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# Empirical Examination of Factors Influencing the Adoption of Green Building Technologies: The Perspective of Construction Developers in Developing Economies

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Received: 27 July 2020; Accepted: 24 September 2020; Published: 30 September 2020



**Abstract:** This study seeks to better understand the determinants of green building technology (GBT) adoption intention of construction developers in developing countries. In order to address these objectives, this study integrates the Diffusion of Innovation theory, the theory of Resource-based View, and the Resource Dependence Theory to analyze and construct the theoretical model of developers' intentions to adopt GBTs from three perspectives, namely, technological, organizational, and environmental. The model was tested using survey data collected from 142 experienced managers in Vietnam. Data analysis was performed by SEM using the partial least squares (PLS) approach. The findings show that perceived GBT advantages, perceived GBT disadvantages, top management leadership, government support, project partners' green building readiness, and social demand of green buildings are the significant factors that affect GBT adoption intention by developers. However, organizational GBT resource and GBT market readiness have no significant effect on developers' GBT adoption intention. Theoretical and practical implications and limitations of the research are discussed, and suggestions for future research are also proposed.

**Keywords:** green building technologies; GBTs; adoption intention; construction developer; developing economies; Vietnam

## 1. Introduction

According to statistics, 40% of energy consumption and 30% of greenhouse gas emissions are by the construction industry worldwide [1]. More and more attention from society focuses on the severe negative influence of the construction sector on public health and safety and natural ecosystems [2]. As a

key strategy for improving the sustainable development of the industry, construction companies have been integrating more and more green practices into their construction plans. Adopting eco-innovations such as green building technologies (GBTs) is considered as one of the most imperative practices to realize green building and achieve construction sustainability [3,4].

The literature presents the definition of GBTs in different ways. However, it consistently reflects that GBT is a branch of eco-innovations in the construction industry to enhance the environmental, social, and economic performance of buildings throughout their life cycle [5]. Generally, GBTs are defined as the general term for innovative products, measures, processes, and technical means which are adopted and implemented to achieve the saving goal in terms of energy, water, land, and material, the reduction of negative impacts on the natural environment, as well as the improvement of public health during the whole life cycle of the construction projects [1,5,6]. Ahmad, et al. [6] also categorized GBTs into seven groups, including indoor illumination technologies, control technologies, resource conservation technologies, renewable energy technologies, resource recovery technologies, air quality technologies, and comfort zone temperature technologies. Many empirical studies have revealed that adopting GBTs into building projects offers simultaneously environmental, economic, and social benefits [1,2,7,8]. Up to now, there has been a series of both empirical and descriptive studies on GBT adoption in different economic contexts and under various perspectives (e.g., Wang, et al. [1], Chan, et al. [9], Bond [10], Chan, et al. [11], Koebel, et al. [12], and Nguyen, et al. [13]). The existing literature helps us to get a better understanding of GBT adoption in the construction industry; however, huge research gaps are still present.

First, there is a lack of reliable theories/models of GBT adoption and diffusion. GBT adoption in the construction sector is very different from adopting non-green innovations in other industrial sectors [1,14]. GBTs have the unique characteristics of environmental and comfortable innovations [1]; therefore, research on GBT adoption and diffusion should be considered under a multiple perspective approach in terms of technological, economic, environmental, social, and political factors, to provide more valuable insights [14]. In many cases, eco-innovation adoption and diffusion can be motivated by political and environmental rather than economic reasons [14,15]. Additionally, the GBTs' adoption into building projects is a process with the participation of very many relevant stakeholders, such as developers, designers, general contractors, subcontractors, suppliers, and governments, even occupants or end-users. It can be said that in the same process of GBT adoption and implementation into a particular building project, there are multiple adopters rather than a single adopter. Moreover, under the market view, adopting GBTs means to make a green building—a commercial product, which will be sold to the end-user; this implies that if the social demand for green buildings is low, it will likely reduce the likelihood of developers adopting GBTs. Hence, whether the relevant theories of conventional innovation adoption would work well for this case is still in doubt. Karakaya, et al. [14] argued that it is necessary to have specific theories for research on eco-innovation diffusion [14,16]. In order to build such a reliable theory, more research is needed to obtain reliable empirical findings from various contexts. For this purpose, extensive studies have been carried out, such as Wang, et al. [1] and Wang, et al. [4] in China, Darko, et al. [17] in Ghana, and Koebel, et al. [12] in the US. The current research seeks to contribute positively to this effort by empirically investigating the influencing factors of the GBTs adoption in a socially oriented transition economy such as Vietnam. Second, the current literature has made limited attempts to examine the appropriate relationships among different social factors on the development of the green building market in developing countries [1,17]. Third, previous studies have largely ignored the influence of resource dependence and social demand on GBT adoption. Finally, recent studies on the GBT adoption have paid little attention to the views of project developers, who are at the center of most sustainability decisions to drive the adoption of sustainable features into buildings [1]. Encouraging GBT adoption needs close cooperation and collaboration of all relevant shareholders of the construction project chain. Construction developers are the key upstream players within the customer network of the projects and play a decisive role in promoting green building [18]. Developers' behavior of adopting green building should play a crucial role in connecting all project

stakeholders to respond [14]. Therefore, it is very important to clearly understand the factors affecting the construction developers' GBT adoption.

