GBT could accelerate its adoption in a country because it can validate the effectiveness of the technology to the public (Potbhare et al., 2009). As such, a lack of GBTs promotion by government could 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 GBTs adoption within Ghana. Djokoto et al. (2014) also identified that lack of strategy to promote was a major barrier to sustainable construction in Ghana. It is therefore considered that the formulation of promotion strategies and promotion teams that can influence the public would be an effective way for the Ghanaian government to promote GBTs adoption.

Lack of green building rating systems and labeling programs is another critical barrier within this group. Internationally recognized green building rating systems, such as the LEED, could be useful for simulating the GBTs adoption at both the international and national levels. But, localized green building rating systems would be more effective at the local level because they may be developed with much more attention given to local sustainability priorities. At present, Ghana does not have its own green building rating systems, and this situation has been found to be a critical barrier to the GBTs adoption in the country. This finding indicates that localized green building rating systems are needed to encourage and incentivize the industry practitioners to push the boundaries on sustainability. Though the GHGBC holds the most important role in this respect, the government and other nongovernmental organizations should be supportive.

7.3.2 Grouping 2: Human-related Barriers

This underlying group accounts for 11.56% of the total variance and comprises five critical barriers, namely (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 people’s attitudes and behaviors.

Lack of financing schemes (e.g., bank loans) ranks among the top five barriers. This finding is in line with previous studies carried out in developing countries (Samari et al., 2013; Luthra et al., 2015; Nguyen et al., 2017) and clearly shows that financial/economic issues are crucial for the GBTs adoption and development in Ghana. The lack of financing schemes, as a barrier to the 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 practitioners might 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 address the lack of financing schemes barrier, banks and other financial institutions should offer financial support in the form of, e.g., soft loans and grants, for GBTs adoption. Learning from the experiences of developed countries may be a very helpful method to promote GBTs adoption in developing countries. In Hong Kong, for example, it is "not difficult to obtain financing from banks for green projects" (Gou et al., 2013) and this helps the green building development in the country. Applying the public-private partnership financing schemes (Osei-Kyei and Chan, 2015) in the green building domain can also afford an opportunity to deal with the lack of financing schemes barrier.

Suppliers play an important 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 about the GBTs. Hence, the unavailability of GBTs suppliers is deemed a critical barrier to the GBTs adoption in the Ghanaian construction market. In order to enhance sustainability performance within an industry, experiences from various industries show that it is necessary to incorporate suppliers into sustainability management initiatives (Zhu et al., 2007; Shen et al., 2017a). This barrier is closely related to the barrier unavailability of GBTs in the local market because if the suppliers of the GBTs are unavailable, then the GBTs themselves may also be unavailable. The research finding of unavailability of GBTs suppliers concurs with studies in Hong Kong (Lam et al., 2009; Gou et al., 2013) and China (Shi 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 the GBTs adoption because if top management do not perceive GBTs as a priority, it is difficult for firms to introduce them on their projects. The GBTs adoption needs top management's involvement and support. Without the top management's commitment or approval, it is virtually impossible to adopt especially new GBTs. Given that the GBTs adoption is a top-down approach wherein 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 a significant correlation between the degree of support from senior management on adoption and the willingness to adopt GBTs and practices. The commitment and support from senior management can foster a conducive environment for innovation. Within 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 the GBTs adoption may have to be driven by external forces such as regulatory requirements.

Another critical barrier to the 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 critical issue within the construction industry, construction stakeholders are naturally resistant to change. This barrier is also closely linked to 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. While the resistance to change has been identified as the most critical barrier to GBTs adoption in some previous studies (Du et al., 2014; Chan et al., 2016; Darko et al., 2017b), based on the results of this study, it can be stated that within the Ghanaian context, resistance to change is only a critical (not the most critical) barrier; cost and financial related barriers are much more critical in the GBTs adoption activity.

Unfamiliarity of construction professionals with GBTs inhibits the adoption of GBTs in Ghana. Arditi and Gunaydin (1997) stated that in order to ensure construction quality, the construction technologies used by the contractor should be familiar to the design professionals. Zhang et al. (2011a) also indicated that the unfamiliarity with GBTs and technical difficulties can lead to delays in the design and construction processes of green building projects. Due to these issues, unfamiliarity of construction professionals with GBTs could cause them to embrace only those traditional building projects that involve 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 the GBTs adoption.

7.3.3 Grouping 3: Knowledge and Information-related Barriers

This underlying group explains 10.42% of the total variance and contains 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 the GBTs adoption creates an increasing and urgent need for green skilled professionals and workers. To achieve high performance results within an organization, skilled workers are needed in every department (Ozorhon and Karahan, 2016). This is even more key in the GBTs adoption as the workers need to be skillful in order for them to be able to efficiently handle all aspects, including the managerial and technological aspects, of the adoption process. With the presence of skillful workers in an organization, the needs may easily be identified and successful adoption could be realized in a rapid manner (Ozorhon and Cinar, 2015). On the contrary, the absence of workers with the necessary skills, expertise, and knowledge may make it difficult for an organization to adopt GBTs. As a critical barrier affecting the GBTs adoption, the lack of knowledge and expertise has been found to be more critical than the lack of training for project staff; however, these two barriers are assumed to be knotted to each other.

Lack of GBTs databases and information cannot encourage the market to implement GBTs, as access to relevant information is of strategic importance to GBTs adoption. Darko et al. (2017b) indicated that availability of better information is highly essential for the GBTs adoption. The present study has identified that lack of GBTs databases and information hampers the adoption of GBTs in Ghana. This shows that it is arduous for practitioners within the current construction market of Ghana to find information and data relating to GBTs. This situation may be attributed to the lack of GBTs suppliers. This barrier should be removed in order to increase the pace of the GBTs adoption. Developing 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 GBTs-related information between construction firms and government departments (Shi et al., 2013).

Lack of awareness of GBTs and their benefits also critically impacts the GBTs adoption within Ghana. Since it is costly to adopt GBTs, the sustainability benefits of GBTs play a key role in driving the GBTs adoption (Chan et al., 2017), as noted earlier. The research finding suggests that a lack of awareness of the sustainability benefits of GBTs represents a critical barrier for Ghanaian practitioners and the public to adopt GBTs. This barrier is closely related to the lack of GBTs R&D. Kibert (2008) contended that it is because of insufficient research affirming the benefits of GBTs that awareness in the industry is lacking. Educating the industry practitioners and the public on the benefits of GBTs could help to promote the GBTs adoption. To educate the industry practitioners and the public, new research showing and quantifying the benefits of GBTs could be conducted and used, or existing research and fact sheets could be used.

7.3.4 Grouping 4: Market-related Barriers

Like group 3, this underlying group also comprises three critical barriers: (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. This group explains 7.33% of the total variance.

Lack of interest from clients and market demand is deemed a critical barrier to GBTs adoption in the Ghanaian construction market. This implies that construction practitioners in Ghana are in a market where the demand for GBTs is low. Djokoto et al. (2014) also identified that lack of demand was a primary barrier to sustainable construction within 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 the GBTs adoption. Because clients are key decision makers in the GBTs adoption (Hwang and Tan, 2012), a lack of interest from them can negatively affect the GBTs adoption. The lack of market demand for GBTs may be attributed to the lack of awareness on the part of the public and consumers (Mao et al., 2015). Thus, increasing public awareness of the benefits of GBTs could greatly help to 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 top barriers in Ghana because most GBTs are not manufactured and sold locally. Mao et al. (2015) argued that, to a certain extent, the GBTs adoption and implementation depends on the GBTs available in the local construction market. This makes the availability of GBTs in the local market crucial for the GBTs adoption. The research findings suggest that Ghanaian practitioners have a tough time trying to find GBTs suppliers within the local market. The GBTs often have to be imported from other countries, such as the US and China, wherein 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.

Another critical barrier to the GBTs adoption and development is limited experience with the use of nontraditional procurement methods. The procurement of GBTs 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. Thus, in order 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 can be difficult to adopt GBTs.

7.3.5 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 GBTs adoption in Ghana. The higher costs of GBTs, identified as the most critical barrier in this study (Table 7.1), is stressed by industry practitioners who show concern about cost when considering the GBTs adoption. As indicated in Table 7.2, higher cost is a key barrier to the GBTs adoption in not only Ghana, but also many developed countries. It is widely 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 could greatly hinder the 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, though it is expected that with more experience, practitioners would be able to address the cost barrier (Chan et al., 2016), incentives could offset the additional 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 within the Ghanaian market.

Risks and uncertainties involved in adopting new technologies is also deemed a critical barrier faced in the GBTs adoption in the Ghanaian construction market. According to Ozorhon and

Karahan (2016), "the more diffused a certain technology in the construction market, the less risky it will become to implement it", as noted earlier. Therefore, as GBTs adoption is relatively new to the Ghanaian construction market, it is hard 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 well 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.

7.4 CHAPTER SUMMARY, CONTRIBUTIONS, AND LIMITATIONS

As a way of implementing sustainability within the construction industry, GBTs adoption has received considerable attention from scholars and practitioners in recent times. However, GBTs adoption in the developing country of Ghana is still in its infancy and facing numerous barriers. These barriers should be addressed in order to facilitate the successful and widespread adoption of GBTs. To this end, this chapter aimed to investigate the critical barriers to the GBTs adoption in Ghana. To attain the aim, 26 barriers were identified from a comprehensive literature review. A questionnaire survey was conducted with 43 professionals in Ghana, and the analysis results first showed that 20 out of the 26 barriers were critical barriers to the 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 showed that while the most critical barriers to the GBTs adoption in the developing country of Ghana generally vary from those in the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all of the countries. Besides, factor analysis revealed that the underlying barrier groupings were government-related barriers, human-related barriers, knowledge and information-related barriers, market-related barriers; and cost and risk-related barriers. The results also showed that the most dominant of the five underlying groups was government-related barriers, representing that there is a need for the government to play a more active role in promoting the GBTs adoption in Ghana.

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

Albeit the objective was attained, this chapter still has some limitations that must be mentioned. These limitations not only warrant future research attention, but must also be considered when interpreting and generalizing the results. First, the criticalities assessment made in this research could be influenced by the respondents' attitudes and experiences, as it was subjective. Apart from that, while the sample size and the KMO value of this study were acceptable for 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 vary from those reported in this study. Moreover, future study could analyze the differences and similarities between the GBTs adoption barriers in Ghana and many more developed countries. Lastly, albeit the findings of this study may be of use to policy makers and practitioners in other developing countries around the world, data collected from a different country may produce different results. Therefore, using the proposed

GBTs adoption barriers, similar studies could be performed in different developing countries, in order to observe market-specific differences, which would help in coming up with market-specific solutions to remove the barriers.

The next chapter reports the empirical findings on the strategies to promote the GBTs adoption in Ghana.

CHAPTER 8 DATA ANALYSIS AND RESULTS – STRATEGIES TO PROMOTE GBTs ADOPTION IN THE CONSTRUCTION INDUSTRY: GHANAIAN PERSPECTIVE [12]

8.1 INTRODUCTION

Chapter 7 investigated the barriers inhibiting the GBTs adoption in Ghana. The present chapter analyzes the strategies to promote the GBTs adoption. Essentially, the strategies studied in this chapter can help to deal with most of the barriers identified in Chapter 7. The objectives of this chapter are to identify the important strategies to promote the GBTs adoption and to establish the underlying factor structure of the strategies. To realize the objectives, 15 potential strategies to promote the GBTs adoption were identified through a comprehensive literature review and interviews with industry professionals. The data collection and analysis methods applied in this chapter are similar to those used in Chapter 6, except that in addition to the descriptive analysis, a detail variable comparison, using Wilcoxon's signed rank test, as explained in section 2.2.2.6, was conducted to identify the most important strategies to promote the GBTs adoption. In the questionnaire survey, the respondents were asked to assess the degree to which each strategy is important to promote GBTs adoption using a five-point rating scale (1 = not important, 2 = less important, 3 = neutral, 4 = important, and 5 = very important). The Cronbach's alpha value was 0.813, which indicated that the data collected are reliable for the statistical analyses. The results of the Shapiro-Wilk test indicated that the data are not normally distributed since all the *p*-values were 0.000. The analysis results are discussed in this chapter and the established factor model of the GBTs adoption promotion strategies is used in the PLS-SEM (Chapter 9).

[12] This chapter has been fully published in Darko, A., and Chan, A. P. C. (2018). Strategies to promote green building technologies adoption in developing countries: The case of Ghana. *Building and Environment*, 130, 74-84.

The first contribution of this chapter is helping to address a gap within the green building body of knowledge, particularly for developing countries. Additionally, the findings of this chapter help in better understanding the key strategies to promote the GBTs adoption and as such could support policy makers, industry stakeholders, and advocates in formulating and implementing appropriate strategies for GBTs adoption promotion. Ultimately, this chapter would benefit the sustainable development of the construction industry in general.

8.2 ANALYSIS RESULTS AND DISCUSSION

Table 8.1 shows the results of the mean analysis as well as the results of other relevant statistical tests (the strategy codes conform to those in Table 4.2). The mean scores of the importance of the strategies range from 3.95 to 4.67. It is worth noting that the mean scores of all the strategies were much greater than 3.00, the middle value of the rating scale. The results imply that all the strategies had significant importance. This could be ascribed to the earlier mentioned vision of Ghanaian professionals and stakeholders to "transform the built environment in Ghana towards sustainability" (GHGBC, 2010). Due to this vision, strategies to promote GBTs adoption have become a necessity rather than an option for Ghana. Although all the strategies were important, ranking them would enable policy makers, stakeholders, and advocates to comprehend which strategies are worth more attention in the promotion of the GBTs adoption. From the results of the mean analysis, the top five strategies (mean ≥ 4.58) were "more publicity through media (e.g., print media, radio, television, and internet)" (ST07), "GBTs-related educational and training programs for developers, contractors, and policy makers" (ST08), "availability of institutional framework for effective GBTs implementation" (ST11), "a strengthened GBTs R&D" (ST12), and "financial and further market-based incentives for GBTs adoption" (ST01).

The results show that these strategies were considered the most important strategies to promote the GBTs adoption and therefore should draw the policy makers', stakeholders', and advocates' attention. These five strategies are discussed below, along with the strategy "mandatory green building policies and regulations" (ST02), as the relatively low rank of this strategy (rank 12) seems surprising.

Table 8.1 Strategies to promote 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)	*p*-value
ST07	4.67	0.522	1	0.000[a]	4.56	0.512	1	4.86	0.363	1	4.62	0.650	5	–0.30	–0.06	0.24	0.237
ST08	4.65	0.613	2	0.000[a]	4.56	0.512	1	4.79	0.579	4	4.62	0.768	8	–0.23	–0.06	0.17	0.311
ST11	4.60	0.541	3	0.000[a]	4.44	0.512	3	4.79	0.579	4	4.62	0.506	2	–0.35	–0.18	0.17	0.104
ST12	4.60	0.583	4	0.000[a]	4.44	0.727	4	4.79	0.426	3	4.62	0.506	2	–0.35	–0.18	0.17	0.351
ST01	4.58	0.663	5	0.000[a]	4.25	0.683	8	4.71	0.611	6	4.85	0.555	1	–0.46	–0.60	–0.14	0.010[b]
ST05	4.51	0.703	6	0.000[a]	4.13	0.806	12	4.86	0.363	1	4.62	0.650	5	*–0.73*	–0.49	0.24	0.008[b]
ST10	4.51	0.736	7	0.000[a]	4.25	0.931	10	4.71	0.611	6	4.62	0.506	2	–0.46	–0.37	0.09	0.242
ST09	4.47	0.702	8	0.000[a]	4.31	0.704	7	4.64	0.745	9	4.46	0.660	9	–0.33	–0.15	0.18	0.275
ST06	4.42	0.763	9	0.000[a]	4.19	0.655	11	4.71	0.611	6	4.38	0.961	13	–0.52	–0.19	0.33	0.066
ST14	4.42	0.763	10	0.000[a]	4.25	0.856	9	4.57	0.756	10	4.46	0.660	9	–0.32	–0.21	0.11	0.495
ST04	4.37	0.874	11	0.000[a]	4.13	1.204	13	4.43	0.514	11	4.62	0.650	5	–0.30	–0.49	–0.19	0.440
ST02	4.35	0.783	12	0.000[a]	4.44	0.814	5	4.21	0.893	12	4.38	0.650	11	0.23	0.06	–0.17	0.714
ST03	4.19	0.906	13	0.000[a]	4.44	0.892	6	4.00	1.038	14	4.08	0.760	15	0.44	0.36	–0.08	0.243
ST13	4.14	1.014	14	0.000[a]	4.06	1.063	14	4.14	0.770	13	4.23	1.235	14	–0.08	–0.17	–0.09	0.634
ST15	3.95	0.815	15	0.000[a]	3.69	0.873	15	3.86	0.770	15	4.38	0.650	11	–0.17	*–0.69*	*–0.52*	0.065

Note: SD = Standard deviation; [a] The Shapiro-Wilk test result is significant at the significance level of 0.05 (p-value < 0.05); [b] The Kruskal-Wallis H test result is significant at the significance level of 0.05 (p-value < 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 15 strategies was 0.089 with a significance level of 0.000.

Table 8.2 Mean ranks from the Kruskal-Wallis H test for the strategies with significant differences in the respondents' views.

Code	M(CS)	M(CT)	M(DP)
ST01	15.94	24.32	26.96
ST05	15.66	27.64	23.73

Note: M(CS) = Mean rank for consultant group; M(CT) = Mean rank for contractor group; M(DP) = Mean rank for developer group.

Table 8.3 *P*-values comparing the assessments for the strategies.

Code	ST07	ST08	ST11	ST12	ST01	ST05	ST10	ST09	ST06	ST14	ST04	ST02	ST03	ST13	ST15
ST07	–	0.822	0.405	0.439	0.415	0.216	0.176	0.039[a]	0.008[a]	0.016[a]	0.048[a]	0.029[a]	0.005[a]	0.003[a]	0.000[a]
ST08		–	0.527	0.674	0.557	0.268	0.268	0.092	0.079	0.087	0.135	0.040[a]	0.002[a]	0.007[a]	0.000[a]
ST11			–	1.000	0.817	0.415	0.317	0.109	0.127	0.114	0.317	0.049[a]	0.002[a]	0.012[a]	0.000[a]
ST12				–	0.819	0.346	0.439	0.134	0.175	0.148	0.135	0.075	0.012[a]	0.005[a]	0.000[a]
ST01					–	0.439	0.683	0.381	0.276	0.257	0.164	0.135	0.036[a]	0.007[a]	0.001[a]
ST05						–	0.890	0.678	0.441	0.451	0.496	0.301	0.073	0.035[a]	0.002[a]
ST10							–	0.507	0.519	0.423	0.425	0.197	0.013[a]	0.031[a]	0.002[a]
ST09								–	0.825	0.678	0.819	0.458	0.058	0.059	0.003[a]
ST06									–	0.980	0.845	0.644	0.128	0.135	0.006[a]
ST14										–	0.937	0.616	0.133	0.160	0.006[a]
ST04											–	0.698	0.151	0.129	0.031[a]
ST02												–	0.071	0.319	0.036[a]
ST03													–	0.950	0.207
ST13														–	0.125
ST15															–

Note: [a] Wilcoxon's signed rank test result is significant at the significance level of 0.05 (*p*-value < 0.05), suggesting that the two compared variables are statistically different.

8.2.1 More Publicity Through Media

"More publicity through media (e.g., print media, radio, television, and internet)" (ST07) was ranked first with the highest mean score (mean = 4.67). Moreover, the Wilcoxon's signed rank test results in Table 8.3 indicate that among the top five strategies, ST07 is the only strategy whose assessment was statistically higher than the assessments for as many as eight of the other strategies not ranked among the top five strategies, which are ST09, ST06, ST14, ST04, ST02, ST03, ST13, and ST15. For the other four strategies ranked among the top five strategies, their assessments were statistically higher than the assessments for only a few of the other strategies not ranked among the top five strategies. For example, the assessment for ST08 was statistically higher than those for only four of the other strategies, which are ST02, ST03, ST13, and ST15. These results represent that ST07 was considered the most important strategy. The importance of this strategy was also supported by Chan et al. (2017) and Potbhare et al. (2009), where more publicity through media was an important promotion strategy for the GBTs and green building guidelines adoptions. Publicity, also known as public relations, is a promotion strategy that can help create a positive image for a product, encourage people to engage in the use of the product, convey the benefits of the product, enhance awareness, and increase demand for the product (Belch and Belch, 2007). Accordingly, more publicity through media is of great importance to the promotion of the GBTs adoption. The research finding could essentially provide concrete evidence that advertising or marketing GBTs in the media – through various media channels: print (newspapers and magazines), radio, television, billboards, internet, etc. – can significantly help advance GBTs adoption in Ghana. Publicity through media could be an easy and effective method of promoting GBTs in the public domain. For instance, publicity through the electronic media of the internet and television takes advantage of innovative technologies to easily reach and communicate with the public (Thackeray et al., 2007) about GBTs. Such communication ought to introduce GBTs and educate the public about the GBTs benefits and the need to adopt GBTs. In addition, to promote GBTs adoption, the government could sponsor media campaigns that draw attention and exposure to GBTs.

8.2.2 GBTs-related Educational and Training Programs for Developers, Contractors, and Policy Makers

The strategy "GBTs-related educational and training programs for developers, contractors, and policy makers" (ST08) was ranked second (mean = 4.65). The role the provision of GBTs-related educational and training programs for developers, contractors, and policy makers plays in promoting GBTs adoption cannot be underrated. Potbhare et al. (2009) also identified that educational programs for developers, contractors, and policy makers was one of the top five most important strategies to catalyze the green building guidelines adoption in the developing country of India. Educating and training developers, contractors, and policy makers about GBTs is of high importance in shaping and driving the GBTs adoption in the industry because they are key stakeholders in the adoption and promotion processes. Developers, for example, have significant and decisive roles in GBTs and practices adoption. According to Mao et al. (2015), developers are not only the key decision makers in the adoption of GBTs, but their usage of GBTs also influence the R&D done by academics, contractors' construction approach, and the investments of manufacturers. Similarly, Hu et al. (2015) and Hu et al. (2017) agree that within the industry, developers are key decision makers in the adoption of green practices because they are the investors. In light of these reasons, developing and implementing effective GBTs-related education and training programs for increasing developers' knowledge and awareness of and expertise in GBTs would certainly have a substantial impact on promoting GBTs adoption. Likewise, as developers have a great capacity to influence firms and individual practitioners within the construction industry in a manner which fosters innovation (Blayse and Manley, 2004), providing them with GBTs-related education and training would not only help their own GBTs adoption, but it would also help them influence or guide other industry participants to accept and embrace GBTs. In that way, GBTs adoption would gradually become an industry-wide accepted practice. The Ghana Real Estate Developers Association (GREDA) is one of the largest and most active construction industry associations in Ghana that makes recommendations to the government about ways to promote real estate development (GREDA, 2014). It is also active in seeking solutions to the problems, including sustainability problems, in the Ghanaian property market (GREDA, 2014). These may possibly explain why "GBTs-related educational and training programs for developers, contractors, and policy makers" was ranked as the second important strategy to promote the GBTs adoption. Although the above discussion focuses more on developers for simplicity, the research result implies that to widely promote the use of GBTs, the GBTs education and training should go beyond only developers' education; it should include other relevant stakeholders, such as policy makers and contractors.

8.2.3 Availability of Institutional Framework for Effective GBTs Implementation

The strategy "availability of institutional framework for effective GBTs implementation" (ST11) occupied the third position (mean = 4.60). This result indicates that to promote the successful and effective implementation of GBTs, an institutional framework that explicitly outlines the roles and responsibilities of all stakeholders is needed, which is consistent with the findings of previous studies (Potbhare et al., 2009; Chan et al., 2017). According to the Global Water Partnership (2008), frameworks are a crucial prerequisite for implementing sustainable practices since they form the basis for successful implementation. Frameworks have two major components, namely legal framework and institutional framework. While the legal framework is determined by national, provincial, and local policies and regulations, which constitutes the "rules of the game", the institutional framework comprises the institutions and organizations with forums and mechanisms, data and capacity building, founded to establish the "rules of the game" and to facilitate stakeholder involvement (Global Water Partnership, 2008). Hence, an institutional framework can simply be defined as a set of formal organizational structures, rules, and informal norms for performing an activity (International Ecological Engineering Society, 2006). In GBTs adoption, an institutional framework can provide an enabling environment for adoption (Lloyd-Williams, 2012) via guiding the behavior of all stakeholders. Ghana needs to develop an efficient institutional framework in order to move forward with the implementation of GBTs. Such a framework must consist of different organizations that could actively promote GBTs adoption at various levels of society. Governmental and nongovernmental organizations, professional institutes, industry associations, community-based organizations, and civil society institutions provide examples of organizations that can be taken into account in developing the institutional framework for GBTs implementation. The framework must clearly outline the roles and responsibilities of each organization.