In order to fill the research gaps, the present study seeks to increase the knowledge on GBT adoption by investigating the determinants of GBT adoption intention by the construction developers in the context of developing economies such as Vietnam. To address this objective, the study developed a conceptual model based on the interactionism perspective that is an integration of the Diffusion of Innovation theory, the theory of resource-based view, and the Resource Dependence Theory. The study tested the model using the survey data collected from 142 respondents in Vietnam. Structural equation model (SEM) using the partial least squares (PLS) approach is performed to analyze the data.

Although this study focused on the context of Vietnam, it is expected that its findings might be beneficial for policymakers and practitioners in other emerging countries with similar socio-economic conditions. Furthermore, the theoretical framework of this research could be utilized in future studies on GBT adoption. Therefore, it is believed that this study would considerably contribute to the global green building body of knowledge.

## 2. The Vietnam Context—A Developing Economy

Vietnam is a socially oriented emerging market economy which is experiencing rapid urbanization. As an essential component of general planning for sustainable development, Vietnam's government has made strong commitments for encouraging the development of the green building and efficient use of energy in both private sectors and public sectors through financial incentives, as well as green building codes. Vietnam has been implementing the National Strategy of green economy and the National Plan of efficient energy use and saving from 2020 to 2030 nationwide. Recently, the government also promulgated the National Regulations on Building Energy Use Efficiency (QCVN 09:2019/BXD). Green building is receiving increasing attention from the government, educational and research institutions, industrial developers, and the public; and it is believed to have great potential to become the key trend in the construction industry in Vietnam [19–22]. Furthermore, it is worth noting that there is a considerable evolution of the determinants of GBT adoption. Previously, the key reasons to adopt GBTs into buildings were mainly corporate social responsibility programs. At present, the main reason to develop green buildings in Vietnam is to provide more health and higher performance building products to people, as well as to differentiate products from the rest of the market.

It can be stated that the green building market in Vietnam is now still in the initial stages of development; in fact, the number of green buildings is growing quite slowly [19]. According to the 2019 statistics, Vietnam had only about 130 green buildings certified by the third-party green building certification systems, such as LEED, LOTUS, and EDGE [23] (see Figure 1). This figure is very low compared to over 2100 projects just in Singapore or over 750 green projects in Australia.

The existence of many unique barriers and challenges can explain the slow development of green buildings in Vietnam. Previous exploratory studies have identified the significant challenges to the green building market in the country, such as lack of data, knowledge, and information related to green building, lack of well-documented green building codes, unavailability of GBT suppliers, lack of incentives to engage in green building, and lack of green building experts [13]. Furthermore, the lack of stakeholder awareness of green building costs and sustainability, as well as the lack of a general governmental and institutional framework, is also considered as one of the biggest challenges for green construction practices in Vietnam [13]. Finally, there are several government bodies in charge to manage and promote sustainable construction activities, such as Green Building Council Vietnam; however, it is argued that they should make more efforts and take strong actions to promote green construction activities [13].

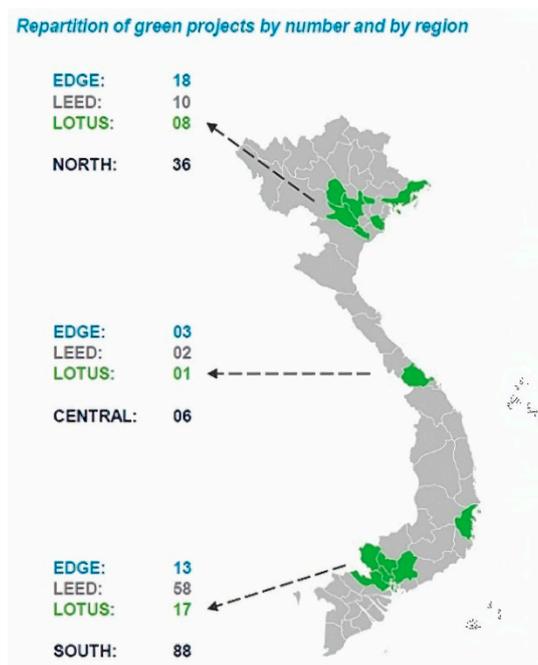


Figure 1. Overview of the Vietnamese green building market. Source: [23].

### 3. Theoretical Foundation and a Conceptual Model

#### 3.1. Literature Review on the Adoption of GBTs

GBT adoption was paid attention in the literature with both exploratory and explanatory studies under various perspectives [1,4,11,17,24–30]. Many previous studies focused on identifying barriers drivers as well as potential challenges to GBT adoption and diffusion, for example, Berardi [26], Chan, et al. [9], Chan, et al. [11], Nguyen, et al. [13], Lam, et al. [29], and Darko, et al. [30]. Although these studies approached from the perspective of different adopters, in general, it was found that the adoption of GBTs depends on the interaction of various factors that can be grouped into three categories, including technological factors (e.g., perceived environmental, economic, social benefits, relative advantages, technical complexity, perceived ease of use of GBTs), potential adopters' organizational factor (e.g., organizational resources, competencies, resistance to change, leadership), and external environmental factor (e.g., availability of reliable GBTs, lack of information, legal regulations, technical codes, external subsidies, project partners' readiness, market demand).

Furthermore, a few studies performed an empirical analysis to investigate the determinants of decision making of GBT adoption based on the different theoretical approaches [1,4,27,28]. For example, according to the rational choice perspective, Wang, et al. [4] and Abu-Elsamen, et al. [27] used the theory of planning behavior and the theory of reasoned action (TRA) to establish the research model of GBT adoption behavior by designers or customers with variables such as adoption motivation, the capability of GBTs, the knowledge structure, defects of GBTs, perceived performance, management support, environmental awareness, attitude, and subjective norms. Based on both the rational choice and evolutionary perspectives, Wang, et al. [1] integrated the Diffusion of Innovation Theory (DOI) with the Technology Acceptance Model to investigate factors influencing GBT adoption behavior by construction developers from various aspects in terms of individual, product, and interaction with a focus on perceived usefulness, perceived ease of use of GBTs, developers' innovativeness, sense of community, competitive advantage, government guarantees, and relevant stakeholders. By approaching from the rational choice, evolutionary, and emotional perspectives, Ozaki [28] combined the DOI with several other theories, including the theory of cognitive behavior, the normative theory for pro-environmental behavior, and the emotional theory of innovation consumption in order to understand the motivation

factors of eco-innovation consumers by focusing on five factors: perceived benefits, social influence, perceived compatibility, controllability, and perceived uncertainty.

In general, the existing literature shows that it is essential for research on GBT adoption under a multiple perspective theoretical model to take into account the impact factors at various levels, such as individual, organization, and inter-organization. However, it is worth noting that the existing literature has ignored the potential factors at the project level, at which many unique characteristics exist in terms of the construction sector. The success of adopting GBTs into a building project requires joint participation, more effective cooperation, and especially the green building resources of all project partners [1]. The developer's decision to adopt GBTs into building projects is likely dependent on the readiness level of green building resources of their project partners, such as government, designers, contractors, subcontractors, suppliers, and so on. For example, a specific developer, whose top managers perceive great benefits of GBT adoption, might not make a decision to adopt GBTs into their green building projects if it is recognized that legal regulations and technical codes on the green building are not yet defined well, or it is tough to select a competent contractor to deliver such projects. Additionally, green buildings built by the developers are often to sell out the market; therefore, adopting GBTs into commercial building projects by the developers is also likely dependent on social demand. The resource-dependent theoretical perspective seems to be explained better in these cases.

In order to contribute additional insights into the existing literature on GBT adoption, the present study adopts a new theoretical framework under the evolutionary and resource dependence perspectives.

### 3.2. Resource Dependence Theory (RDT)

RDT is a well-known theory in the social sciences, used to explain the relationships between organizations and their external environments. It relies on organizational inter- and intrarelations. RDT was developed based on two main opinions of an organization–environment relationships [31]. RDT's first opinion emphasizes that the context in which an organization is embedded accounts for operational activities and outcomes. RDT focuses on the extent to which an organization depends on its external environment, particularly those who control the resources that the organization needs. From external perspectives, the theory implies that an organization's response to external demands can be predicted, to some extent, from the types of resource dependencies. Second, the RDT posits that the social environment may have multiple levels of effects on an organization and defines explicitly the environmental hierarchy: the entire system of interconnected organizations, a set of organizations/individuals with whom the organization communicates, and the organizations' enacted environment.

Drawing on RDT, it suggests the possibility of understanding and predicting the actions of construction developers on GBT adoption through an analysis of their environment in terms of the dependency on external resources, such as government incentives, project partners' green building resources, financial institutions' supports, green building suppliers' readiness, and the users/clients' green building demand [31]. The developers' perceived dependency on external resources might have potential positive or negative impacts on their decision on GBT adoption.