8.2.4 A Strengthened GBTs R&D

Akin to strategy ST11, the strategy "a strengthened GBTs R&D" (ST12) obtained a mean score of 4.60, however since its SD (0.583) was greater than the SD of strategy ST11 (0.541), it was ranked fourth. Having a strong R&D base in green technology is a required ingredient to foster the GBTs adoption. This finding concurs with Li et al. (2014), who stated that to promote green building adoption, it is essential to strengthen technology research and communication. In fact, as stated before, the approach to green building varies between countries and regions. Different countries and regions have a range of characteristics, such as unique traditions and cultures and individual climatic conditions, which shape their approach to green building (WorldGBC, 2017a). In line with this, the GBTs available within the local market also impact the approach to green building. For instance, the architects of the Ridge Hospital in Ghana, which is Africa's first LEED-certified green hospital, as indicated earlier, observed that most of the GBTs in the US and Canada, wherein LEED is most popular, do not exist in Ghana. But with an understanding of the GBTs available locally, they were able to efficiently complete this green project (Bubbs, 2017). In addition, they indicated that although they could have imported several "high-tech" solutions, such an action would be unwise in the long-run, as many local professionals may not be able to successfully operate or maintain them. These show that GBTs adoption depends on a better understanding of the GBTs that are available and could be applied locally. It has been identified that GBTs R&D is crucial to promote the GBTs adoption in Ghana. The R&D efforts may focus on studying the locally available GBTs, their application and applicability, and their performance. As well, the GBTs R&D should conduct proper analyses to highlight the lifecycle costs and environmental, economic, and social benefits of the GBTs. The study result suggests that in order to promote GBTs adoption, government supports for GBTs R&D are needed. As suggested before, the government can establish green technology research institutes and centers and/or support academic institutions, such as universities, to undertake GBTs R&D. Aside from the book and research allowance that the Ghanaian government presently offer to universities, the government has planned to establish a research fund to enable the universities to undertake "special research projects and innovation" (Daily Guide, 2017). It may be advantageous if the government and the universities regard GBTs R&D as a vital component of all of these research funding initiatives. Many developed countries have made good GBTs R&D progress (Berardi, 2013b; Li et al., 2014). Thus, in the process of attempting to strengthen the GBTs R&D, it may be useful for Ghana to communicate with developed countries and learn from their experiences. In the end, to stimulate interest and demand for the GBTs, all GBTs R&D outcomes should be communicated through means such as the media, seminars, development tours, academic and industrial publications, and workshops to educate the industrial practitioners and the public. It could be inferred from the above discussions that strategies ST07, ST08, and ST12 are closely connected. For instance, implementing strategy ST12 might provide valuable information and evidence for use in implementing strategies ST07 and ST08. This may further explain why all of these strategies were considered top strategies in this study.

8.2.5 Financial and Further Market-based Incentives for GBTs Adoption

The strategy "financial and further market-based incentives for GBTs adoption" (ST01) received the fifth position (mean = 4.58). Incentive schemes are a very vital strategy to promote the GBTs adoption. This finding is consistent with Qian et al. (2016), Olubunmi et al. (2016), and Shazmin et al. (2017), who showed that the practice of providing financial and nonfinancial incentives is central to promoting the GBTs and practices adoption in the construction industry. Financial incentives, for example, do not only improve construction stakeholders' motivation to adopt GBTs, but they also help build a solid financial foundation for adopting GBTs. In a way, incentive schemes compel people to adopt GBTs, as they are normally awarded only when certain green requirements have been fulfilled. Given their importance, incentive schemes have been adopted by many developed countries as a strategy for promoting the GBTs and practices adoption. For example, Singapore has launched numerous incentive and funding schemes, e.g., Grant for Energy Efficient Technologies, to accelerate energy-efficient technologies adoption (Green Future Solutions, 2015). The US has also introduced a number of incentive schemes for motivating GBTs adoption (Gou et al., 2013; Mulligan et al., 2014). The tax incentive scheme whereby stakeholders who implement GBTs are offered tax discounts or fully exempted from the payment of tax, is one of the most popular green building incentive schemes in the US (Gou et al., 2013). The gross floor area concession scheme has also been popular in Hong Kong and Singapore for encouraging GBTs adoption (Qian et al., 2016). This is a nonfinancial/regulatory incentive scheme whereby stakeholders who satisfy certain green requirements are granted an extra floor area by the government. The finding of this study infers that Ghanaian practitioners would like to see the government's intervention within the construction market in the form of incentive schemes to help them increase the GBTs adoption pace. In order to do this efficiently, the government might learn from the developed countries' experiences of implementing green building incentives.

8.2.6 Mandatory Green Building Policies and Regulations

Perhaps, the most surprising and interesting aspect of the results is the relatively low rank (rank 12) of the strategy "mandatory green building policies and regulations" (ST02). In fact, there is growing evidence supporting that mandatory government policies and regulations are of the utmost importance in promoting the GBTs and practices adoption (Chan et al., 2009a; Wong et al., 2016; Shen et al., 2017b). To a large extent, this has been because government policies and regulations create mandatory push for stakeholders to engage in the GBTs adoption (Chan et al., 2009a). As such, it is surprising that the Ghanaian professionals did not perceive this strategy as a highly important strategy to promote the GBTs adoption. It could be that the professionals were more optimistic about strategies that could help stakeholders adopt GBTs out of their own volition. Another possible reason could be because most government policies relating to the construction market in Ghana have been ineffective (Appiah, 2007). Despite the relatively low rank of this strategy, the study results, Table 8.1, still suggest that formulating effective policies and regulations aimed at mandating the adoption of GBTs in construction projects would have a positive influence on promoting GBTs adoption in Ghana.

For the reason that the GBTs adoption in Ghana is still in its early stage, government practically holds the most critical and leading role in promoting the GBTs adoption (Hwang et al., 2017a); to formulate and implement proper strategies to drive the industrial practitioners and the public to implement GBTs. This research presents the important strategies to promote GBTs adoption. Because these strategies have been identified from the perspective of experienced practitioners, who would themselves be affected by the strategies when applied, in the Ghanaian construction market, the strategies can serve as an effective checklist for the government, stakeholders, and advocates and when properly used, would surely contribute to the success of promoting GBTs adoption within Ghana. As could be found from the discussions above, the identified strategies are not only typical for Ghana, but have also been relevant for many developed countries, such as the US, Singapore, and Hong Kong. In the application of these strategies, it is very important to often monitor and evaluate their performance and influence on promoting the GBTs adoption in the industry. That would help in making necessary amendments to the strategies to optimize and maximize their effectiveness throughout the various stages of the development of the GBTs adoption. Thus, when the GBTs adoption becomes more mature, future studies would be useful for refining the results of the present research, which could help the government, stakeholders, and advocates revise their strategies accordingly, so as to ensure the continuous promotion of GBTs adoption.

8.3 AGREEMENT AND MEAN DIFFERENCE ANALYSES RESULTS

As indicated in Table 8.1, apart from the overall strategies ranking, this study also analyzed the respondents' agreement regarding the rankings, as well as the differences in views between the respondents from consultant, contractor, and developer companies. The value of Kendall's *W* generated by the test was 0.089, and the associated significance level was 0.000, implying that there exists a significant degree of agreement among the respondents in a particular group. As for the results of the mean difference analysis, it could be noted that generally, the contractors' and developers' views of the importance of the strategies were higher than the consultants' views. This may imply that the contractors and developers attached relatively more importance to the strategies. Moreover, the consultants and contractors showed the largest difference in the view of the importance of "low-cost loans and subsidies from government and financial institutions" (ST05, Diff. (CS–CT) = 0.73). The consultants and developers showed the largest difference in the view of the importance of "more GBTs adoption advocacy by the Ghana Environmental Protection Agency" (ST15, Diff. (CS–DP) = 0.69). Similarly, the contractors and developers showed the largest difference in the view of the importance of ST15 (Diff. (CT–DP) = 0.52). After investigating the differences in views through considering two groups at a time, Kruskal-Wallis H test was implemented to check which of the strategies would have their differences in views to be significant if all of the three groups are combined and compared. According to the Kruskal-Wallis H test results in Table 8.1, the *p*-values of all strategies, except "financial and further market-based incentives for GBTs adoption" (ST01, *p*-value = 0.010) and "low-cost loans and subsidies from government and financial institutions" (ST05, *p*-value = 0.008), were greater than 0.05. The results indicate that the differences in views of the importance of these strategies between the three groups of respondents are not statistically significant. For the strategies ST01 and ST05, the differences in views of their importance are statistically significant. It could be noted that these two strategies are more related to financial issues, and as financial issues remain sensitive issues within the GBTs adoption arena (Mao et al., 2015; Luthra et al., 2015), it is not a surprise that practitioners have different views on them. In Kruskal-Wallis H test application, when a significant difference is observed, the mean ranks for the respondent groups could be inspected to identify the group that is significantly different from the others (Pallant, 2013). In this regard, Table 8.2 indicates that the consultant group had the lowest overall rankings (ST01, mean rank = 15.94; and ST05, mean rank = 15.66) corresponding to the lowest scores on ST01 (mean = 4.25) and ST05 (mean = 4.13) (Table 8.1). These results suggest that the consultant group is the main contributor to the significant differences in the views of strategies ST01 and ST05, which could be attributed to the relatively low mean scores from the consultant group.

8.4 COMPARISON OF RESULTS WITH THE UNITED STATES

Similar to section 6.5, based on the results from this study and those from Darko et al. (2017b), this section compares the top five strategies to promote GBTs adoption between Ghana and the US. This comparison assists in understanding and highlighting the differences and similarities between the strategies for a developing country (Ghana) and those for a developed country (the US). Such an understanding might be of benefit for policy makers, stakeholders, and advocates worldwide. Table 8.4 summarizes the comparison between Ghana and the US. As shown in the table, strategies that were ranked amongst the top five strategies for both Ghana and the US are marked with the symbol "√", and those that were not ranked amongst the top five strategies for the US are marked with the symbol "–". Table 8.4 also shows the individual ranks (in bracket) of the strategies across the two countries. It is interesting to note that the top three strategies for Ghana, "more publicity through media (e.g., print media, radio, television, and internet)", "GBTs-related educational and training programs for developers, contractors, and policy makers", and "availability of institutional framework for effective GBTs implementation", did not appear in the top five strategies for the US; they were ranked ninth, sixth, and tenth within the US, respectively. Additionally, it is worth noting that "a strengthened GBTs R&D" and "financial and further market-based incentives for GBTs adoption" were the only two strategies that appeared in the top five strategies for both Ghana and the US. In this respect, it could be noted that whereas the rank of the strategy "a strengthened GBTs R&D" for Ghana (rank 4) is very close to the US rank (rank 5), the rank of the strategy "financial and further market-based incentives for GBTs adoption" for Ghana (rank 5) seems to be slightly dissimilar from the US rank (rank 1). This finding reveals that while the provision of relevant incentives is deemed the most important strategy to promote the GBTs adoption within the US, in the Ghanaian context, it is only deemed one of the most important strategies. This result may be because in the current economic conditions within developing countries, it is not very likely that governments would provide financial incentives for green building adoption (Nguyen et al., 2017).

Table 8.4 Occurrence of Ghana's top five GBTs adoption promotion strategies in the United States.

Top five strategies to promote the GBTs adoption in Ghana	Ghana[a] (this research)	US[b] (Darko et al., 2017b)
More publicity through media (e.g., print media, radio, television, and internet)	√ (rank 1)	– (rank 9)
GBTs-related educational and training programs for developers, contractors, and policy makers	√ (rank 2)	– (rank 6)
Availability of institutional framework for effective GBTs implementation	√ (rank 3)	– (rank 10)
A strengthened GBTs R&D	√ (rank 4)	√ (rank 5)
Financial and further market-based incentives for GBTs adoption	√ (rank 5)	√ (rank 1)

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

The results comparison amid Ghana and the US has revealed that among the top five strategies to promote GBTs adoption in Ghana, there are three strategies that do not appear in the top five strategies for the US. Based upon this finding, it can be stated that the most important strategies to promote the GBTs adoption in the developing country of Ghana generally differ from those within the developed country of the US. The different conditions and regulations, as well as the different maturity levels of the GBTs adoption activity, in different countries might explain the reason for the differences. However, the findings of this study suggest that irrespective of geographical locations, these two strategies, "a strengthened GBTs R&D" and "financial and further market-based incentives for GBTs adoption", could greatly help in the promotion of the GBTs adoption. It is therefore suggested that international policy makers and advocates should direct more attention toward these strategies in their efforts to promote the successful and wider adoption of GBTs.

8.5 FACTOR ANALYSIS RESULTS

After identifying the important strategies to promote GBTs adoption in Ghana, factor analysis was applied to uncover the underlying structure of the strategies, which is used in Chapter 9 to model the influences of the strategies on the GBTs adoption activity using PLS-SEM. Because all of the 15 strategies had significant importance (Table 8.1), none of them was excluded from the factor analysis. However, further analysis will determine whether some strategies ought to be excluded. The KMO value of 0.612 was above the acceptable threshold of 0.5 (Table 2.4), indicating that the sample is acceptable for factor analysis. The significance level of chi-square in Bartlett's sphericity test was 0.000, suggesting that the population correlation matrix is not an identity matrix (Pallant, 2013). The results of these two tests indicate that factor analysis is appropriate. To further confirm the appropriateness of using factor analysis, the communalities of the variables were examined. MacCallum et al. (1999) mentioned that sample size becomes increasingly important only when communalities are low. In line with this, Field (2013) argued that "with all communalities above 0.60, relatively small samples (less than 100) could be deemed perfectly adequate." Table 8.5 indicates that all communalities were above 0.60, suggesting that the sample is acceptable for factor analysis (Field, 2013). Moreover, because all factor loadings were higher than or equal to 0.50 (Table 8.6), each variable is regarded significant in contributing to interpreting its respective factor (Chan et al., 2010), hence all the variables were retained.

Table 8.5 Communalities.

Code	Initial	Extraction
ST01	1.000	0.716
ST02	1.000	0.762
ST03	1.000	0.895
ST04	1.000	0.719
ST05	1.000	0.661
ST06	1.000	0.776
ST14	1.000	0.664
ST07	1.000	0.790
ST08	1.000	0.656
ST09	1.000	0.691
ST10	1.000	0.647
ST11	1.000	0.778
ST12	1.000	0.662
ST13	1.000	0.691
ST15	1.000	0.787

Table 8.6 Results of EFA on strategies to promote GBTs adoption (rotated component matrix).

Code	Strategies to promote GBTs adoption	Strategy grouping 1	2	3	4	5
Grouping 1: Government regulations and standards						
ST03	Green rating and labeling programs	0.890	–	–	–	–
ST02	Mandatory green building policies and regulations	0.862	–	–	–	–
ST10	Availability of competent and proactive GBTs promotion teams and local authorities	0.543	–	–	–	–
ST04	Better enforcement of green building policies after they have been developed	0.500	–	–	–	–
Grouping 2: Incentives and R&D support						
ST01	Financial and further market-based incentives for GBTs adoption	–	0.832	–	–	–
ST05	Low-cost loans and subsidies from government and financial institutions	–	0.780	–	–	–
ST12	A strengthened GBTs R&D	–	0.712	–	–	–
Grouping 3: Awareness and publicity programs						
ST06	Public environmental awareness creation through workshops, seminars, and conferences	–	–	0.862	–	–
ST07	More publicity through media (e.g., print media, radio, television, and internet)	–	–	0.794	–	–
ST14	Support from executive management	–	–	0.699	–	–
Grouping 4: Education and information dissemination						
ST08	GBTs-related educational and training programs for developers, contractors, and policy makers	–	–	–	0.778	–
ST11	Availability of institutional framework for effective GBTs implementation	–	–	–	0.721	–
ST09	Availability of better information on cost and benefits of GBTs	–	–	–	0.606	–
Grouping 5: Awards and recognition						
ST15	More GBTs adoption advocacy by the Ghana Environmental Protection Agency	–	–	–	–	0.854
ST13	Acknowledging and rewarding GBTs adopters publicly	–	–	–	–	0.593

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

Table 8.7 Total variance explained.

Grouping	Initial eigenvalues Total	Percentage of variance	Cumulative percentage	Rotation sums of squared loadings Total	Percentage of variance	Cumulative percentage
1	4.807	32.048	32.048	2.546	16.970	16.970
2	1.869	12.462	44.510	2.451	16.342	33.312
3	1.620	10.799	55.309	2.387	15.912	49.224
4	1.523	10.153	65.462	2.276	15.172	64.396
5	1.075	7.170	72.631	1.235	8.235	72.631

The extraction method of principal component analysis, with varimax rotation, was used to identify underlying grouped strategies. Five underlying grouped strategies with eigenvalues greater than 1 were extracted (Table 8.6). Table 8.7 shows that these five underlying groupings explain 72.63% of the variance, which is satisfactory (Malhotra, 2006; Zhao et al., 2013). As Table 8.6 shows, all the variables are split into five meaningful groupings, and considering the variables with high loadings in each grouping and their common features, the five underlying groupings could be named as follows: government regulations and standards; incentives and R&D support; awareness and publicity programs; education and information dissemination; and awards and recognition. The main purpose of performing factor analysis on the GBTs adoption promotion strategies is not to establish and thoroughly discuss an unconfirmed factor structure, but to establish a factor structure in order to allow this research to conduct the PLS-SEM to investigate the influences of the different types of GBTs adoption promotion strategies on GBTs adoption (Chapter 9). The established factor structure could also be useful for future research to expand the knowledge base.

8.6 CHAPTER SUMMARY, CONTRIBUTIONS, AND LIMITATIONS

There is a need for strategies that can assist in promoting and accelerating the adoption of GBTs within developing countries. This chapter aimed to identify the important strategies to promote the GBTs adoption within the developing country of Ghana. A literature review and interviews with industry professionals were done to identify 15 potential strategies that were presented in a questionnaire. An empirical questionnaire survey was carried out with 43 professionals with green building experience to assess the relative importance of the strategies. This study is novel in three ways. First, this study is one of the first in developing countries and the first in Ghana to investigate the important strategies to promote GBTs adoption. Second, this study is one of the first to compare between the strategies to promote GBTs adoption for a developing country and a developed country. Finally, this research is also the first to establish the underlying factor structure of the strategies to promote the GBTs adoption.

The analysis results first indicated that "more publicity through media (e.g., print media, radio, television, and internet)", "GBTs-related educational and training programs for developers, contractors, and policy makers", "availability of institutional framework for effective GBTs implementation", "a strengthened GBTs R&D", and "financial and further market-based incentives for GBTs adoption" were the top five strategies to promote the GBTs adoption. Also, the importance of all the strategies were statistically significant, and generally the differences in the views of the importance of the strategies were statistically insignificant. In addition, the comparison of the top five strategies among Ghana and the US revealed that the most important strategies to promote the GBTs adoption in Ghana mostly vary from those in the US. However, the findings suggested that irrespective of geographical locations, "a strengthened GBTs R&D" and "financial and further market-based incentives for GBTs adoption" are two strategies that could greatly help in promoting the GBTs adoption. The implication of this finding is that these strategies need more attention in order to promote the GBTs adoption worldwide. Furthermore, factor analysis showed that the underlying strategy groupings were government regulations and standards; incentives and R&D support; awareness and publicity programs; education and information dissemination; and awards and recognition.

The first contribution of this chapter is helping to address a gap within the green building body of knowledge, particularly for developing countries. Additionally, the findings of this chapter help in better understanding the key strategies to promote the GBTs adoption and as such could support policy makers, industry stakeholders, and advocates in formulating and implementing appropriate strategies for GBTs adoption promotion. Ultimately, this chapter would benefit the sustainable development of the construction industry in general.

Despite the achievement of the objectives, this chapter still has limitations. The first limitation is that the importance assessment made may be influenced by the respondents' experiences and attitudes, as it was subjective. Besides, because the sample size was not very large, one should be cautious when interpreting and generalizing the results. This research analyzed the views of only consultants, contractors, and developers on the strategies, therefore future research could increase the sample size by including the views of the policy makers or government agencies. Moreover, the comparative analysis carried out in this study was limited to only Ghana and the US, hence future research could include many other countries, and by so doing, the comparison would be expanded and improved. Additionally, while this study aims to provide a generic list of strategies to promote the GBTs adoption within Ghana, it is equally important to note that the importance of these strategies could vary depending upon several factors, e.g., the type and scale of projects (e.g., government- or private-funded projects), the sector under consideration (e.g., the residential or commercial sectors), and firm characteristics (e.g., firm size – large or small firms). For the promotion of GBTs adoption in private-funded projects, for example, the provision of financial incentives might be regarded as more important than other promotion strategies for at least two reasons. First, the GBTs adoption may require higher investment costs (Dwaikat and Ali, 2016). Second, most private developers act as "rational economic men" who pursue profit (Mao et al., 2015). To assess the effects of various contextual factors on the importance of the strategies to promote GBTs adoption, future studies should focus on specific contexts when analyzing the strategies.

Because this research was conducted within the developing country of Ghana, the findings and implications could also be beneficial to policy makers, industry stakeholders, and advocates in other developing countries around the world. Nonetheless, data collected and analyzed from different countries may produce different results. Therefore, using the proposed strategies and following this study's methodology, similar studies could be conducted in different developing countries, and the results could be used in observing the market-specific differences.

Promoting the GBTs adoption requires an informed approach in the form of an implementation strategy (Potbhare et al., 2009). Thus, using the factor structures of the GBTs adoption drivers, barriers, and promotion strategies established within Chapters 6, 7, and 8, respectively, the next chapter applies PLS-SEM to investigate the influences of the drivers, barriers, and promotion strategies on the GBTs adoption activity. Based upon the PLS-SEM results, an implementation strategy is proposed to help Ghanaian policy makers, practitioners, stakeholders, and advocates promote the GBTs adoption.

CHAPTER 9 DATA ANALYSIS AND RESULTS – DEVELOPING AN IMPLEMENTATION STRATEGY TO PROMOTE GBTs ADOPTION IN GHANA [13]

9.1 INTRODUCTION

Chapters 6, 7, and 8 analyzed the drivers, barriers, and promotion strategies of GBTs adoption, respectively, and established the underlying structures of the drivers, barriers, and promotion strategies. This chapter aims to develop an implementation strategy to help in the promotion of the GBTs adoption in Ghana. To attain this aim, using CFA, this chapter first tests and confirms the aforesaid underlying factor structures. Then, based on the confirmed factor structures, PLS-SEM is applied to investigate and model the influences of the various types of drivers, barriers, and promotion strategies on the GBTs adoption. Based on the PLS-SEM findings, this chapter proposes the implementation strategy to promote the GBTs adoption. Finally, this chapter presents the validation of the proposed GBTs model to help sustainable housing development, as well as the proposed implementation strategy to help promote GBTs adoption.

Expanding upon Chapters 6, 7, and 8, this chapter adds to the green building body of knowledge by improving understanding of the issues that are significantly correlated to the GBTs adoption. Such an understanding is useful for understanding which areas to focus on to rapidly promote the GBTs adoption. Thus, this chapter could be a useful reference for policy makers, industry practitioners and stakeholders, advocates, and international/foreign organizations interested in the promotion of the GBTs adoption in Ghana. With the help of the outcomes of this chapter, they would have a deeper knowledge of the drivers that significantly drive the GBTs adoption,

[13] This chapter has been fully published in Darko, A., Chan, A. P. C., Yang, Y., Shan, M., He, B. J., and Gou, Z. (2018d). Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case. *Journal of Cleaner Production*, 200, 687-703.

the barriers that significantly hinder the GBTs adoption, and the strategies that can significantly help to deal with the barriers and thus promote the successful and wider adoption of GBTs.