### 3.3. Resource-Based View Theory (RBV)

RBV has its roots in the context of planning and organizational structure. It recommends that organizations develop and create values based on resources that are distinctive, beneficial, and not easily replicable, as well as the managerial competencies regarding combination, control, utilization, and distribution of such resources by top leaders [32,33]. Such organizational resources include tangible resources, for example, plant technology, capitals, machinery, and raw materials, as well as intangible resources, for instance, business process, structures, individual employees skills, experiences, patents, and brand name [32,34,35]. The integration of organizational resources and management competency creates an overall organizational capacity to achieve the desired objective [33–36]. RBV posits that

making organizational decisions, such as GBTs adoption, is influenced by the availability of required resources and the competency of top leaders in using the resources effectively [37].

#### 3.4. *The Diffusion of Innovation (DOI) Theory*

DOI is a concept of how, when, and at what pace of latest technology utilized to better understand the users/organizations' tendency for innovation adoption and decision making within a social context [38]. Under the evolutionary perspective, DOI defines diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system" [38]. Accordingly, innovation, communication channels, time, and social systems are the four critical components of the adoption and diffusion of innovations. The process of innovation diffusion includes five stages: knowledge, persuasion, decision, implementation, and confirmation; these stages typically follow each other in a time-ordered manner. Within the social system in which an innovation is diffused, there are usually five categories of potential adopters identified, including innovators, early adopters, early majority, late majority, and laggards. From a DOI perspective, innovation adoption is often well explained by three general sets of variables: the characteristics or attributes of innovation, the characteristics of decision-making units, and the characteristics of external social and political context [39].

Accordingly, individuals or organizational units shape their own subjective attitude to the change through the perceived features of innovation, such as relative advantage, compatibility, complexity, trialability and observability, which leads to deciding whether or not to continue to the next stages of the process of innovation adoption. From this perspective, this study examines the effect of perceived GBT advantage and disadvantage on the decision making the process of GBT adoption by construction developers.

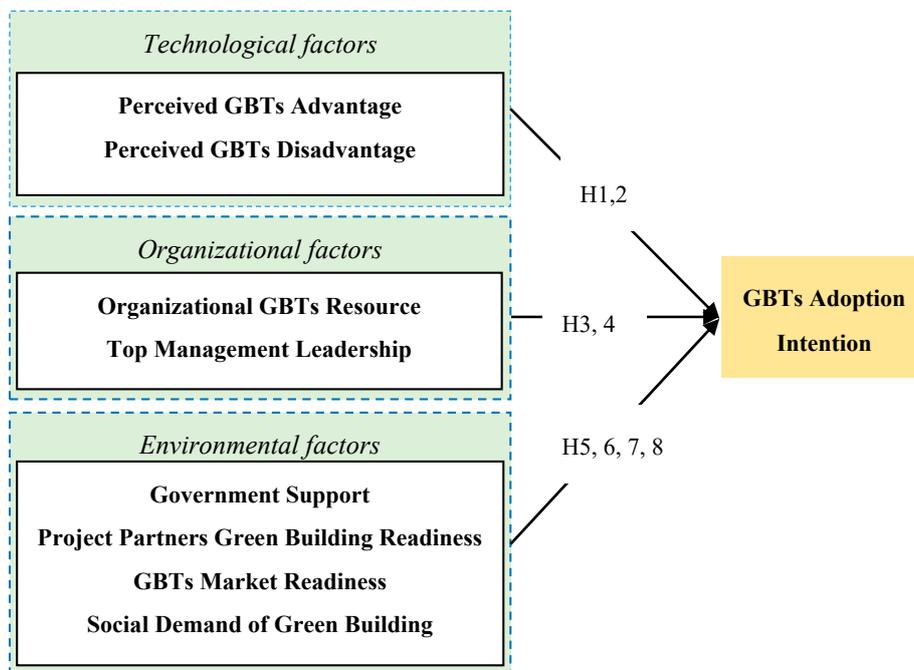
Moreover, the characteristics of decision-making units, which are reflected by organizational socioeconomic characteristics, personality variables, and internal communication behavior, are also considered as important factors, which influence early the decision making of innovation adoption at the knowledge stage of the process [38]. At this first stage, an organizational unit will learn and attempt to determine "what the innovation is and how and why it works". The perceived knowledge of the firm's current competency in adopting and using innovations effectively at this stage will be one of the decisive factors which help to decide whether or not the firm continues to the next stages of the adoption process [38]. This knowledge becomes more critical for complex innovations, such as GBTs. DOI offers an "organizational characteristics" lens through which GBT adoption can be reasonably explained. Thus, RBV complements DOI by emphasizing the role of internal organizational resources and leadership capabilities in construction developers' decision to adopt GBTs. Accordingly, this study examines the role of organizational GBT resources and top management leadership on construction developers' decision-making process towards adopting or rejecting GBTs.