9.2 RESEARCH FRAMEWORK AND HYPOTHESES DEVELOPMENT

9.2.1 Research Framework

Research framework is useful for developing new knowledge (Agherdien, 2007) and could be based upon theory and/or logic (Simon and Goes, 2011). The framework used for this research has a theoretical basis. Aktas and Ozorhon (2015) observed that previous green building-related studies had not developed frameworks for analyzing the green building adoption process. As a result, drawing on existing frameworks for analyzing the general innovation process within the construction industry, Aktas and Ozorhon (2015) developed a framework to analyze the green building adoption process. It was reasonable to do so since green building has been considered an innovation within the construction industry (Yudelson, 2007; Potbhare et al., 2009; Love et al., 2012; Mollaoglu et al., 2016). Aktas and Ozorhon's (2015) framework highlights drivers, barriers, enablers, benefits, resources, and impacts as essential issues associated with the green building adoption process. This framework aims at allowing a comprehensive analysis to attain a deeper understanding of the whole green building adoption process. Based upon Aktas and Ozorhon's (2015) framework, a framework is proposed for guiding the investigation of the influences of barriers, drivers, and promotion strategies on GBTs adoption in the present study (Fig. 9.1). Within this proposed framework, while barriers represent the problems that prevent stakeholders from adopting GBTs, drivers and promotion strategies motivate stakeholders to adopt GBTs (as previously highlighted, drivers represent the benefits of GBTs, and promotion strategies represent the factors like government regulations and incentives). Therefore, similar to Aktas and Ozorhon (2015), whereas barriers are assigned negative sign (–) in the proposed framework, drivers and promotion strategies are assigned positive sign (+). This informs the directions of the research hypotheses, and what it means is that the drivers and promotion strategies work together against the barriers.

Fig. 9.1 Research framework (Darko et al., 2018d).

9.2.2 Hypotheses Development

In order to investigate the influences of various types of GBTs adoption barriers, drivers, and promotion strategies on GBTs adoption, appropriate research hypotheses should be developed. The development of the research hypotheses within this chapter is largely dependent upon the comprehensive literature reviews presented in Chapters 3 and 4, the research framework (Fig. 9.1), and the outcomes of Chapters 6-8. Based upon the outcomes of Chapters 6-8, Table 9.1 summarizes the 15 constructs – i.e., the constructs for GBTs adoption barriers, drivers, and promotion strategies – and their respective measurement items, which are used in the present chapter to examine and model the influences of barriers, drivers, and promotion strategies upon GBTs adoption. As indicated earlier, GBTs adoption in this study is measured using six items, which are also presented in Table 9.1. Firstly, Lam et al. (2009) used some eight items to assess the state of green specifications adoption in Hong Kong. Later, Shi et al. (2013) adapted these items to also assess the state of green construction adoption within China. The measurement items of GBTs adoption were thus developed based on the studies of Lam et al. (2009) and Shi et al. (2013), with some modifications to suit the present study.

Table 9.1 Constructs and their respective measurement items.

Constructs	Code	Measurement items
	Barriers to GBTs adoption	
Government-related barriers (GRB)	GRB1	Lack of government incentives
	GRB2	Lack of green building polices and regulations
	GRB3	Lack of GBTs promotion by government
	GRB4	Lack of local institutes and facilities for GBTs R&D
	GRB5	Lack of green building rating systems and labeling programs
	GRB6	Lack of demonstration projects
	GRB7	Lack of green building technological training for project staff
Human-related barriers (HRB)	HRB1	Resistance to change from the use of traditional technologies
	HRB2	Lack of importance attached to GBTs by senior management
	HRB3	Unfamiliarity of construction professionals with GBTs
	HRB4	Unavailability of GBTs suppliers
	HRB5	Lack of financing schemes (e.g., bank loans)
Knowledge and information-related barriers (KIRB)	KIRB1	Lack of professional knowledge and expertise in GBTs
	KIRB2	Lack of GBTs databases and information
	KIRB3	Lack of awareness of GBTs and their benefits
Market-related barriers (MRB)	MRB1	Unavailability of GBTs in the local market
	MRB2	Lack of interest from clients and market demand
	MRB3	Limited experience with the use of nontraditional procurement methods
Cost and risk-related barriers (CRRB)	CRRB1	Higher costs of GBTs
	CRRB2	Risks and uncertainties involved in adopting new technologies
	Drivers for GBTs adoption	
Environment-related drivers (ERD)	ERD1	Reduced environmental impact
	ERD2	Improved indoor environmental quality
	ERD3	Greater water efficiency
	ERD4	Non-renewable resources conservation
	ERD5	High return on investment
Company-related drivers (CRD)	CRD1	Company image and reputation
	CRD2	Improved occupants' productivity
	CRD3	Better workplace environment
	CRD4	Increased building value
Economy and health-related drivers (EHRD)	EHRD1	Reduced use of construction materials in the economy
	EHRD2	Improved occupants' health and well-being
	EHRD3	Job creation opportunity
Cost and energy-related drivers (CERD)	CERD1	Reduced whole lifecycle costs
	CERD2	Greater energy efficiency
Industry-related drivers (IRD)	IRD1	Setting a standard for future design and construction
	IRD2	Facilitating a culture of best practice sharing
	Promotion strategies for GBTs adoption	
Government regulations and standards (GRS)	GRS1	Mandatory green building policies and regulations
	GRS2	Green rating and labeling programs
	GRS3	Better enforcement of green building policies after they have been developed
	GRS4	Availability of competent and proactive GBTs promotion teams and local authorities
Incentives and R&D support (IRDS)	IRDS1	Financial and further market-based incentives for GBTs adoption
	IRDS2	A strengthened GBTs R&D
	IRDS3	Low-interest loans and subsidies from government and financial institutions
Awareness and publicity programs (APP)	APP1	Public environmental awareness creation through workshops, seminars, and conferences
	APP2	More publicity through media (e.g., print media, radio, television, and internet)
	APP3	Support from executive management
Education and information dissemination (EID)	EID1	GBTs-related educational and training programs for developers, contractors, and policy makers
	EID2	Availability of better information on cost and benefits of GBTs

	EID3	Availability of institutional framework for effective GBTs implementation
Awards and recognition (AR)	AR1	Acknowledging and rewarding GBTs adopters publicly
	AR2	More GBTs adoption advocacy by the Ghana Environmental Protection Agency
	GBTs adoption	
GBTs adoption (GA)	GA1	Specifications should consider GBTs
	GA2	Current construction has not sufficiently considered GBTs
	GA3	GBTs information and databases are not adequately available in your company
	GA4	Our senior management is willing to support GBTs adoption
	GA5	GBTs adoption should be forced by government
	GA6	Guides for implementing GBTs cannot be easily found in Ghana

The comprehensive literature reviews in Chapters 3 and 4 generally suggest that barriers might make it difficult for stakeholders to adopt GBTs; that is, barriers have a potentially negative influence upon GBTs adoption. Conversely, drivers and promotion strategies have been argued to drive stakeholders to adopt GBTs; that is, drivers and promotion strategies have a potentially positive influence on GBTs adoption. In the light of these insights from the literature and the research framework (Fig. 9.1), the following research hypotheses are proposed:

H1a: Government-related barriers have a negative influence on GBTs adoption.

H1b: Human-related barriers have a negative influence on GBTs adoption.

H1c: Knowledge and information-related barriers have a negative influence on GBTs adoption.

H1d: Market-related barriers have a negative influence on GBTs adoption.

H1e: Cost and risk-related barriers have a negative influence on GBTs adoption.

H2a: Environment-related drivers have a positive influence on GBTs adoption.

H2b: Company-related drivers have a positive influence on GBTs adoption.

H2c: Economy and health-related drivers have a positive influence on GBTs adoption.

H2d: Cost and energy-related drivers have a positive influence on GBTs adoption.

H2e: Industry-related drivers have a positive influence on GBTs adoption.

H3a: Government regulations and standards would have a positive influence on GBTs adoption.

H3b: Incentives and R&D support would have a positive influence on GBTs adoption.

H3c: Awareness and publicity programs would have a positive influence on GBTs adoption.

H3d: Education and information dissemination would have a positive influence on GBTs adoption.

H3e: Awards and recognition would have a positive influence on GBTs adoption.

The hypothetical model is presented in Fig. 9.2. The hypotheses are tested in this chapter, and the results contribute towards deepening the understanding of the roles of different factors in hindering or fostering the adoption of GBTs. Such an understanding is crucial to help policy makers and stakeholders formulate and implement proper policies and strategies to advance the GBTs adoption.

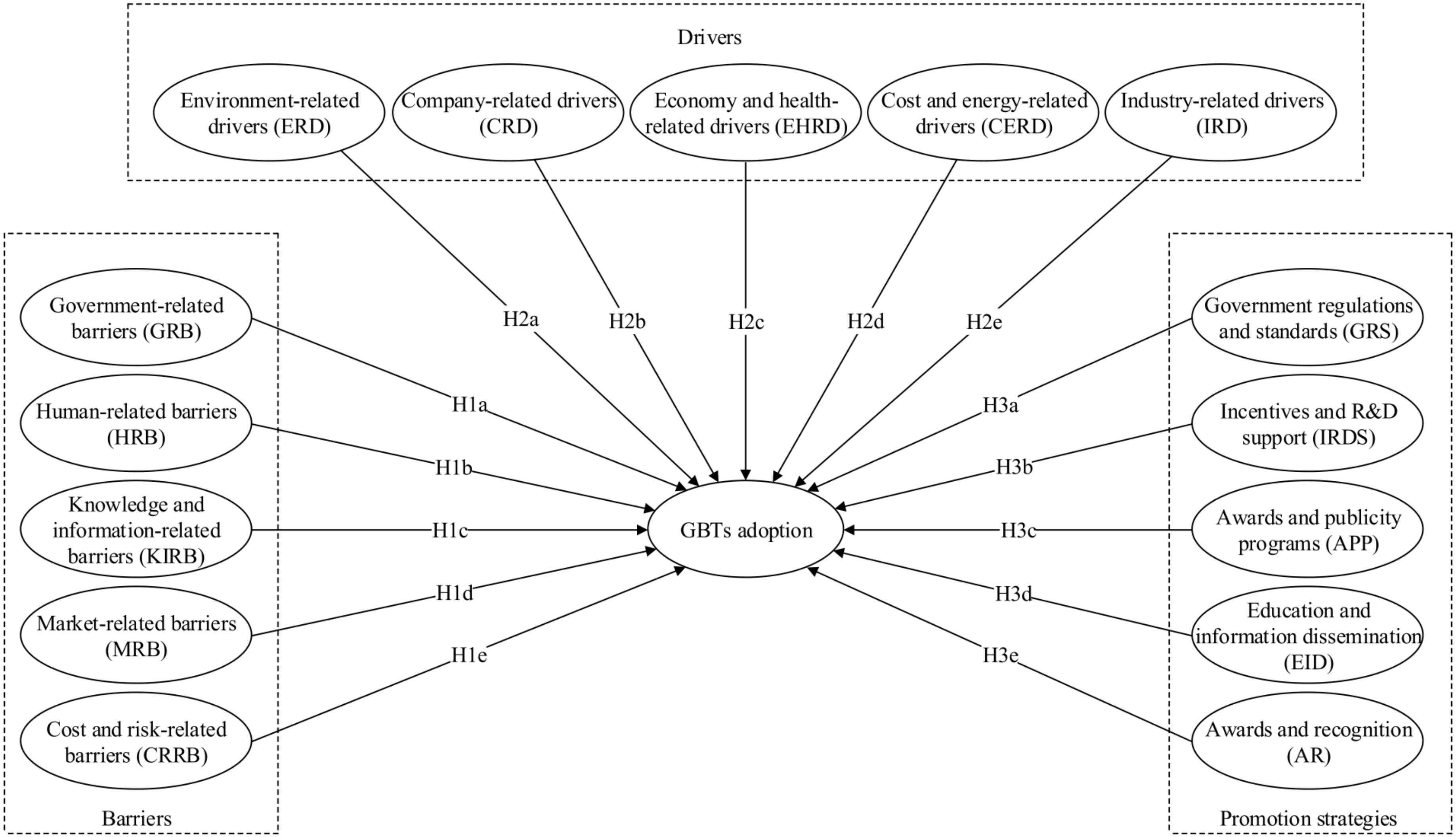


Fig. 9.2 Hypothetical model of the barriers, drivers, and promotion strategies influencing GBTs adoption.

9.3 PLS-SEM RESULTS

9.3.1 Barriers

9.3.1.1 Evaluation of measurement models

Tables 9.2-9.4 show the evaluation results of the measurement models in the model of barriers influencing GBTs adoption (Fig. 9.3). As the CFA factor loading of the measurement item MRB2 was lower than 0.50, it was deleted from the list of measurement items (Table 9.2). It should be noted that after the deletion of any measurement item that required deletion, the analysis was rerun; this procedure was repeated until reliable and valid measurement models were achieved. This study involves only reflective measurement items because the constructs cause the items; that is, the arrows in Figs. 9.3-9.5 point from the constructs to the measurement items. Hair et al. (2014a) stated that reflective measurement items are extremely correlated, interchangeable, and some can be omitted without changing the meaning of the construct. Besides, Nunnally (1978) argued that measurement items with low loadings can be dropped because their contribution to the explanatory power of the model would be insignificant, thus biasing the estimations of other measurement items.

Table 9.2 Measurement model evaluation (for barriers model).

Construct	Measurement item code	Factor loading	Cronbach's alpha	Composite reliability	AVE
GRB	GRB1	0.647	0.841	0.872	0.551
	GRB2	0.788	–	–	–
	GRB3	0.780	–	–	–
	GRB4	0.738	–	–	–
	GRB5	0.828	–	–	–
	GRB6	0.677	–	–	–
	GRB7	0.634	–	–	–
HRB	HRB1	0.678	0.776	0.782	0.539
	HRB2	0.574	–	–	–
	HRB3	0.974	–	–	–
	HRB4	0.510	–	–	–
	HRB5	0.714	–	–	–
KIRB	KIRB1	0.875	0.822	0.894	0.734
	KIRB2	0.893	–	–	–
	KIRB3	0.805	–	–	–
MRB	MRB1	0.628	0.744	0.771	0.569

	MRB3	0.994	–	–	–
CRRB	CRRB1	0.860	0.786	0.792	0.576
	CRRB2	0.642	–	–	–
GA	GA1	0.675	0.737	0.763	0.616
	GA2	0.718	–	–	–
	GA3	0.617	–	–	–
	GA4	0.709	–	–	–
	GA5	0.597	–	–	–
	GA6	0.684	–	–	–

Note: The measurement item MRB2 was removed from the initial model because its factor loading (0.387) was below 0.50; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption; AVE = Average variance extracted.

Table 9.3 Discriminant validity of constructs (for barriers model).

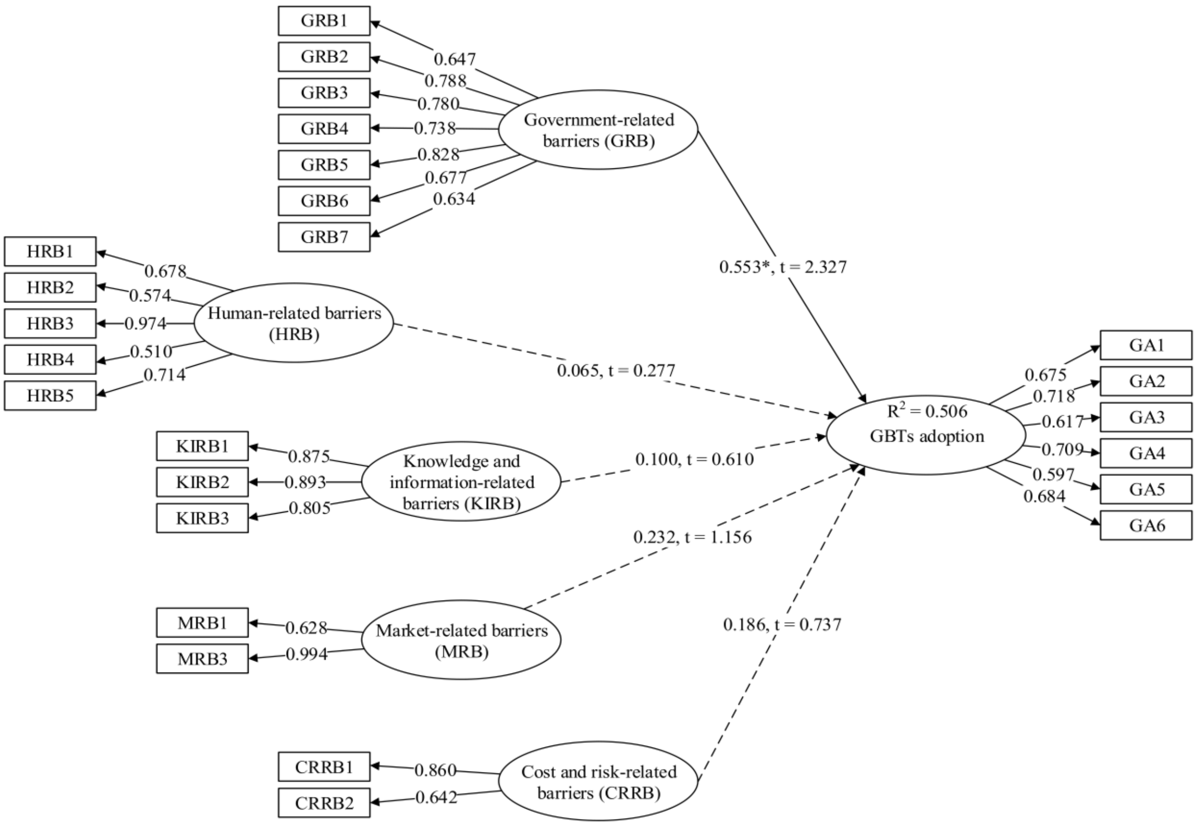
Construct	GRB	HRB	KIRB	MRB	CRRB	GA
GRB	**0.708**	–	–	–	–	–
HRB	0.439	**0.662**	–	–	–	–
KIRB	0.430	0.361	**0.859**	–	–	–
MRB	0.379	0.201	0.274	**0.754**	–	–
CRRB	0.082	0.075	0.014	0.075	**0.759**	–
GA	0.558	0.225	0.326	0.427	0.233	**0.563**

Note: The bold diagonal values are the square root of average variance extracted of each construct, while the other values are the correlations amongst constructs; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption.

Table 9.4 Cross loadings of measurement items (for barriers model).

Measurement item code	GRB	HRB	KIRB	MRB	CRRB	GA
GRB1	**0.647**	0.325	0.298	0.383	0.084	0.402
GRB2	**0.788**	0.204	0.187	0.237	0.244	0.309
GRB3	**0.780**	0.470	0.326	0.256	0.107	0.468
GRB4	**0.738**	0.181	0.370	0.223	0.036	0.402
GRB5	**0.828**	0.378	0.267	0.258	0.144	0.425
GRB6	**0.677**	0.368	0.441	0.333	0.144	0.380
GRB7	**0.634**	0.269	0.154	0.160	0.039	0.084
HRB1	0.264	**0.678**	0.045	0.131	0.161	0.056
HRB2	0.209	**0.574**	0.058	0.176	0.077	0.016
HRB3	0.456	**0.974**	0.398	0.200	0.072	0.251
HRB4	0.166	**0.510**	0.200	0.178	0.116	0.033
HRB5	0.342	**0.714**	0.437	0.330	0.027	0.017
KIRB1	0.310	0.315	**0.875**	0.280	0.041	0.232
KIRB2	0.375	0.243	**0.893**	0.257	0.130	0.322
KIRB3	0.413	0.384	**0.805**	0.170	0.082	0.272
MRB1	0.250	0.146	0.177	**0.628**	0.387	0.051
MRB3	0.365	0.192	0.305	**0.994**	0.080	0.438
CRRB1	0.059	0.056	0.031	0.112	**0.860**	0.208
CRRB2	0.069	0.231	0.020	0.022	**0.642**	0.138
GA1	0.356	0.180	0.041	0.266	0.250	**0.675**
GA2	0.291	0.203	0.051	0.137	0.060	**0.718**
GA3	0.052	0.032	0.245	0.376	0.018	**0.617**
GA4	0.382	0.181	0.376	0.356	0.201	**0.709**
GA5	0.221	0.081	0.188	0.286	0.017	**0.597**
GA6	0.455	0.093	0.160	0.054	0.128	**0.684**

Note: Bold values show that each measurement item had the highest loading on its respective construct; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption.



Note: * Indicates level of significance at $p < 0.05$;
——► Indicates a significant path (hypothesis supported);
·······► Indicates an insignificant path (hypothesis not supported).

Fig. 9.3 Final structural equation model of barriers influencing GBTs adoption.

As Table 9.2 shows, all Cronbach's alpha coefficients and composite reliability scores were above 0.70, indicating an acceptable level of internal consistency reliability of the measurement items. In addition, all factor loadings and AVEs were above 0.50, which provides evidence of convergent validity of the constructs. An AVE above 0.50 indicates that the construct explains more than 50% of the variance in its measurement items, which is satisfactory. Moreover, as shown in Table 9.3, no correlation amongst any two constructs exceeded the square roots of their AVEs, providing the first evidence of discriminant validity of the constructs. Further evidence of discriminant validity is provided by examining the cross loadings of the measurement items. Table 9.4 shows that there is no cross-loading problem, as each measurement item had the highest loading on its corresponding construct. These results show that the measurement models were reliable and valid for the structural path modeling.

9.3.1.2 Evaluation of structural model

Table 9.5 shows the bootstrapping results for the barriers model. The results show that the path linking government-related barriers to GBTs adoption had a *t*-value greater than 1.96, implying that it was statistically significant at the 0.05 level. Therefore, hypothesis H1a was supported. Path coefficients are equivalents of regression weights (Ozorhon and Oral, 2017). The higher the path coefficient, the stronger the influence of an independent variable on the dependent variable (Aibinu and Al-Lawati, 2010). As Murari (2015) advised, a path coefficient ranging from 0.1 to 0.3 indicates a weak influence, 0.3 to 0.5 indicates a moderate influence, and 0.5 to 1.0 indicates a strong influence. In this research, hypothesis H1a, which is the only supported hypothesis in the barriers model, had a path coefficient of 0.553, indicating a strong influence. In contrast, the results did not provide support for hypotheses H1b, H1c, H1d, and H1e; these hypotheses had low path coefficients with *t*-values below 1.65, 1.96, or 2.58. These results show that the influences of human-related barriers, knowledge and information-related barriers, market-related barriers, and cost and risk-related barriers on GBTs adoption were not significant. The final structural equation model depicting the influence of each type of barrier upon GBTs adoption is illustrated in Fig. 9.3. The coefficient of determination (R^2) of the dependent variable, GBTs adoption, was 0.506, indicating a satisfactory level of predictive accuracy and therefore quality of the model (Hair et al., 2014a).

Table 9.5 Structural model evaluation (for barriers model).

Hypothetical path	Path coefficient	*t*-Value	*p*-Value	Interpretation
H1a: GRB → GA	0.553	2.327	0.020*	Supported
H1b: HRB → GA	0.065	0.277	0.782	Not supported
H1c: KIRB → GA	0.100	0.610	0.542	Not supported
H1d: MRB → GA	0.232	1.156	0.248	Not supported
H1e: CRRB → GA	0.186	0.737	0.461	Not supported

Note: * The path coefficient is significant at $p < 0.05$; GRB = Government-related barriers; HRB = Human-related barriers; KIRB = Knowledge and information-related barriers; MRB = Market-related barriers; CRRB = Cost and risk-related barriers; GA = GBTs adoption.