Finally, at all the stages of the adoption process, DOI posits that the features of external social and political contexts may become the essential factors influencing the decision of innovation adoption. The social system is defined as "a set of interrelated units engaged in joint problem solving to accomplish a common goal" [38]. In regard to adopting GBTs into building projects by developers, such interrelated units may include developers, designers, main contractors, subcontractors, suppliers, the government, and even occupants or end-users. DOI offers an "external social system" lens to reasonably explain why a decision to adopt or reject GBTs is made. Thus, RDT complements DOI by emphasizing the role of external resources and support in developers' decision to adopt GBTs. Combining RDT and DOI suggests the possibility of understanding and predicting the actions of construction developers regarding GBT adoption through an evaluation of the developers' perceived dependency on their key green building resource providers [31]. Accordingly, this study examines the roles of government support, project partners' green building readiness, GBT market readiness, and social demand for green building in construction developers' decision to adopt GBTs.

The resource-related lens in RBV and RDT provides an additional implication for DOI that firms may be unable rather than unwilling to adopt GBTs, especially when they lack both internal and external key resources for green building practices. This implication is significant, especially in developing economies such as Vietnam where the green building sector is still in the early stages of development.

### 3.5. A Conceptual Framework: Combining DOI, RBV, and RDT

As discussed above, it is believed that the combination of the DOI, RBV, and RDT theories can better explain the decision making of GBT adoption in the context of developing countries under the technological, organizational, and environmental perspectives. Accordingly, this study examines the factors potentially influencing GBT adoption intention by construction developers under the eight constructs: Perceived GBTs Advantage, Perceived GBTs Disadvantage, Organizational GBTs Resource, Top Management Leadership, Government Support, Project Partners Green Building Readiness, GBTs Market Readiness, and Social Demand of Green Building. A conceptual framework of GBT adoption intention is exhibited in Figure 2.



**Figure 2.** A conceptual model of GBT adoption intention.

This theoretical model has only one dependent variable, namely, GBT adoption intention. Based on the existing literature of GBT adoption and the relevant theories of innovation adoption, the present study describes GBT adoption intention as developers' intention to adopt and implement GBTs into their current and future building projects and operationalizes this construct as follows:

A construction developer is considered to have GBTs adoption intention if, presently or in the near plan: (1) Green building has been integrated into their business strategy; (2) GBTs have been adopted more and more in terms of type and quantity; (3) They have a clear plan to open different categories of building projects that will adopt GBTs; and (4) Green building culture has been becoming one of the unique characteristics of their organizational culture. The nine independent variables are operationalized in the next sections.

### 3.6. Research Hypotheses

#### 3.6.1. Perceived GBT Advantage

The literature shows that GBTs have many relative advantages as compared to non-green building technologies, such as improved company image and reputation, enhanced marketability, increased building value, higher return on investment, and thus a competitive advantage.

GBT adoption practices involve the whole life cycle of the building project, including concept, design, construction, and operation. Construction developers who actively adopt GBTs into their building projects can show their commitment to corporate social responsibility so that they potentially get more subsidies from the government and gain strong customer trust while increasing publicity, corporate image, and market share [40–42]. The literature consistently agreed that marketing benefits are one of the most important drivers to adopt GBTs. Green features may work as a powerful marketing tool for real estate firms [43]. Additionally, through the adoption and application of unique green elements into distinctive green products, the property developer might have great potential to open their new market quickly, get more income for rent, generate higher investment returns, and thus gain more economic benefits [41,44,45]. All of these offer construction developers an important competitive advantage and boost them to participate and invest in the green building market [43]. Therefore, the following hypothesis was proposed.

**Hypothesis 1 (H1).** *Perceived GBT advantage positively affects the construction developers' GBTs adoption intention.*

#### 3.6.2. Perceived GBTs Disadvantage

Besides relative advantages, the literature shows that GBT adoption also brings out many potential disadvantages for construction developers, such as increased initial costs of building projects, increased technical complexity in terms of testability, trialability, installation, low compatibility, increased managerial complexity while delivering building projects, and risk in a delay of building projects [4,11,17,24,46,47].

The initial cost for GB projects is higher as compared to conventional projects because GB practices are mostly more expensive than conventional ones. The United States Green Building Council indicated that the initial cost of GBT-adopted building projects could increase, on average, from 2 to 7% [9]. Wang, et al. [4] cited that the high cost of GBTs is one of the most significant disadvantages and is a crucial factor hindering GBT adoption in both developing and developed markets. Chan, et al. [9] also found that risks and uncertainties about cost were the top five barriers in the USA, Canada, and Australia.

Similarly, time is also another important economic indicator used to determine building project success, particularly for developers. Numerous reasons cause delays in GBT-adopting projects; for example, more time required to approve new GBTs as well as to execute these technologies onsite [9]. Lam, et al. [29] recognized that the concern of project delay is a significant barrier preventing relevant stakeholders from GBT adoption. Regarding technical issues, the compatibility of GBTs with existing traditional construction practices and technical complexity in terms of testability, trialability, and installation will be disadvantaged. According to Koebel, et al. [12], it is not easy to test and validate GBTs, and therefore, they face greater obstacles in adoption. Additionally, Wisdom, et al. [48] suggested that innovations are adaptable only when their purpose is evident, there is good expertise to transfer, implement, and control them, and there is clear research evidence of benefits. Therefore, we propose the following hypothesis:

**Hypothesis 2 (H2).** *Perceived GBT disadvantage negatively affects the construction developers' GBT adoption intention.*

### 3.7. Organizational GBT Resource

Organizational GBT resources are defined as available stocks that are possessed or managed by construction developers to adopt GBTs into building projects successfully. According to the existing literature, these GBT resources should include the presence of a GB project management unit, the GB capability of project teams, GB expertise of staff, GBT database, technical standards and procedures on GB, and availability of budget [2,4,13,17,32,34,35].

Therefore, the realization of GB projects does not proceed like that of traditional construction projects [49]; all project team members need to be equipped with a wide range of professional knowledge and expertise on GB issues, such as technical specifications, green procurement, the GBT market, social and cultural issues, and environmental and safety issues to ensure successful adoption of GBTs in the whole life cycle of the building project [12]. Additionally, according to Lam, et al. [50], GBT databases and related technical standards/procedures available within an organization are very necessary to enhance the GB awareness of the whole company for ensuring the success of the adoption.

The study of Darko, et al. [30] empirically revealed that “lack of knowledge and awareness of GBTs” and “lack of GB expertise/skilled labor” within the company were the most critical barriers to GBT adoption. Wang, et al. [4] also found that the capability of the project team was another considerable factor influencing designers’ GBTs adoption behavior. Additionally, Hwang and Ng [25] showed that the lack of interest and effective communication among the project team members might significantly affect the adoption of green construction practices. Conversely, Darko, et al. [17] empirically discovered that the unfamiliarity with GBTs, reluctance to change from the usage of conventional technologies, lack of professional expertise on GB, and lack of GBT databases were not significant obstacles to GBT adoption. Therefore, we propose the following hypothesis:

**Hypothesis 3 (H3).** *Organizational GBT resources have a positive impact on construction developers’ GBT adoption intention.*

### 3.8. Top Management Leadership

TML refers to the role of top management to manage, encourage, promote, and ensure the success of GBTs adoption through awareness and attitudes, strategic commitments, policies, and incentives. Top management leadership is responsible for developing corporate strategy as well as daily operational activities. Regarding the context of GBT adoption, TML can be determined under key facets including (1) managers’ sound knowledge and awareness of green building, (2) managers’ positive attitude towards sustainable construction, (3) managers’ innovative leadership style, and (4) managers’ sense of community belonging [2,3,9,49].

Commitments and leadership from senior management are key conditions for guiding and enhancing the ability of all employees to adopt and implement GBTs [11,24,51]; this is essential for the planning of green building development [49]. Additionally, corporate environmental policy is the most important driver for firms to adopt GB practices [3]. Darko, et al. [52] also empirically revealed that “resistance to change from the use of traditional technologies” and “attitudes and traditions” by top management is deemed to be the most critical barrier hindering the adoption of GBTs in the construction market. If top leaders do not attach importance to the technologies, it would not be possible to adopt and implement GBTs successfully [2,9]. Adopting GBTs requires the high cooperation and collaboration of relevant stakeholders across enterprises; therefore, in order to achieve the objective of green building, companies need to encourage all employees to positively learn and develop their knowledge of the latest green practices [4]. This will promote employees’ perceptions of the role of GBTs and make a cooperative working space within the enterprise. Therefore, we propose the following hypothesis.

**Hypothesis 4 (H4).** *Top management leadership has a positive impact on construction developers’ GBT adoption intention.*

### 3.9. Government Support

The literature generally recognizes that government support plays the most crucial role in promoting green building [53–55]. Such support is determined by key aspects, including a commitment to GB, providing and enforcing financial and non-financial incentive policies to promote green building, and defining and enforcing technical codes and legal regulations on green building.

Many studies showed that it is necessary to impose mandatory regulations as well as financial incentives on green building to promote various stakeholders' enthusiasm for the development of the green building market [56–58]. Qian and Chan [53] also suggested that governments should enforce appropriate measures, for example, green product rating, financial subsidy, better enforcement of technical standards, and investment loans. Although the public policies' function can involve either positive or negative incentives, Koebel, et al. [12] still proposed that public policies and incentives such as grants, density bonus, tax rebates, performance certification, preferential interest rates, and financial incentives should be considered to implement to promote GBT adoption.