9.3.2 Drivers

9.3.2.1 Evaluation of measurement models

Tables 9.6-9.8 show the evaluation results of the measurement models in the model of drivers influencing GBTs adoption (Fig. 9.4). As the CFA factor loadings of the measurement items GA2, GA4, and GA6 were lower than 0.50, they were deleted from the list of measurement items (Table 9.6). Also, it could be noted from the results in Table 9.6 that the construct GA had a Cronbach's alpha coefficient lower than 0.70; however, since its composite reliability score was above 0.70, it is still considered that its measurement items have an acceptable level of internal consistency reliability. This is because composite reliability provides a more proper measure of internal consistency reliability than Cronbach's alpha (Fornell and Larcker, 1981; Hair et al., 2014a) for certain reasons. For example, composite reliability does not assume that all measurement items have equal loadings as Cronbach's alpha does (Hair et al., 2014a). Also, Cronbach's alpha is sensitive to the number of measurement items within the scale and usually underestimates internal consistency reliability, whereas composite reliability aids PLS-SEM to accommodate different measurement item reliabilities and avoid the underestimation related to Cronbach's alpha (Hair et al., 2014a).

Apart from the two observations above, the interpretation of the results of the measurement models herein (Tables 9.6-9.8) is the same as the interpretation of results in section 9.3.1.1.

Table 9.6 Measurement model evaluation (for drivers model).

Construct	Measurement item code	Factor loading	Cronbach's alpha	Composite reliability	AVE
ERD	ERD1	0.756	0.814	0.856	0.553

	ERD2	0.789	–	–	–
	ERD3	0.808	–	–	–
	ERD4	0.533	–	–	–
	ERD5	0.854	–	–	–
CRD	CRD1	0.725	0.768	0.848	0.584
	CRD2	0.752	–	–	–
	CRD3	0.728	–	–	–
	CRD4	0.846	–	–	–
EHRD	EHRD1	0.757	0.745	0.849	0.653
	EHRD2	0.836	–	–	–
	EHRD3	0.829	–	–	–
CERD	CERD1	0.893	0.737	0.884	0.792
	CERD2	0.886	–	–	–
IRD	IRD1	0.954	0.744	0.876	0.781
	IRD2	0.807	–	–	–
GA	GA1	0.859	0.624	0.795	0.583
	GA3	0.546	–	–	–
	GA5	0.901	–	–	–

Note: The measurement items GA2, GA4, and GA6 were removed from the initial model because their factor loadings (0.344, 0.417, and 0.033, respectively) were below 0.50; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption; AVE = Average variance extracted.

Table 9.7 Discriminant validity of constructs (for drivers model).

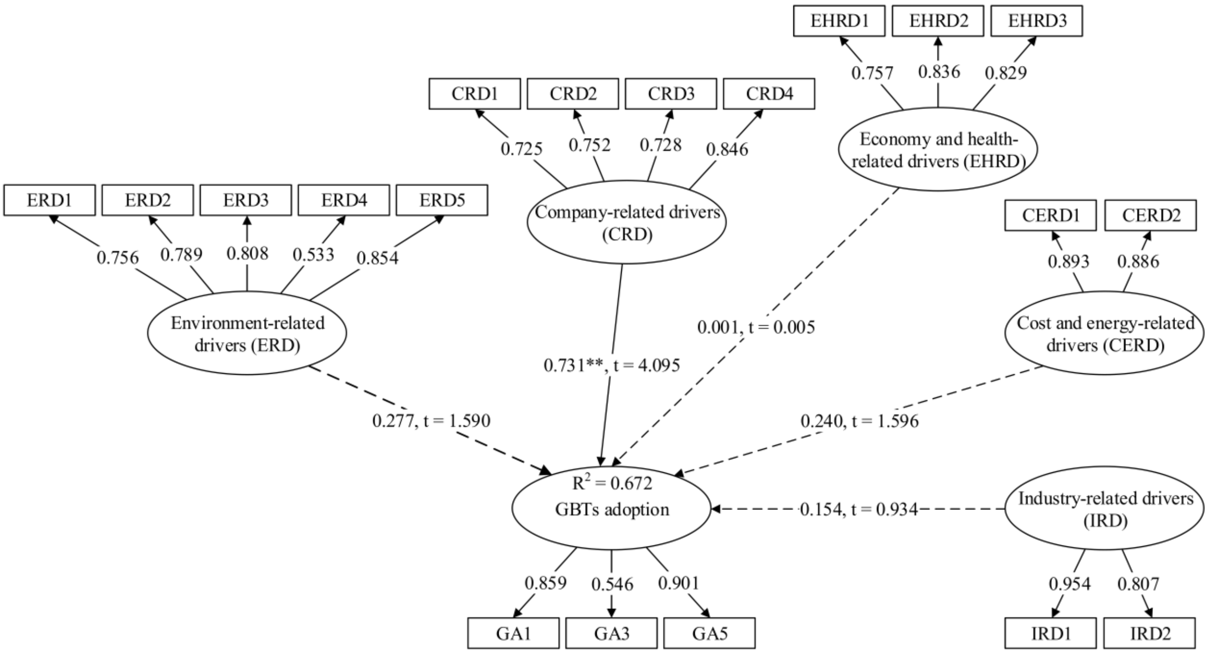
Construct	ERD	CRD	EHRD	CERD	IRD	GA
ERD	**0.743**	–	–	–	–	–
CRD	0.628	**0.764**	–	–	–	–
EHRD	0.535	0.548	**0.808**	–	–	–
CERD	0.397	0.366	0.348	**0.890**	–	–
IRD	0.351	0.426	0.380	0.355	**0.884**	–
GA	0.331	0.710	0.394	0.452	0.453	**0.763**

Note: The bold diagonal values are the square root of average variance extracted of each construct, while the other values are the correlations amongst constructs; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption.

Table 9.8 Cross loadings of measurement items (for drivers model).

Measurement item code	ERD	CRD	EHRD	CERD	IRD	GA
ERD1	**0.756**	0.279	0.295	0.171	0.224	0.150
ERD2	**0.789**	0.512	0.326	0.375	0.364	0.206
ERD3	**0.808**	0.405	0.502	0.511	0.355	0.232
ERD4	**0.533**	0.230	0.359	0.288	0.149	0.021
ERD5	**0.854**	0.669	0.503	0.234	0.227	0.381
CRD1	0.323	**0.725**	0.347	0.210	0.315	0.477
CRD2	0.560	**0.752**	0.545	0.393	0.326	0.426
CRD3	0.700	**0.728**	0.536	0.291	0.306	0.438
CRD4	0.421	**0.846**	0.338	0.262	0.355	0.736
EHRD1	0.402	0.308	**0.757**	0.168	0.188	0.396
EHRD2	0.591	0.447	**0.836**	0.391	0.341	0.363
EHRD3	0.297	0.522	**0.829**	0.237	0.232	0.351
CERD1	0.377	0.342	0.372	**0.893**	0.249	0.408
CERD2	0.328	0.308	0.246	**0.886**	0.384	0.396
IRD1	0.301	0.389	0.374	0.372	**0.954**	0.491
IRD2	0.350	0.378	0.284	0.221	**0.807**	0.250
GA1	0.265	0.613	0.304	0.331	0.373	**0.859**
GA3	0.189	0.295	0.107	0.214	0.070	**0.546**
GA5	0.300	0.647	0.412	0.453	0.475	**0.901**

Note: Bold values show that each measurement item had the highest loading on its respective construct; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption.



Note: ** Indicates level of significance at $p < 0.01$;
——▶ Indicates a significant path (hypothesis supported);
┈┈▶ Indicates an insignificant path (hypothesis not supported).

Fig. 9.4 Final structural equation model of drivers influencing GBTs adoption.

9.3.2.2 Evaluation of structural model

Table 9.9 shows the bootstrapping results for the drivers models. The results show that the path linking company-related drivers to GBTs adoption had a *t*-value greater than 2.58, implying that it was statistically significant at the 0.01 level. Therefore, hypothesis H2b was supported; this is the only supported hypothesis within the drivers model and it had a path coefficient of 0.731, indicating a strong influence. On the other hand, the results did not provide support for hypotheses H2a, H2c, H2d, and H2e; these hypotheses had low path coefficients with *t*-values below 1.65, 1.96, or 2.58. These results show that the influences of environment-related drivers, economy and health-related drivers, cost and energy-related drivers, and industry-related drivers on GBTs adoption were not significant. The final structural equation model depicting the influence of each type of driver on GBTs adoption is illustrated in Fig. 9.4. The

R^2 of GBTs adoption was 0.672, indicating a satisfactory level of predictive accuracy and hence quality of the model (Hair et al., 2014a).

Table 9.9 Structural model evaluation (for drivers model).

Hypothetical path	Path coefficient	*t*-Value	*p*-Value	Interpretation
H2a: ERD → GA	0.277	1.590	0.112	Not supported
H2b: CRD → GA	0.731	4.095	0.000**	Supported
H2c: EHRD → GA	0.001	0.005	0.996	Not supported
H2d: CERD → GA	0.240	1.596	0.110	Not supported
H2e: IRD → GA	0.154	0.934	0.350	Not supported

Note: ** The path coefficient is significant at $p < 0.01$; ERD = Environment-related drivers; CRD = Company-related drivers; EHRD = Economy and health-related drivers; CERD = Cost and energy-related drivers; IRD = Industry-related drivers; GA = GBTs adoption.

9.3.3 Promotion Strategies

9.3.3.1 Evaluation of measurement models

Tables 9.10-9.12 show the evaluation results of the measurement models within the model of promotion strategies influencing GBTs adoption (Fig. 9.5). As the CFA factor loadings of the measurement items GRS3 and GA6 were lower than 0.50, they were deleted from the list of measurement items (Table 9.10). Apart from this observation, the interpretation of the results of the measurement models herein (Tables 9.10-9.12) is the same as the interpretation of results in section 9.3.1.1.

Table 9.10 Measurement model evaluation (for promotion strategies model).

Construct	Measurement item code	Factor loading	Cronbach's alpha	Composite reliability	AVE
GRS	GRS1	0.898	0.814	0.890	0.731
	GRS2	0.925	–	–	–
	GRS4	0.729	–	–	–
IRDS	IRDS1	0.992	0.763	0.767	0.551
	IRDS2	0.508	–	–	–
	IRDS3	0.708	–	–	–
APP	APP1	0.670	0.785	0.830	0.626
	APP2	0.713	–	–	–
	APP3	0.960	–	–	–
EID	EID1	0.866	0.800	0.881	0.712
	EID2	0.785	–	–	–
	EID3	0.877	–	–	–
AR	AR1	0.713	0.802	0.876	0.659
	AR2	0.946	–	–	–
GA	GA1	0.917	0.766	0.895	0.809
	GA2	0.723	–	–	–
	GA3	0.656	–	–	–
	GA4	0.711	–	–	–

	GA5	0.882	–	–	–

Note: The measurement items GRS3 and GA6 were removed from the initial model because their factor loadings (0.408 and 0.321, respectively) were below 0.50; GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption; AVE = Average variance extracted.

Table 9.11 Discriminant validity of constructs (for promotion strategies model).

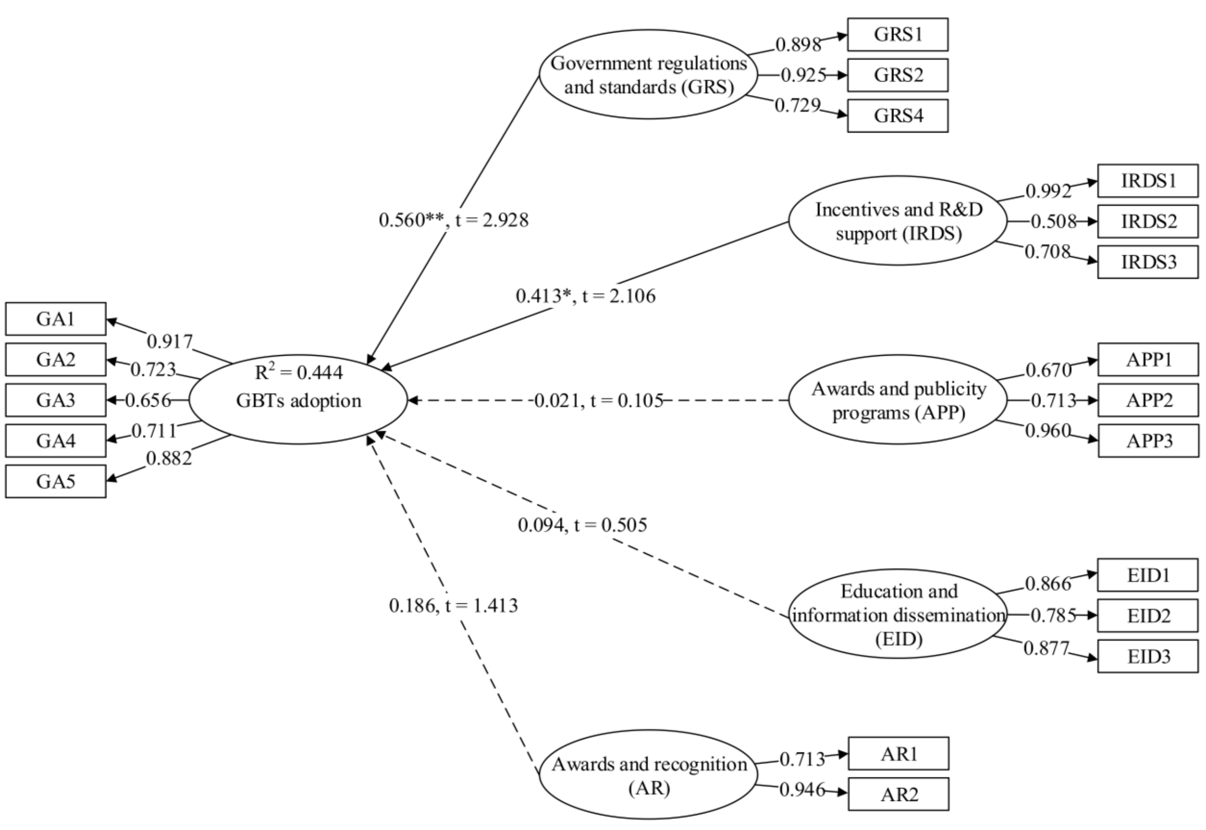
Construct	GRS	IRDS	APP	EID	AR	GA
GRS	**0.855**	–	–	–	–	–
IRDS	0.079	**0.742**	–	–	–	–
APP	0.406	0.197	**0.791**	–	–	–
EID	0.476	0.208	0.366	**0.844**	–	–
AR	0.004	0.005	0.195	0.001	**0.836**	–
GA	0.509	0.058	0.216	0.173	0.180	**0.900**

Note: The bold diagonal values are the square root of average variance extracted of each construct, while the other values are the correlations amongst constructs; GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption.

Table 9.12 Cross loadings of measurement items (for promotion strategies model).

Measurement item code	GRS	IRDS	APP	EID	AR	GA
GRS1	**0.898**	0.103	0.277	0.249	0.011	0.457
GRS2	**0.925**	0.057	0.347	0.472	0.052	0.497
GRS4	**0.729**	0.209	0.458	0.545	0.080	0.334
IRDS1	0.075	**0.992**	0.208	0.206	0.007	0.061
IRDS2	0.271	**0.508**	0.248	0.374	0.090	0.004
IRDS3	0.166	**0.708**	0.136	0.298	0.041	0.012
APP1	0.191	0.224	**0.670**	0.339	0.147	0.061
APP2	0.131	0.193	**0.713**	0.480	0.131	0.057
APP3	0.446	0.154	**0.960**	0.278	0.185	0.249
EID1	0.340	0.056	0.196	**0.866**	0.033	0.176
EID2	0.410	0.261	0.398	**0.785**	0.080	0.130
EID3	0.486	0.260	0.379	**0.877**	0.043	0.119
AR1	0.079	0.337	0.254	0.309	**0.713**	0.084
AR2	0.004	0.005	0.195	0.001	**0.946**	0.180
GA1	0.486	0.061	0.216	0.193	0.232	**0.917**
GA2	0.234	0.432	0.057	0.344	0.212	**0.723**
GA3	0.054	0.287	0.199	0.088	0.391	**0.656**
GA4	0.401	0.263	0.345	0.167	0.072	**0.711**
GA5	0.426	0.186	0.169	0.111	0.079	**0.882**

Note: Bold values show that each measurement item had the highest loading on its respective construct; GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption.



Note: ** Indicates level of significance at $p < 0.01$;
* Indicates level of significance at $p < 0.05$;
——► Indicates a significant path (hypothesis supported);
·········► Indicates an insignificant path (hypothesis not supported).

Fig. 9.5 Final structural equation model of promotion strategies influencing GBTs adoption.

9.3.3.2 Evaluation of structural model

Table 9.13 shows the bootstrapping results for the promotion strategies model. The results show that the path linking government regulations and standards to GBTs adoption had a *t*-value greater than 2.58, implying that it was statistically significant at the 0.01 level. Thus, hypothesis H3a was supported; this hypothesis had a path coefficient of 0.560, indicating a strong influence. Moreover, the path linking incentives and R&D support to GBTs adoption had a *t*-value greater than 1.96, suggesting that it was statistically significant at the 0.05 level. Hence, hypothesis H3b was supported with a path coefficient of 0.413, indicating that although the influences of both "government regulations and standards" (GRS) and "incentives and

R&D support" (IRDS) on GBTs adoption were significant, the influence of GRS was stronger than that of IRDS. As for hypotheses H3c, H3d, and H3e, they had low path coefficients with *t*-values below 1.65, 1.96, or 2.58, indicating that they were not supported. That is to say, the influences of awareness and publicity programs, education and information dissemination, and awards and recognition on GBTs adoption were not significant. The final structural equation model depicting the influence of each type of promotion strategy on GBTs adoption is illustrated in Fig. 9.5. The R^2 of GBTs adoption was 0.444, which indicates a satisfactory level of predictive accuracy and hence quality of the model (Hair et al., 2014a).

Table 9.13 Structural model evaluation (for promotion strategies model).

Hypothetical path	Path coefficient	*t*-Value	*p*-Value	Interpretation
H3a: GRS → GA	0.560	2.928	0.003**	Supported
H3b: IRDS → GA	0.413	2.106	0.032*	Supported
H3c: APP → GA	0.021	0.105	0.917	Not supported
H3d: EID → GA	0.094	0.505	0.614	Not supported
H3e: AR → GA	0.186	1.413	0.158	Not supported

Note: ** The path coefficient is significant at $p < 0.01$; * The path coefficient is significant at $p < 0.05$. GRS = Government regulations and standards; IRDS = Incentives and R&D support; APP = Awareness and publicity programs; EID = Education and information dissemination; AR = Awards and recognition; GA = GBTs adoption.

9.4 DISCUSSION OF PLS-SEM RESULTS

In this research, a model was proposed to investigate the influences of various types of barriers, drivers, and promotion strategies on GBTs adoption in the construction industry. The validity of the model was tested based upon data collected from the developing country of Ghana. This section discusses the results of the PLS-SEM.

9.4.1 Barriers

The PLS-SEM results supported a significantly negative influence of government-related barriers on GBTs adoption. Further, the results suggest that government-related barriers are the most significant barrier hindering the adoption of GBTs in the Ghanaian construction industry.

The result can be interpreted that the higher the government-related barriers, the lower the level of GBTs adoption. The research finding is consistent with Djokoto et al. (2014), who pointed out that the adoption of sustainable construction has been low in Ghana because of the lack of government support. Government-related barriers have been considered major barriers to the adoption of GBTs and practices in various other countries as well. For example, in China, Shen et al. (2017b) identified that lack of incentives from the government is one of the significant barriers encountered in green procurement adoption; while in Singapore, Hwang et al. (2017b) found that lack of government support is a top barrier inhibiting green business parks adoption. Government-related barriers in this study (Table 9.1) refer to issues that fall within the purview of government (Chan et al., 2018) and hence their resolution may, to a large extent, require the government’s interventions. Because governmental initiatives, such as green building policies and regulations as well as incentives, that could encourage GBTs adoption among construction stakeholders are currently absent in Ghana (Darko et al., 2017a), GBTs adoption is significantly negatively influenced by government-related barriers (path coefficient of 0.553). The lack of government incentives leads to lack of motivation and better financial foundation for many stakeholders to deal with the high investment that might be required for the adoption of GBTs; the high investment may be in terms of finance, time, and human resource (Zailani et al., 2017). Similarly, lack of green building policies and regulations as well as authoritative rating systems may obstruct GBTs adoption because there would be no regulatory or mandatory requirements from the policy makers for companies and the stakeholders to comply with, and therefore they might not be committed to GBTs adoption. Likewise, successful GBTs adoption and promotion requires increased public awareness of the benefits of GBTs (Sadiq, 2018). Hence, the lack of R&D initiatives to improve the understanding of GBTs and their benefits significantly impedes GBTs adoption. Additionally, both government promotion of GBTs and demonstration projects are vital for increasing the pace of GBTs adoption because they help validate the effectiveness of the GBTs to the general public (Potbhare et al., 2009). As a result, the lack of promotion by government and the lack of demonstration projects hamper GBTs adoption within the industry and the public.

On the contrary, this study found that human-related barriers, knowledge and information-related barriers, market-related barriers, and cost and risk-related barriers are not significantly linked to GBTs adoption. This suggests that these groups of barriers do not significantly affect GBTs adoption within the Ghanaian construction industry. According to Hwang et al. (2017b), at the initial stage of GBTs adoption, the government practically holds the leading and central role in promoting GBTs adoption; the government-oriented approaches, such as technical and financial supports, green policies and regulations, and incentives, are critical to attracting the industrial practitioners and stakeholders to adopt GBTs. This could explain why at the present stage of GBTs adoption within Ghana, government-related barriers are the only barrier with a significant negative influence on GBTs adoption. Besides, the research finding that knowledge and information-related barriers do not have a significant influence on GBTs adoption is in line with Zailani et al. (2017), who discovered that information-related barriers do not have a significant influence on product return management adoption, which is a sustainable business practice. Furthermore, lack of importance attached to GBTs by senior management and limited experience with the use of nontraditional procurement methods, for example, which are within the human-related barriers and the market-related barriers, respectively, were found to be insignificant barriers of GBTs adoption in Darko et al.'s (2017b) study as well. Nevertheless, the insignificant influence of cost and risk-related barriers is still an interesting finding of this research, as cost is one of the most cited barriers to adopting GBTs and practices (Dwaikat and Ali, 2016; Darko and Chan, 2017). This finding may be because the respondents believed that promotion strategies such as the government providing relevant incentives can help offset the additional cost involved in adopting GBTs.

9.4.2 Drivers

The PLS-SEM results revealed that company-related drivers have a significant positive influence on GBTs adoption. The results further suggest that company-related drivers are the governing drivers of GBTs adoption in the Ghanaian construction industry (path coefficient of 0.731). This is in line with the result of Ozorhon and Oral's (2017) study, in which firm-related drivers were found to have a positive influence on driving innovation within the construction industry. This research finding may be because GBTs adoption is a relatively new practice in Ghana and many individuals are still unaware of the individual-level benefits (Darko et al., 2017c) associated with it. In consequence, the companies with experienced professionals who are aware of the benefits that the company can gain by investing in GBTs adoption are leading and driving the GBTs adoption activity. At the company level, there are a number of benefits that can be derived from the adoption of GBTs, including good company image and reputation, improved productivity, better workplace environment, and increased building value. Previous studies stress the importance of these benefits in driving GBTs adoption (Zhang et al., 2011b; Darko et al., 2017c). Because company-related drivers could provide sound reasons for GBTs adoption, they should serve as a motivation for GBTs adoption. Corporate social responsibility (CSR) is an indispensable factor for companies to improve their public image and reputation (Zitzler et al., 2000), and GBTs adoption is a useful means for companies to demonstrate their commitment to CSR and environmental sustainability (Zhang et al., 2018). Hence, in order to improve company image and reputation, GBTs adoption is advised. The case studies presented by Zhang et al. (2011b) indicated that GBTs adoption helped developer companies to improve their public image and reputation as well as their competitiveness. These benefits significantly drive GBTs adoption because the good public image, for example, allows the company to more easily attract high-income customers. Specifically, the good image allows the company to trade its green buildings at relatively higher prices. Increased building value remains a noteworthy driver, as green buildings generally have higher market values than non-green buildings (Chan et al., 2016). Management should be concerned about the productivity of employees. Improved productivity is another key driver and it encourages companies to implement GBTs. Previous studies indicated that adopting GBTs in a company building would result in more productive employees (Issa et al., 2010; Al Horr et al., 2016). In this respect, it has been identified that GBTs adoption could help increase the productivity of employees by 6 to 25% (Brager and de Dear, 1998; Rocky Mountain Institute, 1998; Kats, 2003; Ries et al., 2006; Paul and Taylor, 2008). These productivity benefits could be linked to the better workplace environment that can be achieved through GBTs adoption. For example, GBTs like green roof could help provide better thermal comfort for employees to improve their productivity, which can translate into financial benefits for the company. Hence, improved productivity can greatly drive a company to adopt GBTs. In conclusion, this study suggests that company-related drivers are the major driver of GBTs adoption. When considering GBTs adoption, companies (e.g., developer and construction companies) must not merely consider the possible high investment cost; they must also carefully think about and evaluate the potential benefits. In addition, they must be aware that while some benefits might be short-term, others might be long-term. This could help them sustain their commitment to GBTs adoption.