Darko, et al. [3] conducted a questionnaire survey and found that all the respondents who are from consultant units, general contractors, construction developers, and architectural firms consistently recognized the decisive role of government legislations and policies in promoting green building. Darko, et al. [30] empirically revealed that “lack of government incentives/supports for implementing GBTs” was the fifth-ranked barrier in the US. Khoshnavar, et al. [59] revealed that the impact of legislation and policies was the premier driver for implementing green construction initiatives in the context of Malaysia. A series of previous studies also provided strong empirical evidence showing that government regulations and incentive policies are essential drivers which influence stakeholders to act sustainably in the construction sector (e.g., Murtagh, et al. [60], Low, et al. [41], Serpell, et al. [61], Gou, et al. [40]).

It is worth noting that construction developers, especially in developing economies, are very much dependent on their government as the government control key resources, namely land resources and the construction permitting power that the developers need to start any of their projects. Therefore, government support seems to be an important factor that should be considered to understand the developers' decision regarding GBT adoption. We propose:

**Hypothesis 5 (H5).** *Government support has a positive impact on construction developers' GBT adoption intention.*

### 3.10. GBT Market Readiness

GBT market readiness can refer to the availability of green building technologies, available suppliers of green products, green building rating systems, competent human resources on GB, and associated knowledge and information database. These resources are necessary for all stakeholders to complete their green building projects. Therefore, according to the RDT theory, developers' decision regarding GBT adoption is likely affected by the GBTs' market readiness.

The literature on GB consistently shows an apparent association between GBT market readiness and the positive level of GBT adoption [25,62]. Many previous studies, i.e., Potbhare, et al. [62], Hwang and Ng [25], and Aktas and Ozorhon [51] empirically confirmed that the unavailability of tested and reliable GBTs in the local market might provide rational reasons for stakeholders to refuse to adopt GBTs. Another study based in Ghana—a developing economy, also revealed that a lack of GBT suppliers as well as conflicts between green vs traditional technologies were critical barriers to GBT adoption [11]. Darko, et al. [17] empirically showed that lack of R&D activities on GBTs, lack of GB rating systems, and lack of demonstration projects were statistically significant barriers to GBT adoption. Additionally, the case studies of Berardi [26] found that the lack of information and poor coordination among project stakeholders will often increase the unwillingness to adopt energy-saving technologies.

In Vietnam, the green building market is now undeveloped with many existing problems, such as low applicability of GBTs, lack of suppliers of green products, lack of demonstration projects, lack of skilled labor resources, lack of specific tools or laboratory to test and validate GBTs, and especially, lack of significant financial supports from the finance and banking sector [20]. Therefore, we propose the following hypothesis.

**Hypothesis 6 (H6).** *GBTs' market readiness has a positive impact on the developers' GBT adoption intention.*

### 3.11. Project Partners' Green Building Readiness

Project partners' green building readiness can refer to the knowledge, experience, and ability regarding the green building of external project partners, such as general contractors, subcontractors, designers, project management consultants, supervising consultants, and upstream technology suppliers. Generally, the construction developers need to cooperate with their external project partners in order to obtain essential resources to deliver their GB projects effectively [17,56].

The literature consistently acknowledges that all project partners need to have very high readiness in terms of technology, labor resource, managerial and financial capability to overcome challenges to ensure the effective adoption of GBTs [25,47,63,64]. Wang, et al. [1] in an empirical study in China revealed that the GB readiness of relevant stakeholders positively impacts construction developers' perceived ease of use of GBTs. Furthermore, Berardi [26] also empirically found that the lack of GB knowledge by other stakeholders might negatively influence the developers' green building adoption in the Western context.

Additionally, the RDT theory [31] supposes that organizational behaviors are perceived as the outcomes of the external contexts. Accordingly, construction developers must continuously rethink their decision regarding GBT adoption. If such a decision requires essential resources which, for some reason, are unavailable, this situation limits the developers' readiness and willingness to adopt GBTs. Therefore, to explain why the GBTs adoption is, or is not, taken by construction developers in Vietnam, it is necessary to pay attention to one of its determinants, namely, external project partners' green building readiness. Therefore, this paper puts forward the hypothesis:

**Hypothesis 7 (H7).** *Project partners' green building readiness has a positive impact on construction developers' GBT adoption intention.*

### 3.12. Social Demand for Green Building

Social demand for green buildings can refer to different aspects, such as demand for green residential or/and office buildings, the demand for green industrial buildings, and demand for other green service real estate markets, such as resorts, condotel, officetel, shophouse. Koebel, et al. [12] argued that market characteristics are important factors for green innovation adoption and diffusion. Accordingly, the market with a larger population, higher incomes, and education might require greater demand for green innovation in residential buildings. Attitude, lifestyle, behavior, and culture of customers/tenants likely play a key role in developing the GB market [58]. Positive demand for GB by customers will motivate the construction industry to meet more green standards, which boosts GBT adoption [3,9]. Djokoto, et al. [65] and Rodriguez-Nikl, et al. [66] reported that a lack of public awareness and social demand was one of the major barriers to the adoption of green building practices. Zhang, et al. [7] empirically revealed that the absence of customer demand has a negative influence on green building strategies in the Chinese construction industry.