Conversely, this study found that environment-related drivers, economy and health-related drivers, cost and energy-related drivers, and industry-related drivers are not significantly linked to GBTs adoption. This infers that these driver groups are not leading drivers of GBTs adoption within the Ghanaian construction industry. However, when cost and energy-related drivers, for example, must be analyzed, greater energy efficiency should be highlighted as a critical issue because Ghana has over the last four decades seen several major energy crises (Agyarko, 2013; Gyamfi et al., 2018).

9.4.3 Promotion Strategies

The analysis results infer that government regulations and standards are the most significant strategy to promote GBTs adoption in the developing country of Ghana, followed by incentives and R&D support. This may further explain why government-related barriers were also deemed the most significant barrier that hinders the GBTs adoption because it is rational to assume that government regulations and standards may greatly help overcome government-related barriers such as the lack of green building policies and regulations. This result may also imply that the respondents were consistent in their responses, contributing to the reliability of the results. The results indicated that government regulations and standards would have a significant positive influence on GBTs adoption. While there are several compelling arguments in the literature that support this finding (Chan et al., 2009a; Wong et al., 2016), quantifying the influence of government regulations and standards on GBTs adoption has been given very little scholarly attention. Mulligan et al. (2014) showed that there is little research on the connection between government regulation and the adoption of GBTs and practices. This study has quantified the influence of government regulations and standards in terms of promoting the adoption of GBTs and found that government regulations and standards would have a strong positive influence (path coefficient of 0.560). Government regulations and standards would have a significant influence on GBTs adoption because they would exert regulatory pressure on companies and stakeholders to adopt GBTs. As evidenced by Shen et al. (2017a), regulatory pressure is the main reason for stakeholders to adopt GBTs and practices. Gou et al. (2013) also showed that the adoption of GBTs and practices is one of the activities within the construction industry that "if you don't legislate, people won't start to do it". The present research implies that with mandatory green building policies and regulations in place, the Ghanaian government could significantly promote the adoption of GBTs. Faced with mandatory requirements from the government, stakeholders would have no other choice than to adopt GBTs in their projects in order to avoid fines and penalties due to noncompliance. However, after creating these policies and regulations, the government should attach great importance to their enforcement. This is because, owing to the lack of enforcement, construction stakeholders in some countries have reported low levels of awareness and usage of many of the green policies and regulations that have been issued and enacted by the policy makers (Mulligan et al., 2014). Therefore, better enforcement of green building policies after they have been developed is essential to promoting GBTs adoption. Likewise, green building rating systems are among the important strategies to promote the GBTs adoption. This agrees with Li et al. (2017), who stated that the establishment of reliable and effective green building rating systems is highly important to promoting green building. To promote GBTs adoption, green building rating systems need to be developed and implemented. Ghana however, at present, does not have its own green building rating systems and hence applies the US's LEED and the South Africa's Green Star rating systems. Although these international rating systems may be helpful in promoting GBTs adoption in Ghana, it would be more useful to create localized rating systems taking into account local sustainability priorities. In this respect, the government and other relevant stakeholders (e.g., advocates and NGO's) should help the Ghana Green Building Council to create relevant green building rating systems. This might also be a promising area for researchers to explore. Another key promotion strategy is availability of competent and proactive GBTs promotion teams and local authorities. According to DuBose et al. (2007), GBTs adoption stands a higher chance of success if there are strong champions to promote it. The study by Blayse and Manley (2004) also indicated that the presence of strong champions plays a pivotal role in promoting innovations, including green innovation, in the construction industry.

The statistical analysis results also showed that incentives and R&D support would have a significant positive influence on GBTs adoption (path coefficient of 0.413). Several previous studies concur that the strategy of providing green building incentives is extremely important to stimulating the adoption of GBTs and practices (Olubunmi et al., 2016; Qian et al., 2016; Shazmin et al., 2016; Shazmin et al., 2017; Onuoha et al., 2018). The research finding is also in parallel with that of Fernández et al., (2018), wherein it was identified that spending on R&D contributes positively to the implementation of sustainable development initiatives. Firstly, as defined by Ozdemir (2000), an incentive is “something that influences people to act in certain ways”. Within the construction industry, green building incentives motivate and compel stakeholders to adopt GBTs in their projects. Generally, there are two main categories of incentives provided by local authorities to promote the adoption of GBTs, which are financial and nonfinancial incentives. While financial incentives aim to offset the extra cost involved in adopting GBTs, nonfinancial incentives provide additional benefits or rights (e.g., technical assistance) to the GBTs adopter. To greatly promote GBTs adoption, the provision of financial incentives, such as direct grants, discounted development application fees, and tax reliefs, is strongly suggested to the government of Ghana. These financial incentives should be provided to stakeholders and firms that support GBTs adoption. Several other countries in the world including the United States, Italy, Spain, Romania, Canada, and Bulgaria (Shazmin et al., 2016) have also adopted financial incentives in promoting GBTs adoption; the Ghanaian government can learn from the experiences of these countries. Also, GBTs adoption would be promoted if the government and financial institutions provide low-interest loans to stakeholders who use

GBTs (The State of Michigan, 2010; Shan et al., 2017b). For the nonfinancial incentives, the government could adopt the gross floor area concession scheme, for example, which has been widely adopted to promote GBTs adoption in developed countries including Hong Kong and Singapore (Qian et al., 2016). Furthermore, having a strong R&D base in green technology would greatly help promote GBTs adoption as R&D is essential for discovering and developing innovative technologies and solutions (Zhang, 2015), and for studying the potential benefits of these innovations. Essentially, the result of this study provides additional support and argument for policy makers to promote GBTs R&D expenditure in both the public and private sectors. The government allocating a certain budget to establish green technology R&D centers and institutes would play an important part in shaping and promoting the adoption of GBTs.

On the other hand, this study found that awareness and publicity programs, education and information dissemination, and awards and recognition are not significantly linked to GBTs adoption. This suggests that these promotion strategy groups would not greatly influence GBTs adoption within the Ghanaian construction industry. The findings might be associated with the fact that effective green building regulations and incentives were regarded as more important to promote the adoption of GBTs than strategies that are linked to awareness and education.

This research highlights the need to reinforce the government's participation in promoting GBTs adoption. Using the promotion strategies of "government regulations and standards" and "incentives and R&D support" to overcome the government-related barriers may significantly help to promote the GBTs adoption. Similarly, it could be concluded that companies, such as developer, contractor, and consultant companies, have a key role to play in the adoption and promotion of GBTs, so they should consider the potential benefits of GBTs and be committed to GBTs adoption. This research has investigated the influences of various kinds of barriers, drivers, and promotion strategies on GBTs adoption. Based on the findings, an implementation strategy for the promotion of GBTs adoption is proposed and illustrated in Fig. 9.6. This implementation strategy has been proposed based on the findings from Ghana. Though it might be useful for other countries, following this research's methodology, similar implementation strategies could be developed for any other country. To ensure the effectiveness of the proposed implementation strategy, only the issues that were found to be significantly linked to the GBTs adoption were included in the implementation strategy. Besides, since it is only when potential adopters are motivated to adopt GBTs that they will think about the potential barriers (Potbhare et al., 2009), the identification of the significant drivers of the GBTs adoption is put as the first step in the implementation strategy. As the significant drivers can motivate and lead companies to implement GBTs, it is essential to promote them in the industry and the public. Identification of the significant barriers is the second step in the implementation strategy, while the third step is the identification of the significant strategies to address the barriers and promote the GBTs adoption. Policy makers and practitioners can apply this implementation strategy in their efforts to promote the adoption of GBTs in the construction industry.

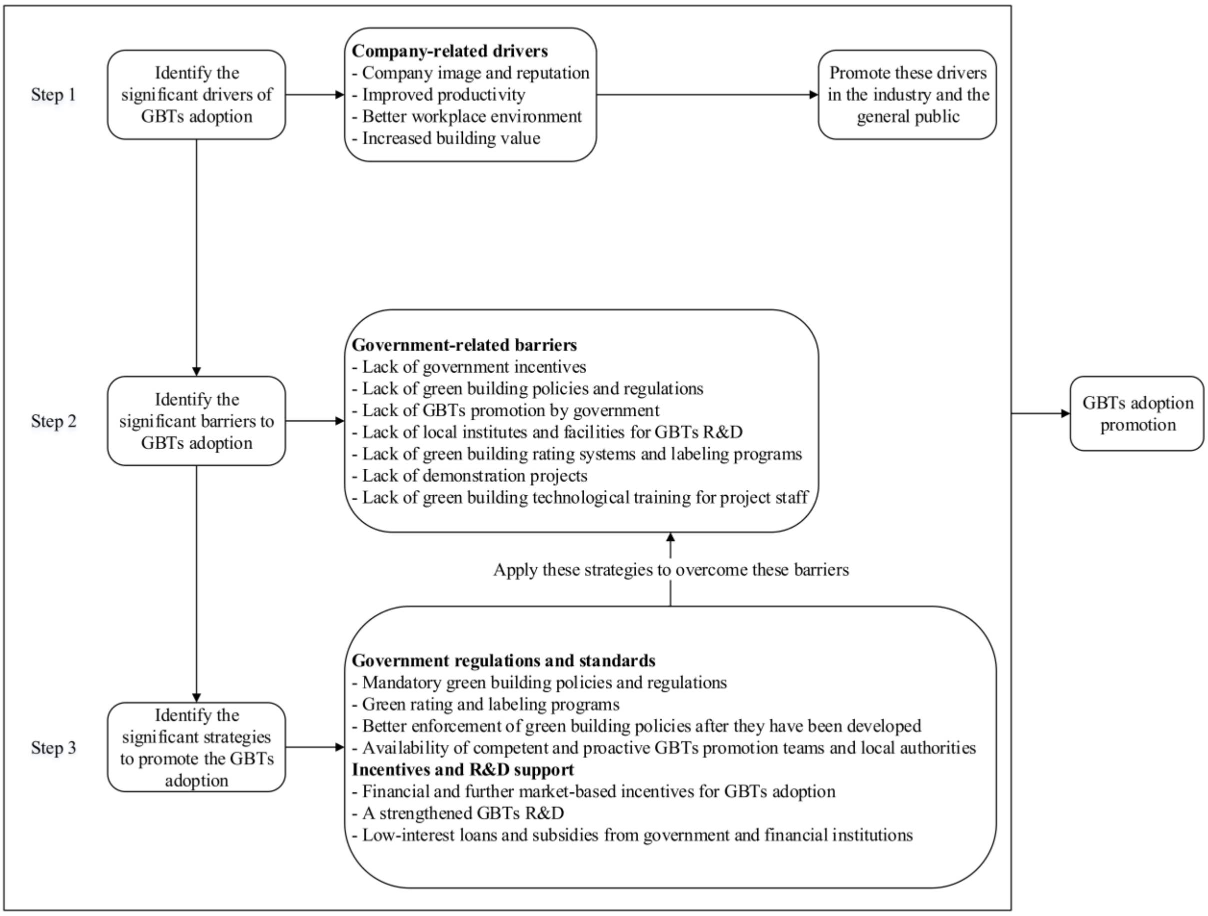


Fig. 9.6 An implementation strategy to promote GBTs adoption.

9.5 VALIDATION OF GBTs MODEL AND IMPLEMENTATION STRATEGY

According to Hu et al. (2016), validation represents a core final step within a research cycle. The main purpose of validation is to test the credibility and acceptability of the research outputs or models (Cheung, 2009; Ameyaw, 2014; Osei-Kyei, 2018). It should be highlighted that one challenge associated with the validation process is that there is no standard process to determine which validation methods and statistical tests should be used in the validation process (Sargent, 1991). Accordingly, Law (2007) claimed that the approach to validation depends mainly upon the specific purpose of the research study.

Validation has to do with "doing the right things" (Lucko and Rojas, 2010). That is, validation aims at ensuring that the various stages of the research methodology used adhered to the highest quality standards so as to generate results that are credible and acceptable to practitioners/users. Yeung (2007) argued that validation assesses the accuracy, reliability, practicality, suitability, objectivity, and appropriateness of a framework or system. Lucko and Rojas (2010) indicated that there are six types of validation in the construction management domain, namely construct validity, content validity, criterion validity, external validity, internal validity, and face validity. This study developed a validation questionnaire considering external validity, internal validity, construct validity, and content validity. External validity deals with the generalizability of the research outputs and models (Hu et al. 2016). In this study, external validity assesses whether the proposed GBTs model to aid sustainable housing development and implementation strategy to promote GBTs adoption can be generalized in Ghana. Internal validity deals with causality. Lucko and Rojas (2010) contended that internal validity is preoccupied with the derivability of relationships within data. In this research, internal validity assesses whether the aforesaid GBTs model and implementation strategy are easily understandable for practice (Osei-Kyei, 2018). Construct validity deals with the operationalization of theoretical constructs (Lucko and Rojas, 2010). It assesses whether the research measures what it is intended to measure (Hu et al. 2016). Explicitly, construct validity tests the suitability and comprehensiveness of the aforesaid GBTs model and implementation strategy. Lastly, content validity assesses whether the content of the research correctly reflects the reality (Lucko and Rojas, 2010). In this research, content validity assesses whether the GBTs model and implementation strategy could help sustainable housing development and promote GBTs adoption within Ghana, respectively, if they are properly used (Ameyaw, 2014).

The processes of research validation may be grouped into quantitative and qualitative (Yang et al. 2010; Ameyaw, 2014). While the quantitative approach of research validation uses research designs that involve the use of objective and numerical data to test hypothesized relationships among variables, the qualitative approach utilizes research designs that involve opinion-based, rather than, numerical data (Lucko and Rojas, 2010). An example of the quantitative approach is the employment of paired *t*-tests for validation (Ameyaw, 2014), whereas validating research outcomes and models on the basis of construct validity, external validity, internal validity, and content validity represents a typical example of the qualitative approach (Lucko and Rojas, 2010). In this study, a qualitative approach of research validation was adopted. The reason why this approach was implemented is that the proposed GBTs model and implementation strategy are associated with abstract constructs that are arduous to quantitatively assess (Ameyaw, 2014; Hu et al. 2016; Osei-Kyei, 2018). Hence, it was more appropriate to collect opinion-based data against prescribed assessment criteria.

9.5.1 Validation Survey

Similar to Ameyaw (2014) and Osei-Kyei (2018), a validation questionnaire survey was carried out to validate the credibility, suitability, and quality of the proposed GBTs model to support sustainable housing development, as well as the proposed implementation strategy to promote GBTs adoption in Ghana. Email-based questionnaire survey was adopted because it is not very expensive in terms of time and money, and allows a researcher to easily reach and communicate with target respondents (Andrews et al., 2003; Ameyaw, 2014). The validation questionnaire (see Appendix C) comprised six statements that were modified from Osei-Kyei (2018). Like the AHP survey, the eight respondents who have had over 6 years' green building experience within Ghana (Table 2.6) were invited to take part in the validation questionnaire survey. All of these respondents have also had over 10 years' experience within the Ghanaian construction industry. Eventually, five out of the eight respondents responded to the validation survey. This sample size was deemed adequate and reasonable for the validation survey, for the reason that it was comparable to the six and seven respondents for the validation questionnaire surveys by Osei-Kyei (2018) and Ameyaw (2014), respectively.

9.5.2 Validation Results

To each of the six validation statements, the respondents were asked to respond based on their level of agreement, using a five-point scale (1 = strongly disagree, 2 = disagree, 3 = natural, 4 = agree, and 5 = strongly agree). Table 10.1 displays the validation questionnaire survey results. It is noteworthy that all of the six validity statements with respect to both the GBTs model and implementation strategy had mean scores greater than 4.00. This result implies that, in general, the respondents considered all of the four validation aspects (external validity, internal validity, construct validity, and content validity) of both the GBTs model and implementation strategy to be adequate.

Table 9.14 Validation results of the GBTs model and implementation strategy.

No.	Validation aspects/statements	Responses R1	R2	R3	R4	R5	Mean
	The model of the GBTs to achieve sustainable housing development						
1	The identified GBTs to achieve sustainable housing development in Accra, Ghana are reasonable	5	5	5	4	4	4.60
2	The GBTs model is easily understandable and could be used in the industry	5	4	4	5	4	4.40
3	The GBTs within each GBT category are appropriate	4	4	4	5	4	4.20
4	The GBTs model is inclusive	5	3	4	4	5	4.20
5	The appropriate use of the GBTs model would definitely help to achieve sustainable housing development	5	4	4	5	5	4.60
6	Overall, the GBTs model is suitable for helping to achieve sustainable housing development in Ghana	4	4	5	3	5	4.20
	The implementation strategy to promote GBTs adoption						
1	The significant GBTs adoption drivers, barriers, and promotion strategies identified are reasonable and correctly reflect the current situations in Ghana	5	4	4	4	4	4.20
2	The implementation strategy is easily understandable and could be used in the industry	5	5	5	4	5	4.80
3	The steps within the implementation strategy are appropriate	4	5	5	5	4	4.60

4	The implementation strategy is inclusive	4	5	3	5	4	4.20
5	The appropriate use of the implementation strategy would definitely help to promote the GBTs adoption in the industry	5	5	5	4	4	4.60
6	Overall, the implementation strategy is suitable for helping to promote GBTs adoption in Ghana	5	4	5	4	5	4.60

Note: The five respondents are represented with R1-R5.

For both the GBTs model and implementation strategy, statements 1 and 6 were associated to external validity. Statement 1 obtained mean scores of 4.60 and 4.20 on the GBTs model and implementation strategy, respectively, implying that the identified GBTs to achieve sustainable housing development, as well as the significant GBTs adoption drivers, barriers, and promotion strategies identified are very reasonable within the context of Ghana. Besides, statement 6 had mean scores of 4.20 and 4.60 on the GBTs model and implementation strategy, respectively. These results first suggest that the overall suitability of the GBTs model for helping to achieve sustainable housing development within Ghana is high. The results also suggest that the overall suitability of the implementation strategy for the promotion of GBTs adoption in Ghana is high. Vis-à-vis the internal validity of the GBTs model and implementation strategy, the mean scores of statement 2 – 4.40 on the GBTs model; and 4.80 on the implementation strategy – show that both the GBTs model and implementation strategy are easily understandable and could be effectively used in the construction industry. Statements 3 and 4 were meant for measuring the construct validity of both the GBTs model and implementation strategy. Regarding the GBTs model, statement 3 obtained a mean score of 4.20, whereas it had a mean score of 4.60 on the implementation strategy. Also, statement 4 had a mean score of 4.20 on both the GBTs model and implementation strategy. These results first represent that the appropriateness of the GBTs within each GBT category in the GBTs model, as well as the appropriateness of the steps inside the implementation strategy are high. Second, the results indicate that the inclusiveness of both the GBTs model and implementation strategy are high. The content validity of the GBTs model and that of the implementation strategy were measure using statement 5. This statement had a mean score of 4.60 on both the GBTs model and implementation strategy. The result first implies that the tendency of achieving sustainable housing development would be high, if the GBTs model is properly used in the industry. It also represents that the tendency of achieving the successful promotion of the widespread GBTs adoption in the industry would be high, if the implementation strategy is appropriately used by policy makers, practitioners, stakeholders, and advocates.

In general, the high mean scores obtained for the four validation aspects suggest that the GBTs model to assist sustainable housing development in Ghana and the implementation strategy to promote GBTs adoption in Ghana are reliable, credible, inclusive, and appropriate. To facilitate the adoption and use of the GBTs model and implementation strategy, certain measures have been, or must be, implemented. First, the GBTs model and implementation strategy have been made available to users via publishing/reporting them in Darko et al. (2018a) and Darko et al. (under review), respectively. Second, they will be introduced to the GHGBC. Also, workshops, seminars, conferences, public tours, and the media might be used to introduce the GBTs model and implementation strategy, their backgrounds and significances to the industry practitioners, public and private policy makers, consultant, contractor, and developer companies, and the general public at large. As regards presenting the GBTs model and implementation strategy at conferences organized by industry associations and professional bodies, conferences organized by professional bodies such as the Ghana Institute of Construction (GIOC), Ghana Institute of Surveyors (GhIS), and Ghana Institute of Engineers (GhIE) might be valuable platforms to more efficiently and effectively introduce them to the local companies, practitioners, and policy makers. An in-depth and comprehensive explanation of the value of and how to use the GBTs model and implementation strategy to these local stakeholders can play a key role in facilitating their adoption and use within the industry.

9.6 CHAPTER SUMMARY, CONTRIBUTIONS, AND LIMITATIONS

Various barriers, drivers, and promotion strategies influence GBTs adoption in the construction industry. However, very little is known about the quantitative influences of barriers, drivers, and promotion strategies upon the GBTs adoption. This chapter examined and modeled the quantitative influences of various types of barriers, drivers, and promotion strategies on GBTs adoption inside the Ghanaian construction industry. The data were collected via a questionnaire survey with professionals with green building experience. PLS-SEM was used to analyze the data. The results showed that government-related barriers have a significant negative influence on GBTs adoption. Additionally, the results indicated that company-related drivers have a significant positive influence on GBTs adoption. Furthermore, it was found that "government regulations and standards" and "incentives and R&D support" are two promotion strategies that would have significant positive influences on GBTs adoption.

The practical implication is that to promote GBTs adoption in Ghana, the government needs to take a proactive role. For example, if incentives are provided for GBTs adoption, the lack of government incentives barrier can be addressed, and stakeholders would be motivated to adopt GBTs. Likewise, the lack of green building policies and regulations barrier could be addressed if the government and other public policy makers enact mandatory green building policies and regulations that would form regulatory pressure for companies and stakeholders to adopt GBTs. The policy makers should also promote GBTs R&D within both the public and private sectors. As per the results, company-related drivers are the major driver of the GBTs adoption. Thus, it may be necessary for companies to fully support and promote GBTs adoption because that may help them enhance their public image and reputation, improve their productivity, and gain other benefits.

The findings and models resulting from this research could be of great value and utility for researchers, policy makers, industry practitioners, and advocates seeking empirical quantitative evidence and explanations vis-à-vis the influences of barriers, drivers, and promotion strategies upon GBTs adoption within the construction industry. A clear understanding of which barriers, drivers, and promotion strategies could significantly influence GBTs adoption is beneficial to the successful adoption and promotion of GBTs in the construction industry. The awareness of the barriers and promotion strategies that are significantly correlated to GBTs adoption can aid policy makers and advocates to devise strategies to mitigate the barriers and hence promote the GBTs adoption. The appreciation of the drivers may help developer, contractor, and consultant companies to understand the important benefits GBTs adoption could offer, and thereafter help them to make informed decisions vis-à-vis whether or not to adopt GBTs. To the green building body of knowledge, the key contribution this research makes is developing quantitative models that explicate how various types of barriers, drivers, and promotion strategies influence GBTs adoption in the construction industry.

Though the research aim was achieved, there are some limitations to the conclusions. First, although the sample was adequate to perform the PLS-SEM, it is nevertheless a relatively small sample. However, the findings of this study still provide invaluable insights into the influences of different types of barriers, drivers, and promotion strategies on GBTs adoption and, when appropriately used, would definitely help in promoting GBTs adoption. In addition, because of the lack of a sampling frame for this study, the nonprobability sampling approach was used. In spite of the inherent limitation, this sampling approach was suitable for selecting respondents upon the basis of their willingness to participate in the research, rather than selecting them from the population randomly. Lastly, since the findings were mainly interpreted within the context of Ghana, there might be some limitations on generalizations, which is a common problem of country-specific studies.

Nonetheless, the findings and implications of this research may be useful to policy makers, practitioners, stakeholders, and advocates in other, especially developing, countries around the world. In addition, this study may be useful to foreign and international organizations interested in implementing and promoting GBTs within Ghana. Based on the findings, an implementation strategy that could help policy makers, practitioners, and advocates to promote GBTs adoption within the construction industry was proposed. While this implementation strategy could help to promote GBTs adoption within Ghana at this early stage of GBTs adoption and development, when the GBTs adoption activity becomes more mature, similar future studies should be done. These future studies are necessary because the barriers and drivers might change over time and, therefore, they might help to refine and improve the promotion strategies as well as the overall implementation strategy. Moreover, as part of the findings of this research, invaluable insights are offered into strategies to promote GBTs adoption. However, this research did not touch on the way forward for the government to implement these strategies, therefore warranting future research in this direction. Besides, the method in this study could be adopted to investigate the influences of barriers, drivers, and promotion strategies upon GBTs adoption in other countries, and the findings could be based upon to propose localized implementation strategies to help to more efficiently promote the widespread adoption of GBTs within those countries.

CHAPTER 10 CONCLUSIONS AND RECOMMENDATIONS

10.1 INTRODUCTION

Chapters 1-9 present various aspects of this research study. Chapter 1 offers an introduction to this research; Chapter 2 describes the research methodology; Chapters 3 and 4 review the extant literatures on the various issues addressed in this study; and Chapters 5-9 report upon empirical research about various areas. The present chapter concludes this research study. The research objectives are reviewed, and major conclusions presented. Moreover, this chapter explains the theoretical and practical significance and value of the research study. Finally, this chapter also touches on the limitations of the present research and offers recommendations for the future research.

10.2 REVIEW OF RESEARCH OBJECTIVES AND CONCLUSIONS

The overall aims of this study were to develop a model to outline GBTs to achieve sustainable housing development in Ghana, and to develop an implementation strategy to aid the promotion of GBTs adoption within Ghana. To achieve these aims, the following specific objectives were established:

1. To identify the important GBTs to achieve sustainable housing development in Ghana, and to contextualize the GBTs as a model to assist sustainable housing development;
2. To identify the major drivers for GBTs adoption in Ghana, and to examine the influences of the drivers on the GBTs adoption activity;
3. To identify the critical barriers to GBTs adoption in Ghana, and to examine the influences of the barriers on the GBTs adoption activity;

4. To identify the important strategies to promote GBTs adoption in Ghana, and to examine the likely influences of the strategies on the GBTs adoption activity; and
5. To develop an implementation strategy, based on the study results, to help in promoting GBTs adoption in Ghana.

A range of research methods were adopted in realizing these objectives (see Chapter 2). While the principal findings and conclusions relating to each research objective have been presented in Chapters 5-9, they are summarized and highlighted below via reviewing each of the research objectives.

Objective 1: To identify the important GBTs to achieve sustainable housing development in Ghana, and to contextualize the GBTs as a model to assist sustainable housing development

To identify the GBTs to achieve sustainable housing development, a comprehensive review of relevant published literature was first carried out in Chapter 3. Based upon this comprehensive literature review, 28 GBTs were identified. These 28 GBTs were evaluated on their importance via a questionnaire survey with industry professionals with green building experience in Ghana. The results (Chapter 5) indicated that 19 of the 28 GBTs examined in this study were important to achieve sustainable housing development. The top five important GBTs were: (1) application of natural ventilation, (2) application of energy-efficient lighting systems, (3) optimizing building orientation and configuration, (4) application of energy-efficient HVAC system, and (5) installation of water-efficient appliances and fixtures (e.g., low-flow toilets). The 19 important GBTs shaped a conceptual model of the GBTs to achieve sustainable housing development, and by means of AHP, priorities were established amongst the various GBTs in different GBT categories that were developed based upon the comprehensive literature review – energy efficiency, water efficiency, indoor environmental quality enhancement technologies, and control systems. Based on the AHP results, the conceptual model was modified to develop the final model of the GBTs to achieve the sustainable housing development. This final GBTs model was further validated with five industry professionals. In summary, the validation results verified the credibility and reliability of the GBTs model for sustainable housing development within Ghana. The results and model resulting from this research objective can support industry professionals responsible for decision-making during the design phase of housing development to identify, select, and implement the most apt combinations of GBTs to achieve sustainability in the housing development.

Objective 2: To identify the major drivers for GBTs adoption in Ghana, and to examine the influences of the drivers on the GBTs adoption activity

A comprehensive literature review concerning the drivers for GBTs and practices adoption was conducted in Chapter 3. Eventually, 21 drivers were extracted from the extant literature. These 21 drivers were assessed through a questionnaire survey with professionals with green building experience. The results (Chapter 6) first indicated that 16 drivers were significant. The top five drivers that greatly drive the GBTs adoption were identified as: (1) setting a standard for future design and construction, (2) greater energy efficiency, (3) improved occupants' health and well-being, (4) non-renewable resources conservation, and (5) reduced whole lifecycle costs. In order to draw more global implications from this research, the Ghanaian findings about the top GBTs adoption drivers were compared with findings from the developed country of the US. The results of the comparative analysis indicated that the highest rank of "setting a standard for future design and construction" is unique for GBTs adoption in only Ghana, not in the US. But, it was found that these three drivers, "greater energy efficiency", "improved occupants' health and well-being", and "reduced whole lifecycle costs", could be highly pivotal for driving all GBTs adoption activities irrespective of geographical locations. Factor analysis was applied to establish the underlying grouped drivers of the 16 significant GBTs adoption drivers. This was necessary for the examination and modeling of the quantitative influences of the drivers upon GBTs adoption. Five underlying grouped drivers were identified: (1) environment-related drivers, (2) company-related drivers, (3) economy and health-related drivers, (4) cost and energy-related drivers, and (5) industry-related drivers.

The PLS-SEM technique was implemented to examine and model the influences of the various types of drivers on GBTs adoption (see Chapter 9). The results indicated that company-related drivers have a significant positive influence upon GBTs adoption. The outcomes and developed PLS-SEM model of the drivers influencing GBTs adoption would be of great value and utility for researchers, policy makers, industry practitioners, as well as advocates seeking empirical quantitative evidence and explanations about the influences of drivers upon GBTs adoption in the construction industry. The PLS-SEM results on the GBTs adoption drivers also formed a key part of the foundation on which the implementation strategy to promote GBTs adoption in Ghana was developed within Chapter 9. The outcomes and model resulting from this research objective can help companies (such as developer, consultant, and contractor companies), policy makers, and advocates promote the more widespread adoption of GBTs within the construction industry. They can be instructive in GBTs adoption decision-making.

Objective 3: To identify the critical barriers to GBTs adoption in Ghana, and to examine the influences of the barriers on the GBTs adoption activity

Twenty-six potential barriers to GBTs adoption were identified via a comprehensive literature review conducted in Chapter 4. The questionnaire survey results (Chapter 7) indicated that 20 barriers were critical to the GBTs adoption in Ghana. The top five most critical barriers were: (1) higher costs of GBTs, (2) lack of government incentives, (3) lack of financing schemes (e.g., bank loans), (4) unavailability of GBTs suppliers, and (5) lack of local institutes and facilities for GBTs R&D. In order for this study to be of interest and useful to the broader/global audience, this study performed a comparative analysis of the top five GBTs adoption barriers between Ghana and three developed countries, the US, Canada, and Australia. The key finding was that whereas the most critical barriers to the GBTs adoption in Ghana generally differ from the most critical GBTs adoption barriers inside the developed countries of the US, Canada, and Australia, higher costs of GBTs remains a top barrier in all of the countries. This indicates that removing the higher cost barrier could play a significant role in promoting the GBTs adoption internationally. Factor analysis was applied to establish the underlying grouped barriers of the 20 critical GBTs adoption barriers. Five underlying barriers were obtained: (1) government-related barriers, (2) human-related barriers, (3) knowledge and information-related barriers, (4) market-related barriers, and (5) cost and risk-related barriers. Based on these barrier groupings, policy makers, practitioners, stakeholders, and advocates might be able to come up with holistic and integrated strategies to overcome the barriers and thus promote the GBTs adoption (Chan et al., 2016).

The PLS-SEM technique was implemented to examine and model the influences of the various types of barriers on GBTs adoption (Chapter 9). The results indicated that government-related barriers have a significant negative influence upon GBTs adoption. The results and developed PLS-SEM model of the barriers influencing GBTs adoption could be of great value and utility for researchers, policy makers, industry practitioners, as well as advocates seeking empirical quantitative evidence and explanations vis-à-vis the influences of barriers upon GBTs adoption in the construction industry. The PLS-SEM results on the GBTs adoption barriers also formed a major part of the foundation on which the implementation strategy to promote GBTs adoption in Ghana was developed inside Chapter 9. The outcomes and model resulting from this research objective could help policy makers, practitioners, and advocates promote the more widespread adoption of GBTs within the construction industry. They might also be useful for international organizations interested in implementing and promoting GBTs in Ghana.

Objective 4: To identify the important strategies to promote GBTs adoption in Ghana, and to examine the likely influences of the strategies on the GBTs adoption activity

So as to identify the strategies to promote GBTs adoption, a comprehensive review of relevant literature was done within Chapter 4, which allowed the identification of 12 potential strategies to promote the GBTs adoption. This 12-promotion strategy list was improved via face-to-face interviews with industry professionals with green building experience in Ghana. In the end, 15 potential strategies to promote GBTs adoption were identified thru a comprehensive literature review and interviews with industry professionals. Thereafter, the relative importance of these strategies was examined through a questionnaire survey with industry professionals in Ghana. The results (Chapter 8) indicated that all the 15 strategies examined were important. However, the top five important strategies to promote the GBTs adoption were (1) more publicity through media (e.g., print media, radio, television, and internet), (2) GBTs-related educational and training programs for developers, contractors, and policy makers, (3) availability of institutional framework for effective GBTs implementation, (4) a strengthened GBTs R&D, and (5) financial and further market-based incentives for GBTs adoption. Comparing the results with the developed country of the US revealed that the most important strategies to promote

GBTs adoption in Ghana generally differ from the most important strategies to promote GBTs adoption within the US. However, the findings suggested that irrespective of geographical locations, “a strengthened GBTs R&D” and “financial and further market-based incentives for GBTs adoption” are two strategies that can greatly assist in promoting GBTs adoption. Thus, these strategies need more attention in order to promote the GBTs adoption worldwide. Factor analysis was used to establish the underlying strategy groupings of the 15 strategies to promote GBTs adoption. Five underlying strategy groupings were attained: (1) government regulations and standards, (2) incentives and R&D support, (3) awareness and publicity programs, (4) education and information dissemination, and (5) awards and recognition.

The PLS-SEM technique was implemented to examine and model the influences of the various types of promotion strategies upon the GBTs adoption (Chapter 9). The results indicated that “government regulations and standards” and “incentives and R&D support” would have significant positive influences upon the GBTs adoption. The results and developed PLS-SEM model of the promotion strategies influencing GBTs adoption may be of great value and utility for researchers, policy makers, industry practitioners, as well as advocates seeking empirical quantitative evidence and explanations about the influences of promotion strategies on GBTs adoption in the construction industry. The PLS-SEM results on the GBTs adoption promotion strategies also formed a key part of the foundation upon which the implementation strategy to promote GBTs adoption in Ghana was developed in Chapter 9. The outcomes and model from this research objective can help policy makers, industry stakeholders, and advocates formulate and implement proper strategies to promote the widespread GBTs adoption in the construction industry.

Objective 5: To develop an implementation strategy, based on the study results, to help in promoting GBTs adoption in Ghana.

Based upon the PLS-SEM results regarding the quantitative influences of barriers, drivers, and promotion strategies on GBTs adoption, an implementation strategy to promote GBTs adoption in Ghana was developed in Chapter 9. Similar to the implementation strategy to promote the adoption of green building guidelines within India, developed by Potbhare et al. (2009), the implementation strategy to promote GBTs adoption in Ghana, developed in the present study, comprises three key steps: Step 1 – identification of the significant drivers of GBTs adoption; Step 2 – identification of the significant barriers to GBTs adoption; and Step 3 – identification of the significant strategies to promote the GBTs adoption. Each of these steps within the implementation strategy incorporates only the issues that, based on the PLS-SEM, were found to have significant influences upon the GBTs adoption, helping to ensure the effectiveness of the implementation strategy. The implementation strategy was further validated with five industry professionals. In conclusion, the validation results demonstrated the credibility and reliability of the implementation strategy for the promotion of GBTs adoption in Ghana.

10.3 VALUE AND SIGNIFICANCE OF THE STUDY

The findings of this research have been presented and thoroughly discussed in Chapters 5-9. In these chapters, based upon the research findings, a number of recommendations are put forward for policy makers, industry practitioners and stakeholders, as well as advocates to consider in their efforts to promote the GBTs adoption. Besides, the value, significance, and contributions of this study based on each research objective have been thoroughly discussed in these chapters. So, in order to avoid significant, needless repetitions, this section only briefly summarizes the value and significance of this research. This study makes significant contributions to industrial practice and the green building body of knowledge, especially for developing countries. The findings of each research objective offer invaluable practical implications for GBTs adoption and promotion within Ghana and other, especially developing, countries the world over.

First, this research identified the important GBTs to achieve sustainable housing development in Ghana, with a particular focus on Accra. This is the first study to do so within the context of Ghana, and the clear understanding of the GBTs and the developed GBTs model may help the practitioners in the country to identify, select, and implement the most proper combinations of GBTs to achieve the sustainable housing development. While the findings might be useful for sustainable housing development within other cities of Ghana, and beyond, that share similar environmental characteristics with Accra, this study creates a valuable basis for exploring the important GBTs to attain sustainable housing development in other cities. The proposed GBTs could be used for conducting similar studies in various locations.

Second, analyzing and modeling the GBTs adoption barriers, drivers, and promotion strategies within Ghana provided findings that not only address important gaps in the green building body of knowledge for developing countries, but are also invaluable for policy makers, practitioners, stakeholders, companies, and advocates to promote the GBTs adoption within the construction industry. The findings are also beneficial for international and foreign organizations interested in the promotion of GBTs adoption in Ghana to attain more sustainable buildings development. The implementation strategy developed in this study could be used for the promotion of GBTs adoption within Ghana and other countries. Overall, this study is very important for Ghana and other developing countries, as Ghana and several other developing countries are at the moment still within the early stages of GBTs adoption and development. Lastly, this study is significant to the sustainable development of the construction industry at large.

10.4 LIMITATIONS OF THE STUDY

Despite achieving the research aims and objectives, this study still has certain limitations that should be acknowledged. First, because GBTs adoption in Ghana is limited and still in its initial stages, the questionnaire surveys for this research study were based on relatively small samples of industry experts with green building experience. Second, the analysis of the GBTs to achieve sustainable housing development was limited to Accra, Ghana. It may be hard to generalize the findings beyond Accra. Moreover, as the evaluations and assessments made in this study were generally subjective, they might be influenced by the respondents' experiences and attitudes. Additionally, this research focused specifically on GBTs adoption in Ghana and consequently there might be some limitations on generalization. Other research objective-specific limitations can be found in the chapter summary, contributions, and limitations sections of Chapters 5-9.

10.5 RECOMMENDATIONS FOR FUTURE RESEARCH

Although the present study has analyzed several issues that are crucial to the promotion of the GBTs adoption in the construction industry, there are still avenues for future research:

First, this research identified the important GBTs to achieve sustainable housing development and contextualized these as a model to assist sustainable housing development. Future research could focus on specific GBTs and use the AHP or other multi-criteria decision-making methods to assess the criteria that affect the selection of each GBT. Based on the results, robust decision support systems could be established to support the selection of specific GBTs for sustainable housing development in the industry.

Second, the implementation strategy to promote GBTs adoption developed in this research has been developed based upon the current significant issues associated with GBTs adoption within Ghana. Since these issues might change over time, it may be useful for future research to follow the methodology of this research to refine and improve this implementation strategy, especially when the GBTs adoption activity becomes more mature.

Third, although the findings and implications of this study may be useful for policy makers and practitioners in other developing countries, since this study focused on the developing country of Ghana, future studies could focus on other developing countries. This could help to establish findings, models, and implementation strategies that can aid to more effectively and efficiently promote the GBTs adoption within specific countries. This is necessary as different countries have different regulations and conditions that shape their green building approach (Aktas and Ozorhon, 2015; WorldGBC, 2017a). Comparative studies between many more developing and developed countries could also be done in the future to highlight the key GBTs adoption lessons that developing countries could learn from the developed ones.

Lastly, future research must target larger sample sizes. The present study analyzed the opinions of professionals from developer, consultant, and contractor companies. As the findings suggest that the government has a critical role to play in the promotion of the GBTs adoption, including the views of government officials or agencies (or policy makers) might be a good approach for the future research to increase the sample size.

Other research objective-specific recommendations for future research can be found within the chapter summary, contributions, and limitations sections of Chapters 5-9.

10.6 CHAPTER SUMMARY

This chapter presented the conclusions and recommendations of this research study. The major conclusions from the five research objectives were presented. Similarly, the significance of this study was summarized, followed by the limitations of this study and recommendations for future research. That is, this chapter closes this research study. The following pages contain the appendices and references for this study.

APPENDIX A

QUESTIONNAIRE FOR GENERAL SURVEY

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DEPARTMENT OF
BUILDING & REAL ESTATE
建築及房地產學系

Dear Sir/Madam,

Invitation to participate in a Ph.D. research study

We write to humbly invite you to take part in an ongoing Ph.D. study entitled **"Adoption of green building technologies in Ghana: Development of a model of green building technologies and issues influencing their adoption"**. This Ph.D. study is being carried out under Professor Albert P. C. Chan's supervision, and funded via The Hong Kong Polytechnic University's Postgraduate Studentship Scholarship. Moreover, it primarily aims at promoting green building technologies (GBTs) adoption in Ghana. This survey is core to achieving the research aims and objectives.

The survey questionnaire is attached to this letter and will take approximately 15-20 minutes to complete. Be assured that all of the responses and information we collect will be kept in the strictest confidence and only used for academic purposes. We are willing to share the research outputs with you upon your request.

We would highly appreciate if you could also suggest other knowledgeable practitioners who would be willing to contribute to this research to us.

Thank you for your invaluable time. If you have any questions, please email Amos Darko at amos.darko@ or Professor Albert P. C. Chan at albert.chan@

Yours sincerely,

Amos Darko (Ph.D. Candidate)

Professor Albert P. C. Chan (Head of the Department of Building and Real Estate, PolyU)

Adoption of Green Building Technologies in Ghana: Development of a Model of Green Building Technologies and Issues Influencing Their Adoption

Instructions

1. Please draw upon your experience inside the construction market of Ghana to complete this survey.
2. Please complete the questionnaire within **3 weeks**, and the completed questionnaire will be collected in person by the researcher.
3. Your mobile number: ___________________ and email address: _____________________

Section One: Background Information of Respondent

Q1. What type of company do you work for?
Contractor ☐; Consultant ☐; Developer ☐; Other(s) (specify): ___________________

Q2. What type of building projects does your organization specialize in? (tick all that apply).
Residential ☐; Commercial/Office ☐; Educational ☐; Industrial ☐; Other(s) (specify): ___________________

Q3. What is your profession?
Engineer ☐; Architect ☐; Project manager ☐; Other(s) (specify): ___________________

Q4. Your years of working experience in the construction industry.
1-5yrs ☐; 6-10yrs ☐; 11-15yrs ☐; 16-20yrs ☐; Over 20yrs ☐

Q5. Your years of experience in green building.
1-3yrs ☐; 4-6yrs ☐; Over 6yrs ☐

Section Two: GBTs to Achieve Sustainable Housing Development in Accra, Ghana

Please indicate the level of importance of each of the following GBTs to achieve sustainable housing development in Accra, Ghana. Use the following scale: **1 = not important; 2 = less important; 3 = neutral; 4 = important; 5 = very important**.

Note: You may refer to the definition of a GBT, if necessary, in section seven (last page).

No.	GBTs to achieve sustainable housing development	Level of importance
	Energy efficiency technologies	Low ⟺ High
1	Application of energy-efficient lighting systems	☐1; ☐2; ☐3; ☐4; ☐5
2	Application of energy-efficient windows	☐1; ☐2; ☐3; ☐4; ☐5
3	Application of energy-efficient HVAC system	☐1; ☐2; ☐3; ☐4; ☐5
4	Use of energy-efficient appliances (e.g., energy-efficient refrigerators)	☐1; ☐2; ☐3; ☐4; ☐5
5	Application of solar technology to generate electricity	☐1; ☐2; ☐3; ☐4; ☐5
6	Application of rooftop wind turbines to generate electricity	☐1; ☐2; ☐3; ☐4; ☐5
7	Integrative use of natural lighting with electric lighting technology	☐1; ☐2; ☐3; ☐4; ☐5
8	Application of solar water heating technology	☐1; ☐2; ☐3; ☐4; ☐5
9	Application of solar shading devices	☐1; ☐2; ☐3; ☐4; ☐5

10	Application of ground source heat pump technology	☐1; ☐2; ☐3; ☐4; ☐5
11	Use of wooden logs to provide structure and insulation	☐1; ☐2; ☐3; ☐4; ☐5
12	Optimizing building orientation and configuration	☐1; ☐2; ☐3; ☐4; ☐5
13	Application of natural ventilation	☐1; ☐2; ☐3; ☐4; ☐5
	Water efficiency technologies	
14	Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	☐1; ☐2; ☐3; ☐4; ☐5
15	Rainwater harvesting technology	☐1; ☐2; ☐3; ☐4; ☐5
16	Grey water reclaiming and reuse technology	☐1; ☐2; ☐3; ☐4; ☐5
	Indoor environmental quality enhancement technologies	
17	Ample ventilation for pollutant and thermal control	☐1; ☐2; ☐3; ☐4; ☐5
18	Application of indoor CO_2 monitoring devices	☐1; ☐2; ☐3; ☐4; ☐5
19	Application of low emission (low-E) finishing materials	☐1; ☐2; ☐3; ☐4; ☐5
20	Optimizing building envelope thermal performance	☐1; ☐2; ☐3; ☐4; ☐5
21	Application of solar chimney for enhanced stack ventilation	☐1; ☐2; ☐3; ☐4; ☐5
22	Use of efficient type of lighting (lighting output and color)	☐1; ☐2; ☐3; ☐4; ☐5
	Materials and resources efficiency technologies	
23	Underground space development technology	☐1; ☐2; ☐3; ☐4; ☐5
24	Use of environmentally friendly materials for HVAC systems	☐1; ☐2; ☐3; ☐4; ☐5
	Control systems	
25	HVAC control	☐1; ☐2; ☐3; ☐4; ☐5
26	Security control	☐1; ☐2; ☐3; ☐4; ☐5
27	Audio visual control	☐1; ☐2; ☐3; ☐4; ☐5
28	Occupancy/motion sensors	☐1; ☐2; ☐3; ☐4; ☐5
	If there are any GBTs omitted by this questionnaire, please list and rate them	
1		☐1; ☐2; ☐3; ☐4; ☐5
2		☐1; ☐2; ☐3; ☐4; ☐5
3		☐1; ☐2; ☐3; ☐4; ☐5
4		☐1; ☐2; ☐3; ☐4; ☐5
5		☐1; ☐2; ☐3; ☐4; ☐5

Section Three: General Statements About GBTs Adoption

Please indicate your level of agreement with the following statements about GBTs adoption in Ghana. Use the following scale: **1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree**.

No.	Statements	Level of agreement Low ⟺ High
1	Specifications should consider GBTs	☐1; ☐2; ☐3; ☐4; ☐5
2	Current construction has not sufficiently considered GBTs	☐1; ☐2; ☐3; ☐4; ☐5
3	GBTs information and databases are not adequately available in your company	☐1; ☐2; ☐3; ☐4; ☐5
4	Our senior management is willing to support GBTs adoption	☐1; ☐2; ☐3; ☐4; ☐5
5	GBTs adoption should be forced by government	☐1; ☐2; ☐3; ☐4; ☐5
6	Guides for implementing GBTs cannot be easily found in Ghana	☐1; ☐2; ☐3; ☐4; ☐5

Section Four: Drivers for GBTs Adoption

Please indicate your level of agreement on each of the following drivers for GBTs adoption in Ghana. Use the following scale: **1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree**.

No.	Drivers for GBTs adoption	Level of agreement Low ⟺ High
1	Greater energy efficiency	☐1; ☐2; ☐3; ☐4; ☐5
2	Reduced whole lifecycle costs	☐1; ☐2; ☐3; ☐4; ☐5
3	Company image and reputation	☐1; ☐2; ☐3; ☐4; ☐5
4	Improved occupants' health and well-being	☐1; ☐2; ☐3; ☐4; ☐5
5	Improved occupants' productivity	☐1; ☐2; ☐3; ☐4; ☐5
6	Non-renewable resources conservation	☐1; ☐2; ☐3; ☐4; ☐5
7	Reduced environmental impact	☐1; ☐2; ☐3; ☐4; ☐5
8	Improved indoor environmental quality	☐1; ☐2; ☐3; ☐4; ☐5
9	Greater water efficiency	☐1; ☐2; ☐3; ☐4; ☐5
10	Commitment to social responsibility	☐1; ☐2; ☐3; ☐4; ☐5
11	Waste reduction	☐1; ☐2; ☐3; ☐4; ☐5
12	High return on investment	☐1; ☐2; ☐3; ☐4; ☐5
13	Reduced use of construction materials in the economy	☐1; ☐2; ☐3; ☐4; ☐5
14	Attraction and retention of quality employees	☐1; ☐2; ☐3; ☐4; ☐5
15	Enhanced marketability	☐1; ☐2; ☐3; ☐4; ☐5
16	High rental income	☐1; ☐2; ☐3; ☐4; ☐5
17	Better workplace environment	☐1; ☐2; ☐3; ☐4; ☐5
18	Increased building value	☐1; ☐2; ☐3; ☐4; ☐5
19	Setting a standard for future design and construction	☐1; ☐2; ☐3; ☐4; ☐5
20	Job creation opportunity	☐1; ☐2; ☐3; ☐4; ☐5
21	Facilitating a culture of best practice sharing	☐1; ☐2; ☐3; ☐4; ☐5
	If there are any drivers omitted by this questionnaire, please list and rate them	
1		☐1; ☐2; ☐3; ☐4; ☐5
2		☐1; ☐2; ☐3; ☐4; ☐5
3		☐1; ☐2; ☐3; ☐4; ☐5
4		☐1; ☐2; ☐3; ☐4; ☐5
5		☐1; ☐2; ☐3; ☐4; ☐5

Section Five: Barriers to GBTs Adoption

Please indicate how critical each of the following barriers is to GBTs adoption in Ghana. Use the following scale: **1 = not critical; 2 = less critical; 3 = neutral; 4 = critical; 5 = very critical**.

No.	Barriers to GBTs adoption	Level of criticality Low ⟺ High
1	Higher costs of GBTs	☐1; ☐2; ☐3; ☐4; ☐5
2	Lack of GBTs databases and information	☐1; ☐2; ☐3; ☐4; ☐5
3	Lack of professional knowledge and expertise in GBTs	☐1; ☐2; ☐3; ☐4; ☐5
4	Lack of awareness of GBTs and their benefits	☐1; ☐2; ☐3; ☐4; ☐5
5	Lack of government incentives	☐1; ☐2; ☐3; ☐4; ☐5
6	Lack of local institutes and facilities for GBTs research and development (R&D)	☐1; ☐2; ☐3; ☐4; ☐5
7	Lack of green building policies and regulations	☐1; ☐2; ☐3; ☐4; ☐5
8	Lack of green building rating systems and labeling programs	☐1; ☐2; ☐3; ☐4; ☐5
9	Unfamiliarity of construction professionals with GBTs	☐1; ☐2; ☐3; ☐4; ☐5
10	High degree of distrust about GBTs	☐1; ☐2; ☐3; ☐4; ☐5
11	Conflicts of interests among various stakeholders in adopting GBTs	☐1; ☐2; ☐3; ☐4; ☐5
12	Lack of interest from clients and market demand	☐1; ☐2; ☐3; ☐4; ☐5
13	Unavailability of GBTs in the local market	☐1; ☐2; ☐3; ☐4; ☐5
14	Adoption of GBTs is time consuming and causes project delays	☐1; ☐2; ☐3; ☐4; ☐5
15	Resistance to change from the use of traditional technologies	☐1; ☐2; ☐3; ☐4; ☐5

16	Complex and rigid requirements involved in adopting GBTs	☐1; ☐2; ☐3; ☐4; ☐5
17	Lack of GBTs promotion by government	☐1; ☐2; ☐3; ☐4; ☐5
18	Lack of importance attached to GBTs by senior management	☐1; ☐2; ☐3; ☐4; ☐5
19	Risks and uncertainties involved in adopting new technologies	☐1; ☐2; ☐3; ☐4; ☐5
20	Lack of green building technological training for project staff	☐1; ☐2; ☐3; ☐4; ☐5
21	Unavailability of GBTs suppliers	☐1; ☐2; ☐3; ☐4; ☐5
22	Lack of financing schemes (e.g., bank loans)	☐1; ☐2; ☐3; ☐4; ☐5
23	High market prices and rental charges of green buildings resulting from GBTs application	☐1; ☐2; ☐3; ☐4; ☐5
24	Long payback periods from adopting GBTs	☐1; ☐2; ☐3; ☐4; ☐5
25	Lack of demonstration projects	☐1; ☐2; ☐3; ☐4; ☐5
26	Limited experience with the use of nontraditional procurement methods	☐1; ☐2; ☐3; ☐4; ☐5
	If there are any barriers omitted by this questionnaire, please list and rate them	
1		☐1; ☐2; ☐3; ☐4; ☐5
2		☐1; ☐2; ☐3; ☐4; ☐5
3		☐1; ☐2; ☐3; ☐4; ☐5
4		☐1; ☐2; ☐3; ☐4; ☐5
5		☐1; ☐2; ☐3; ☐4; ☐5

<u>Section Six: Strategies to Promote GBTs Adoption</u>

Please indicate the level of importance of each of the following strategies to promote the GBTs adoption in Ghana. Use the following scale: **1 = not important; 2 = less important; 3 = neutral; 4 = important; 5 = very important**.

No.	Strategies to promote GBTs adoption	Relative importance Low ⟺ High
1	Financial and further market-based incentives for GBTs adoption	☐1; ☐2; ☐3; ☐4; ☐5
2	Mandatory green building policies and regulations	☐1; ☐2; ☐3; ☐4; ☐5
3	Green rating and labeling programs	☐1; ☐2; ☐3; ☐4; ☐5
4	Better enforcement of green building policies after they have been developed	☐1; ☐2; ☐3; ☐4; ☐5
5	Low-cost loans and subsidies from government and financial institutions	☐1; ☐2; ☐3; ☐4; ☐5
6	Public environmental awareness creation through workshops, seminars, and conferences	☐1; ☐2; ☐3; ☐4; ☐5
7	More publicity through media (e.g., print media, radio, television, and internet)	☐1; ☐2; ☐3; ☐4; ☐5
8	GBTs-related educational and training programs for developers, contractors, and policy makers	☐1; ☐2; ☐3; ☐4; ☐5
9	Availability of better information on cost and benefits of GBTs	☐1; ☐2; ☐3; ☐4; ☐5
10	Availability of competent and proactive GBTs promotion teams and local authorities	☐1; ☐2; ☐3; ☐4; ☐5
11	Availability of institutional framework for effective GBTs implementation	☐1; ☐2; ☐3; ☐4; ☐5
12	A strengthened GBTs R&D	☐1; ☐2; ☐3; ☐4; ☐5
13	Acknowledging and rewarding GBTs adopters publicly	☐1; ☐2; ☐3; ☐4; ☐5
14	Support from executive management	☐1; ☐2; ☐3; ☐4; ☐5
15	More GBTs adoption advocacy by the Ghana Environmental Protection Agency	
	If there are any strategies omitted by this questionnaire, please list and rate them	
1		☐1; ☐2; ☐3; ☐4; ☐5
2		☐1; ☐2; ☐3; ☐4; ☐5
3		☐1; ☐2; ☐3; ☐4; ☐5
4		☐1; ☐2; ☐3; ☐4; ☐5
5		☐1; ☐2; ☐3; ☐4; ☐5

-The End–

Thank you for your valuable time and participation

Section Seven: Definition of GBTs

No.	GBTs to achieve sustainable housing development	Definition
	Energy efficiency technologies	
1	Application of energy-efficient lighting systems	Installation of energy saving lighting systems such as T-5 fluorescent tube with electronic ballast, LED lights, solar lamps, and voice-activated light perception technology
2	Application of energy-efficient windows	This includes advanced glazing systems such as Low-E glazing, gas-filled glazing, triple-pane windows, self-operable windows, and double window
3	Application of energy-efficient HVAC system	Heating, ventilation, and air-conditioning (HVAC) system that use less energy
4	Use of energy-efficient appliances (e.g., energy-efficient refrigerators)	Appliances such as energy-efficient rated refrigerators, dishwashers, and washing machines
5	Application of solar technology to generate electricity	Application of systems that collect and convert solar (sun) energy into other useful forms of energy (mainly electricity)
6	Application of rooftop wind turbines to generate electricity	Renewable energy source that generates energy by wind power
7	Integrative use of natural lighting with electric lighting technology	Designing the building in a way that brings in natural light to supplement electric lighting
8	Application of solar water heating technology	Systems that utilize sun rays to heat water for various domestic purposes
9	Application of solar shading devices	Technologies to avoid excessive heat or solar gain into the building, useful especially in very sunny warm climates
10	Application of ground source heat pump technology	A renewable energy technology for heating and cooling internal spaces by transferring heat from the ground
11	Use of wooden logs to provide structure and insulation	Using wooden materials for structural insulation
12	Optimizing building orientation and configuration	Proper orientation of the building to impart energy savings
13	Application of natural ventilation	Taking advantage of nature to provide ventilation in design
	Water efficiency technologies	
14	Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	This includes appliances such as dual flush WCs and water saving faucets that can save up to 50% of water than conventional ones
15	Rainwater harvesting technology	Water management system that collects and recycles rainwater for purposes such as irrigation and drainage, and eliminates the need to use potable water for such purposes
16	Grey water reclaiming and reuse technology	A system for collecting, filtering, and keeping of waste water for reuse where potable water must not be used
	Indoor environmental quality enhancement technologies	
17	Ample ventilation for pollutant and thermal control	Providing adequate ventilation in order to achieve good indoor air quality
18	Application of indoor CO_2 monitoring devices	Devices installed within the building to ensure good supply of fresh air and minimize energy waste in ventilation
19	Application of low emission (low-E) finishing materials	Using materials such as ceiling coverings and wall panel systems with low emissions to promote the health of occupants and decrease harmful indoor airborne pollutants
20	Optimizing building envelope thermal performance	An approach to enhance the thermal insulation, reflectivity, heat storage capacity, etc. of the building envelope
21	Application of solar chimney for enhanced stack ventilation	Designing to ensure effective air movement (in and out) within a building. Providing solar induced-air ventilation by using solar chimney. Air in the chimney is heated by solar energy.
22	Use of efficient type of lighting (lighting output and color)	For example, light emitting diode (LED) bulbs that improve room illuminance and are about 80% more energy-efficient than conventional bulbs
	Materials and resources efficiency technologies	
23	Underground space development technology	Making good use of underground design to provide ample building space while saving land resources
24	Use of environmentally friendly materials for HVAC systems	Using materials that have less negative impacts on the environment for heating, ventilation, and air-conditioning (HVAC) systems

	Control systems	
25	HVAC control	Systems that control and ensure optimal energy savings in HVAC systems
26	Security control	Security control systems that may employ radio frequency or ultrasonic signals to communicate information from entry sensing devices to central alarms for ensuring the safety of residents of sustainable homes
27	Audio visual control	Systems for controlling and enhancing home entertainment media
28	Occupancy/motion sensors	Used in buildings to control electric lighting. Lights are turned on and off automatically in response to a detection of or no detection of motion. This saves energy in lighting
Some references: Zhang et al., 2011a, b; Ahmad et al., 2016; Roufechaei et al., 2014		

APPENDIX B

QUESTIONNAIRE FOR AHP SURVEY

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DEPARTMENT OF
BUILDING & REAL ESTATE
建築及房地產學系

Dear Sir/Madam,

We are highly thankful for your kind assistance and contribution to our previous questionnaire survey about GBTs adoption in Ghana. Based upon the valuable feedback you provided in the previous survey, we have been able to identify the GBTs that are important to attain sustainable housing development in Accra, Ghana. Based upon your background information you provided in the previous survey, we found that you are one of the most experienced practitioners in terms of green building in Ghana. Hence, you are among the eight practitioners selected to participate in this second, final round of the survey.

We kindly request your assistance in evaluating the comparability of the important GBTs using analytic hierarchy process (AHP). This will help us to establish priorities among the GBTs and, as a result, develop a GBTs model to assist sustainable housing development in Ghana. Please see below for the research problem and guidelines for undertaking the AHP evaluation.

Problem

You are posed with the problem of selecting GBTs for a proposed residential building within a residential area in Accra, Ghana. The client tells you that while she is willing to spend money on GBTs to achieve a "sustainable building", she needs the building to be equipped with the most proper combination of the different GBTs. Also, the client has asked you to consider the climatic conditions of Accra in selecting the GBTs in order to optimize the performance of the building. You have decided to select the GBTs on the basis of their relative importance, and to employ the AHP to make the GBT choices that will best meet the needs of the client.

Guidelines for assigning importance weights

Through pairwise comparisons, each GBT must be assessed to indicate the strength with which it dominates another with respect to the GBT category under which they are compared, and in terms of achieving the main objective (i.e., achieving sustainable housing development). The scale for assigning the importance weights is a 9-point scale, defined in the table below.

Scale

Weight	Definition	Explanation
1	Equal importance	Two GBTs contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one GBT over another
5	Essential or strong importance	Experience and judgment strongly favor one GBT over another
7	Very strong importance	A GBT is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one GBT over another is the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is necessary
Reciprocals of previous values	If factor "*i*" has one of the previously mentioned numbers assigned to it when compared to factor "*j*", then *j* has the reciprocal value when compared to *i*.	

Two GBTs can be weighted from 1 to 9 depending upon whether they are equal or one is more important. The GBT that is less important takes the inverse of the scale. It can be found from the table above that when two GBTs have equal importance, a score of 1 is given. This normally occurs when a GBT is compared with itself. Moreover, when one GBT is from moderately to strongly important, it takes a score of 4 and so on, and you can continue to quantify how much each GBT is important than the other. For example, in the table below, "energy efficient HVAC system" is moderately important than "energy efficient lighting systems', and very strongly important than "energy efficient windows". This means that when "energy efficient lighting systems" is compared with "energy efficient HVAC system", "energy efficient lighting systems" is preferred by 1/3 of "energy efficient HVAC system".

Pairwise comparison example

Energy efficiency technologies	Energy efficient HVAC system	Energy efficient lighting systems	Energy efficient windows
Energy efficient HVAC system	1	3	7
Energy efficient lighting systems	1/3	1	4
Energy efficient windows	1/7	1/4	1

Please the pairwise comparison questionnaire can be found on the next pages. It will take about 20-25 minutes to complete, and the researcher will stay during the evaluation to help deal with any problems you may encounter.

Thank you for your time and feedback. They are very valuable to the success of this research.

Yours sincerely,

Amos Darko (Ph.D. Candidate)

Professor Albert P. C. Chan (Head of the Department of Building and Real Estate, PolyU)

Pairwise Comparison Questionnaire

Q1. Please indicate the level of importance of each energy efficiency technology compared to each other in relation with achieving sustainable housing development in Accra, Ghana.

Pairwise comparison for energy efficiency technologies

Technologies	Application of natural ventilation	Application of energy-efficient lighting systems	Optimizing building orientation and configuration	Application of energy-efficient HVAC system	Use of energy-efficient appliances (e.g., energy-efficient refrigerators)	Application of solar technology to generate electricity	Integrative use of natural lighting with electric lighting technology	Application of energy-efficient windows	Application of solar shading devices
Application of natural ventilation	1								
Application of energy-efficient lighting systems		1							
Optimizing building orientation and configuration			1						
Application of energy-efficient HVAC system				1					
Use of energy-efficient appliances (e.g., energy-efficient refrigerators)					1				
Application of solar technology to generate electricity						1			
Integrative use of natural lighting with electric lighting technology							1		
Application of energy-efficient windows								1	
Application of solar shading devices									1

Q2. Please indicate the level of importance of each water efficiency technology compared to each other in relation with achieving sustainable housing development in Accra, Ghana.

Pairwise comparison for water efficiency technologies

Technologies	Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	Rainwater harvesting technology	Grey water reclaiming and reuse technology
Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	1		
Rainwater harvesting technology		1	
Grey water reclaiming and reuse technology			1

Q3. Please indicate the level of importance of each indoor environment quality enhancement technology compared to each other in relation with achieving sustainable housing development in Accra, Ghana.

Pairwise comparison for indoor environmental quality enhancement technologies

Technologies	Application of low emission (low-E) finishing materials	Ample ventilation for pollutant and thermal control	Use of efficient type of lighting (lighting output and color)
Application of low emission (low-E) finishing materials	1		
Ample ventilation for pollutant and thermal control		1	
Use of efficient type of lighting (lighting output and color)			1

Q4. Please indicate the level of importance of each control system compared to each other in relation to achieving sustainable housing development in Accra, Ghana.

Pairwise comparison for control systems

Control systems	HVAC control	Security control	Occupancy/motion sensors
HVAC control	1		
Security control		1	
Occupancy/motion sensors			1

-The End-
Thank you for your valuable time and participation

APPENDIX C

VALIDATION QUESTIONNAIRE

THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學

DEPARTMENT OF BUILDING & REAL ESTATE 建築及房地產學系

Questionnaire for Validating the Model of Green Building Technologies to Achieve Sustainable Housing Development in Ghana, and Implementation Strategy to Promote GBTs Adoption in Ghana

Purpose of this survey

To validate that the model of green building technologies (GBTs) to achieve sustainable housing development in Ghana, and implementation strategy to promote GBTs adoption within Ghana are reliable, credible, inclusive, and appropriate.

Background

The GBTs model and implementation strategy were developed as part of the deliverables of a Ph.D. research study carried out at The Hong Kong Polytechnic University in Hong Kong by Mr. Amos Darko, under Professor Albert P. C Chan's supervision. In general, the study aimed at promoting the GBTs adoption in developing countries. The GBTs model and implementation strategy were developed as a result of a general questionnaire survey and an analytic hierarchy process (AHP) survey with professionals with green building experience in Ghana. The surveys were conducted from January to July 2017.

Instructions

This document has 9 pages (1 page of background and instructions, and 8 pages that describe the GBTs model and implementation strategy). At the end of this document, you are kindly asked to indicate your level of agreement with statements aimed at validating the GBTs model and implementation strategy.

All of your contributions towards this Ph.D. research study, from the general survey until now, are highly appreciated. Please kindly return the completed questionnaire (this document) to Mr. Amos Darko by email (amos.darko@   ) within **two weeks** from today, 2 April 2018.

Thank you very much in advance for your kind contribution.

Yours sincerely,

Amos Darko (Ph.D. Candidate)

Professor Albert P. C. Chan **(**Head of the Department of Building and Real Estate, PolyU)

<u>The Model of Green Building Technologies to Achieve Sustainable Housing Development in Ghana</u>

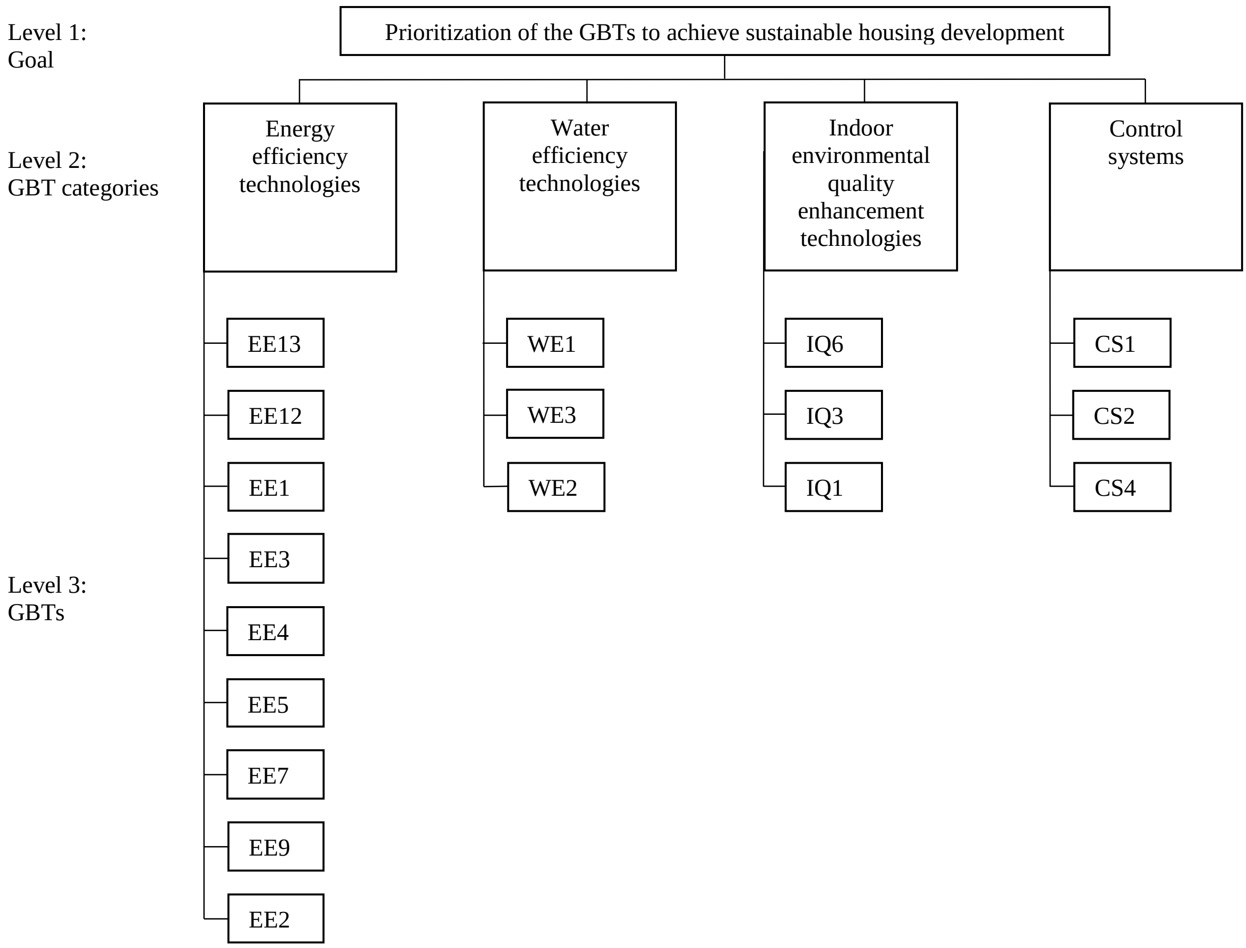
The aforesaid general survey helped in identifying the important GBTs to achieve sustainable housing development in Accra, Ghana. After identifying these important GBTs, the AHP was used to determine the mean (importance) weight of each GBT in each GBT category, as shown in Table 1. These mean weights represent priorities amongst the GBTs within a particular GBT category, helping to differentiate in general the more important GBTs from the less important ones. The higher the mean weight, the more important a GBTs would be. For example, in Table 1, "application of natural ventilation" is more important than all of the other GBTs in the energy efficiency category, "installation of water-efficient appliances and fixtures" is more important than any other GBT within the water efficiency category, and so on and so forth. Based on the results in Table 1, a simple model of the GBTs to achieve sustainable housing development in Ghana (Fig. 1) was developed. The model displays hierarchies of the GBTs within each GBT category. Applying this model, for example, if one wishes to select the most important energy efficiency technology for sustainable housing development, then application of natural ventilation (EE13) may be considered first. However, if the aim is to select the most appropriate combination of energy efficiency technologies, water efficiency technologies, indoor environmental quality enhancement technologies, and control systems to achieve sustainable housing development, then the following combination might be considered first: application of natural ventilation (EE13), installation of water-efficient appliances and fixtures (e.g., low-flow toilets) (WE1), use of efficient type of lighting (lighting output and color) (IQ6), and HVAC control (CS1). Based upon this model, several other combinations of GBTs could be made and implemented to help achieve sustainable housing development.

Please go through Table 1 and Fig. 1 and then kindly indicate your level of agreement with the statements at the end of this document aimed at validating the GBTs model (Fig. 1).

Table 1 Mean weights of GBTs to achieve sustainable housing development.

GBT categories	Code	List of GBTs	Mean weight
Energy efficiency	EE13	Application of natural ventilation	0.254
	EE12	Optimizing building orientation and configuration	0.238
	EE1	Application of energy-efficient lighting systems	0.207
	EE3	Application of energy-efficient HVAC system	0.108
	EE4	Use of energy-efficient appliances (e.g., energy-efficient refrigerators)	0.102
	EE5	Application of solar technology to generate electricity	0.031
	EE7	Integrative use of natural lighting with electric lighting technology	0.027
	EE9	Application of solar shading devices	0.021
	EE2	Application of energy-efficient windows	0.012
Water efficiency	WE1	Installation of water-efficient appliances and fixtures (e.g., low-flow toilets)	0.356
	WE3	Grey water reclaiming and reuse technology	0.348
	WE2	Rainwater harvesting technology	0.296
Indoor environmental quality enhancement	IQ6	Use of efficient type of lighting (lighting output and color)	0.399
	IQ3	Application of low emission (low-E) finishing materials	0.374
	IQ1	Ample ventilation for pollutant and thermal control	0.227
Control systems	CS1	HVAC control	0.436
	CS2	Security control	0.380
	CS4	Occupancy/motion sensors	0.184

Note: Mean weights in descending order.



Note: The codes at the Level 3 correspond to the codes in Table 1.

Fig. 1 Final model of GBTs to achieve sustainable housing development.

<u>The Implementation Strategy to Promote GBTs Adoption in Ghana</u>

The development of the implementation strategy to promote GBTs adoption in Ghana (Fig. 5) involved several activities including a partial least squares structural equation modeling (PLS-SEM) of the barriers, drivers, and promotion strategies influencing GBTs adoption in Ghana. Prior to the PLS-SEM, the barriers to, drivers for, and strategies to promote GBTs adoption in Ghana were identified (see the measurement items in Table 2), and factor analysis was used to establish the constructs underlying these barriers, drivers, and promotion strategies (see the constructs in Table 2) (also see Darko et al., 2017; Chan et al., 2018; Darko and Chan, 2018). Then, PLS-SEM was used to examine the quantitative influences of the barriers, drivers, and promotion strategies on the GBTs adoption. The PLS-SEM results about the barriers, drivers, and promotion strategies are summarized in Figs. 2-4, respectively. For the meanings of the codes or abbreviations in Figs. 2-4, please refer to Table 2. Here are brief explanations of the key findings in the Figs. 2-4. According to the PLS-SEM results, Fig. 2 shows that government-related barriers have a significant negative influence on GBTs adoption in Ghana, whereas the influences of the other types of barriers are insignificant. This result was considered reasonable because at the initial stages of GBTs adoption and development in a country, the government practically holds the most essential role in promoting the GBTs adoption (Hwang et al., 2017). Regarding the drivers, Fig. 3 indicates that company-related drivers have a significant positive influence on GBTs adoption, while the influences of the other types of drivers are insignificant.

About the strategies to promote the GBTs adoption, Fig. 4 shows that "government regulations and standards" and "incentives and R&D support" would have significant positive influences on the GBTs adoption, while the other types of promotion strategies would have insignificant influences. Based on these results from the PLS-SEM, a simple implementation strategy to help promote the GBTs adoption in Ghana is developed (see Fig. 5). To ensure the effectiveness of this implementation strategy, only the barriers, drivers, and promotion strategies identified to have significant influences on the GBTs adoption are included in the implementation strategy. Moreover, there are three key steps in the implementation strategy: Step 1 – identification of the significant drivers of GBTs adoption; Step 2 – identification of the significant barriers to GBTs adoption; and Step 3 – identification of the significant strategies to promote the GBTs adoption. As it is only when potential adopters are motivated to adopt GBTs that they will think about the potential barriers (Potbhare et al., 2009), the identification of the significant drivers of the GBTs adoption is put as the first step in the implementation strategy. As the significant drivers can motivate and lead companies to implement GBTs, it is necessary to promote them in the industry and the public. As well, the implementation strategy advocates that applying the significant promotion strategies to overcome the significant barriers could help to promote the GBTs adoption.

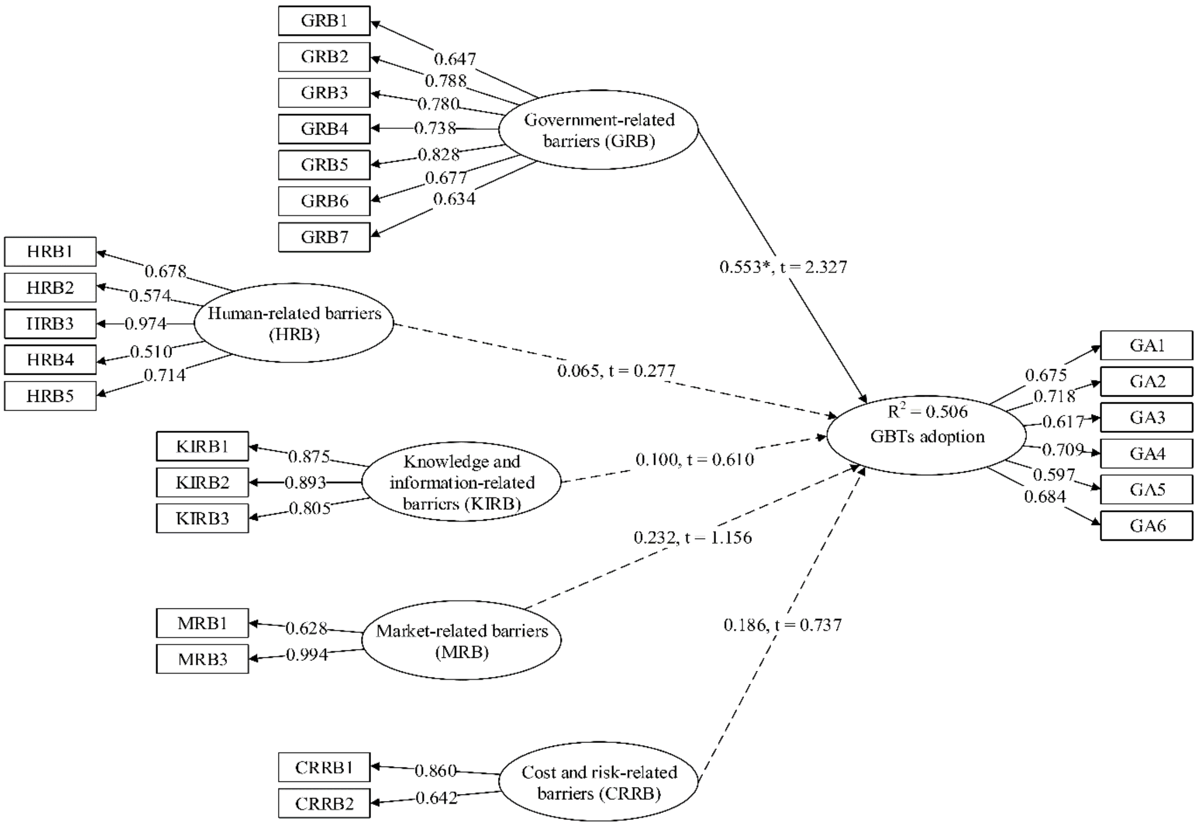
Please go through Table 2 and Figs. 2-4, and then kindly indicate your level of agreement with the statements at the end of this document aimed at validating the implementation strategy (Fig. 5).

Table 2 Constructs and their respective measurement items

Constructs	Code	Measurement items
	Barriers to GBTs adoption	
Government-related barriers (GRB)	GRB1	Lack of government incentives
	GRB2	Lack of green building polices and regulations
	GRB3	Lack of GBTs promotion by government
	GRB4	Lack of local institutes and facilities for GBTs R&D
	GRB5	Lack of green building rating systems and labeling programs
	GRB6	Lack of demonstration projects
	GRB7	Lack of green building technological training for project staff
Human-related barriers (HRB)	HRB1	Resistance to change from the use of traditional technologies
	HRB2	Lack of importance attached to GBTs by senior management
	HRB3	Unfamiliarity of construction professionals with GBTs
	HRB4	Unavailability of GBTs suppliers
	HRB5	Lack of financing schemes (e.g., bank loans)
Knowledge and information-related barriers (KIRB)	KIRB1	Lack of professional knowledge and expertise in GBTs
	KIRB2	Lack of GBTs databases and information
	KIRB3	Lack of awareness of GBTs and their benefits
Market-related barriers (MRB)	MRB1	Unavailability of GBTs in the local market
	MRB2	Lack of interest from clients and market demand
	MRB3	Limited experience with the use of nontraditional procurement methods
Cost and risk-related barriers (CRRB)	CRRB1	Higher costs of GBTs
	CRRB2	Risks and uncertainties involved in adopting new technologies
	Drivers for GBTs adoption	
Environment-related drivers (ERD)	ERD1	Reduced environmental impact
	ERD2	Improved indoor environmental quality
	ERD3	Greater water efficiency
	ERD4	Non-renewable resources conservation
	ERD5	High return on investment
Company-related drivers (CRD)	CRD1	Company image and reputation
	CRD2	Improved occupants' productivity
	CRD3	Better workplace environment
	CRD4	Increased building value
Economy and health-related drivers (EHRD)	EHRD1	Reduced use of construction materials in the economy

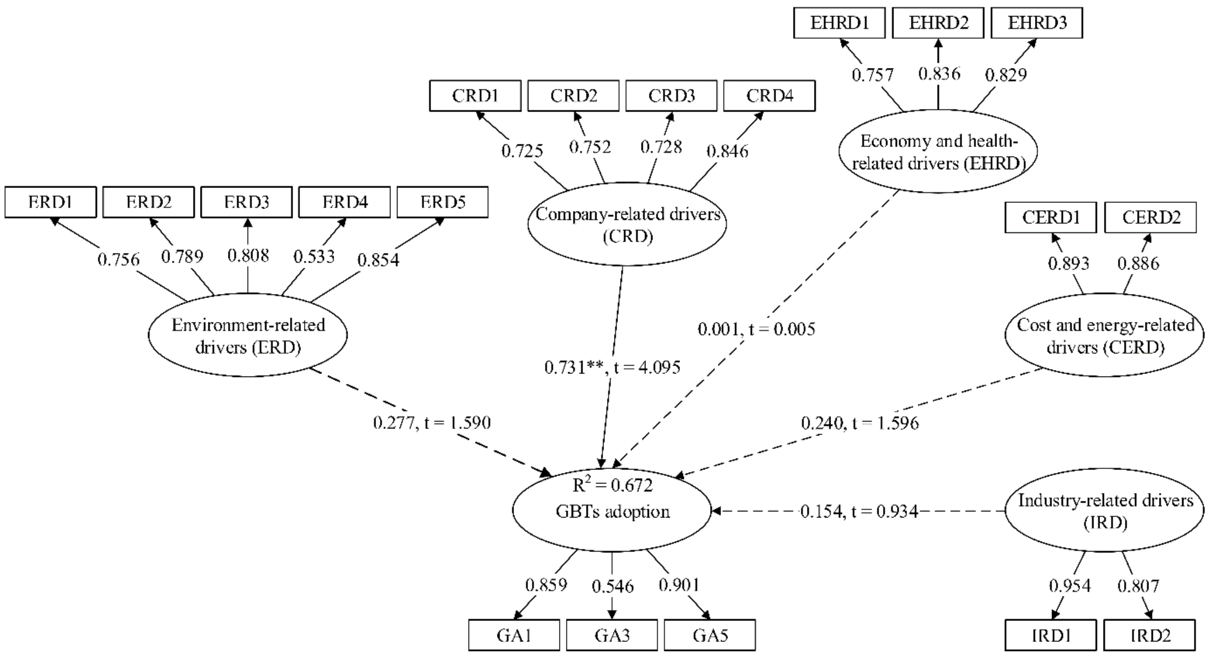
	EHRD2	Improved occupants' health and well-being
	EHRD3	Job creation opportunity
Cost and energy-related drivers (CERD)	CERD1	Reduced whole lifecycle costs
	CERD2	Greater energy efficiency
Industry-related drivers (IRD)	IRD1	Setting a standard for future design and construction
	IRD2	Facilitating a culture of best practice sharing
	Promotion strategies for GBTs adoption	
Government regulations and standards (GRS)	GRS1	Mandatory green building policies and regulations
	GRS2	Green rating and labeling programs
	GRS3	Better enforcement of green building policies after they have been developed
	GRS4	Availability of competent and proactive GBTs promotion teams and local authorities
Incentives and R&D support (IRDS)	IRDS1	Financial and further market-based incentives for GBTs adoption
	IRDS2	A strengthened GBTs R&D
	IRDS3	Low-interest loans and subsidies from government and financial institutions
Awareness and publicity programs (APP)	APP1	Public environmental awareness creation through workshops, seminars, and conferences
	APP2	More publicity through media (e.g., print media, radio, television, and internet)
	APP3	Support from executive management
Education and information dissemination (EID)	EID1	GBTs-related educational and training programs for developers, contractors, and policy makers
	EID2	Availability of better information on cost and benefits of GBTs
	EID3	Availability of institutional framework for effective GBTs implementation
Awards and recognition (AR)	AR1	Acknowledging and rewarding GBTs adopters publicly
	AR2	More GBTs adoption advocacy by the Ghana Environmental Protection Agency
	GBTs adoption	
GBTs adoption (GA)	GA1	Specifications should consider GBTs
	GA2	Current construction has not sufficiently considered GBTs
	GA3	GBTs information and databases are not adequately available in your company
	GA4	Our senior management is willing to support GBTs adoption
	GA5	GBTs adoption should be forced by government
	GA6	Guides for implementing GBTs cannot be easily found in Ghana

Note: R&D = research and development.



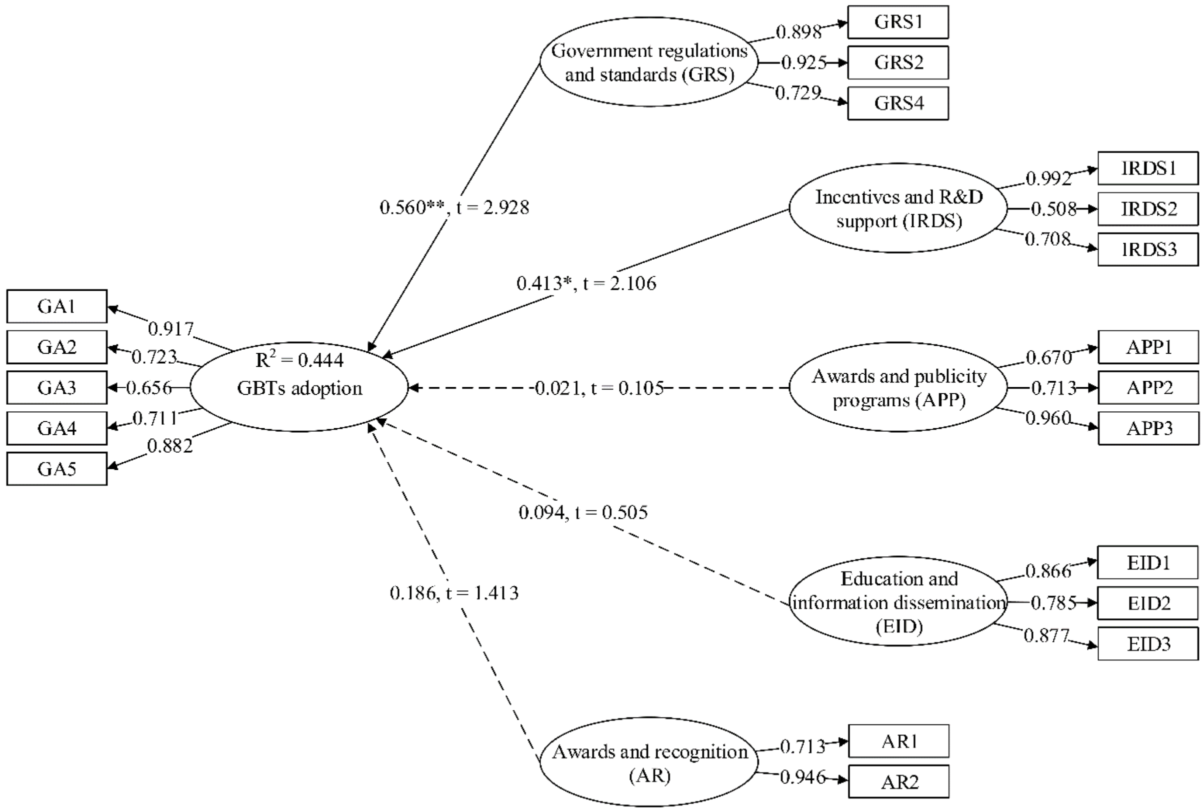
Note: * Indicates level of significance at $p < 0.05$;
——▶ Indicates a significant path (hypothesis supported);
·······▶ Indicates an insignificant path (hypothesis not supported).

Fig. 2 Final structural equation model of barriers influencing GBTs adoption.



Note: ** Indicates level of significance at $p < 0.01$;
——▶ Indicates a significant path (hypothesis supported);
·······▶ Indicates an insignificant path (hypothesis not supported).

Fig. 3 Final structural equation model of drivers influencing GBTs adoption.



Note: ** Indicates level of significance at $p < 0.01$;
* Indicates level of significance at $p < 0.05$;
———▶ Indicates a significant path (hypothesis supported);
·········▶ Indicates an insignificant path (hypothesis not supported).

Fig. 4 Final structural equation model of promotion strategies influencing GBTs adoption.

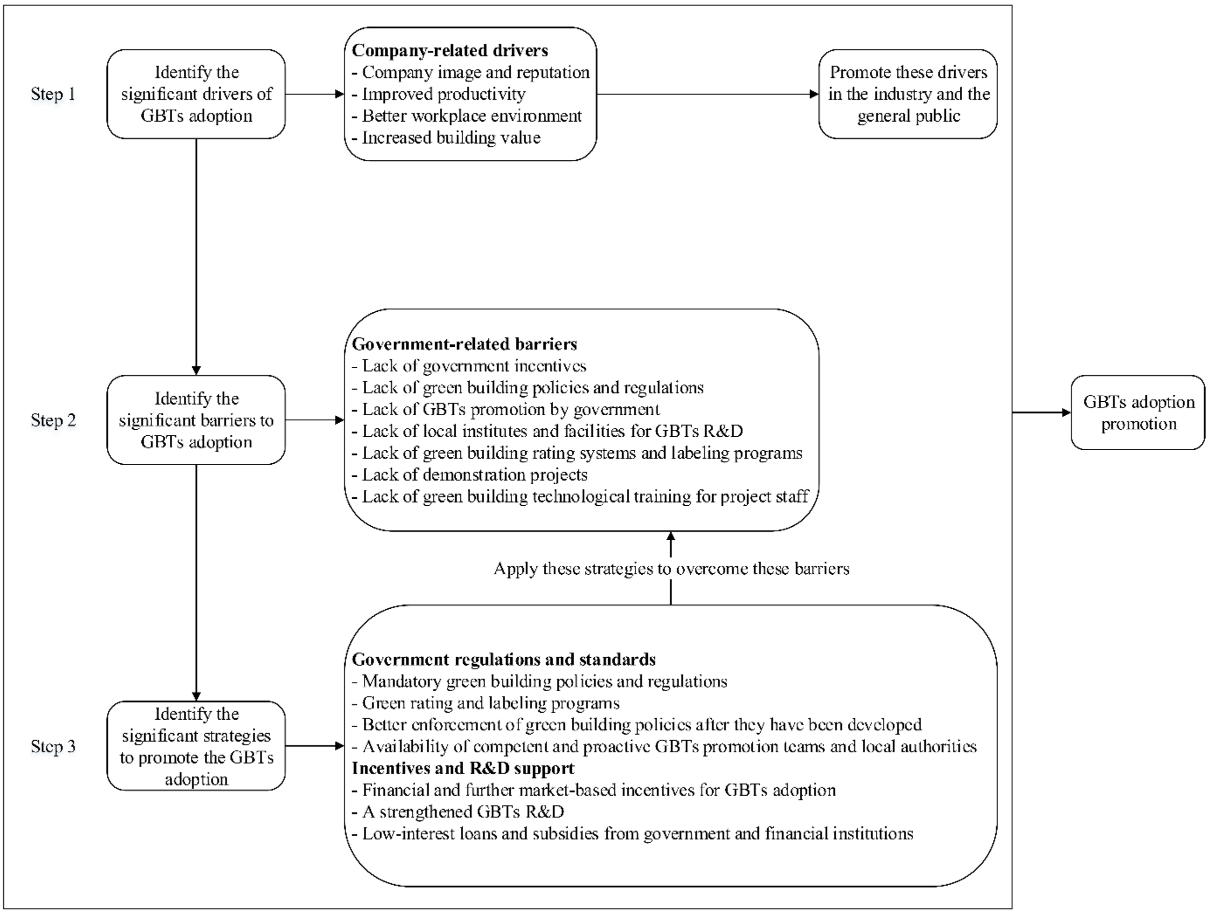


Fig. 5 An implementation strategy to promote GBTs adoption.

Validation Questionnaire for the GBTs Model

Please indicate your level of agreement with the following statements about the model of GBTs to achieve sustainable housing development in Ghana (Fig. 1). Use the following scale: **1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree**.

No.	Statements	Level of agreement
		Low ⟺ High
1	The identified GBTs to achieve sustainable housing development in Accra, Ghana are reasonable	☐1; ☐2; ☐3; ☐4; ☐5
2	The GBTs model is easily understandable and could be used in the industry	☐1; ☐2; ☐3; ☐4; ☐5
3	The GBTs within each GBT category are appropriate	☐1; ☐2; ☐3; ☐4; ☐5
4	The GBTs model is inclusive	☐1; ☐2; ☐3; ☐4; ☐5
5	The appropriate use of the GBTs model would definitely help to achieve sustainable housing development	☐1; ☐2; ☐3; ☐4; ☐5
6	Overall, the GBTs model is suitable for helping to achieve sustainable housing development in Ghana	☐1; ☐2; ☐3; ☐4; ☐5

Validation Questionnaire for the Implementation Strategy to Promote GBTs Adoption

Please indicate your level of agreement with the following statements about the implementation strategy to promote GBTs adoption in Ghana (Fig. 5). Use the following scale: **1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree**.

No.	Statements	Level of agreement
		Low ⟺ High
1	The significant GBTs adoption drivers, barriers, and promotion strategies identified are reasonable and correctly reflect the current situations in Ghana	☐1; ☐2; ☐3; ☐4; ☐5
2	The implementation strategy is easily understandable and could be used in the industry	☐1; ☐2; ☐3; ☐4; ☐5
3	The steps within the implementation strategy are appropriate	☐1; ☐2; ☐3; ☐4; ☐5
4	The implementation strategy is inclusive	☐1; ☐2; ☐3; ☐4; ☐5
5	The appropriate use of the implementation strategy would definitely help to promote the GBTs adoption in the industry	☐1; ☐2; ☐3; ☐4; ☐5
6	Overall, the implementation strategy is suitable for helping to promote GBTs adoption in Ghana	☐1; ☐2; ☐3; ☐4; ☐5

Please, if any, give other general comments on the GBTs model and implementation strategy in the box below. You may also provide comments that could help to improve the GBTs model and implementation strategy.

-The End–

Thank you for your valuable time and participation

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