Additionally, RDT supposes that customers are one of the key resources on which companies depend, and the success of an enterprise is closely associated with its customer demand. Wherever an enterprise takes action will likely depend on the social demand for products made by the action [31]. Therefore, we propose the following hypothesis:

**Hypothesis 8 (H8).** *Social demand for green buildings has a significant impact on construction developers' GBT adoption intention.*

## 4. Research Methodology

### 4.1. Measurement Model Identification

The measurement model was developed based on theoretical modeling, statistical testing, and refinement. A total of 39 measurement items are identified from the extensive literature review and are presented in Table 1. The study then performed confirmatory factor analysis (CFA) to test the reflective constructs and conducted other analyses to test the formative constructs. The constructs and their respective indicators are shown in Appendix A.

**Table 1.** Variables in the Conceptual Model.

Latent Variables	Type	Items *
Perceived GBT Advantage (Ad)	Reflective	Ad1 to Ad6
Perceived GBT Disadvantage (Disad)	Reflective	Disad1 to Disad5
Organizational GBT Resource (OGR)	Formative	OGR1 to OGR5
Top Management Leadership (TML)	Reflective	TML1 to TML4
Government Support (GovS)	Reflective	GovS1 to GovS3
GBTs Market Readiness (GMR)	Reflective	GMR1 to GMR6
Project Partner GBT Readiness (PPR)	Formative	PPR1 to PPR3
Social Demand for Green Building (SDGB)	Formative	SDGB1 to SDGB3
GBT Adoption Intention into building projects (GAI)	Reflective	GAI1 to GAI4
Total of measurement items		39

\* Items measured on a 5-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5).

### 4.2. Questionnaire Design

In this study, data were collected through a questionnaire survey, which has been widely applied in construction management research. The items were reviewed and refined by an expert panel consisting of two researchers and three green building developers for its content validity.

The questionnaire consisted of three main sections. The first section is to introduce the objectives of the research and assure confidentiality and anonymity. The second section consists of the questions to collect the respondents' profile, and the third section contains questions about the respondents' opinions on factors potentially influencing GBT adoption by their organization. The respondents were asked to rate the extent to which they agree with the statements by using a 5-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree) and also encouraged to identify any inappropriate factors on the list or any other factors missing from the list.

Before distributing the final questionnaire survey, a pilot study was adopted to test and refine the quality of the questionnaire. The pilot study involved a team of three practical experts, a senior lecturer, and a postgraduate researcher who have much experience in green building. They were asked to assess the questionnaire in terms of structure, language, coverage of possible factors.

### 4.3. Data Collection

The survey was executed in March and April 2019 in Hanoi and Ho Chi Minh, Vietnam. These cities were selected because they are economical and political centers and the largest construction markets in which the majority of the green building projects were located. Moreover, most of the developers based in these cities manage offices and conduct building projects in other regions of Vietnam as well. Therefore, the investigation was conducted in these cities, which can offer valuable findings of the current knowledge of GBT adoption throughout the country.

Self-administering the survey via post or e-mail often collects a very low number of responses in the cultural context of Vietnam; therefore, this study administered the survey in person and adopted

both the “snowball” and “systematic random” sampling techniques. The target population was all real estate developers, and respondents are managers who have an in-depth awareness of their own enterprise and practical experience in the Vietnam construction industry. The sampling frame is the list of such developers in Hanoi and Ho Chi Minh City issued by the Ministry of Construction. Firstly, the systematic random sampling technique (i.e., every third item) was used to choose the first 12 companies. Contacts were then established with the managers of these organizations via personal contacts. At this stage, a total of 31 completed questionnaires were administered in person. These people were then also asked to introduce other potential respondents. Next, a total of 250 copies were distributed, 153 completed questionnaires were obtained, and 11 were excluded because of missing information. Therefore, a total of 142 responses were collected. The sample was checked for consistency resulting in a final dataset of 142 valid cases, which offers the response rate of 56.8%. As compared with previous studies on green building, this sample size was relatively good for performing statistical analyses [52]. The demographic characteristics of the sample can be seen in Figures 3 and 4. Additionally, the majority of the respondents (about 95%), had at least three years of experience in the green building sector. These show that the developers surveyed have a higher level of education and experience in green building.

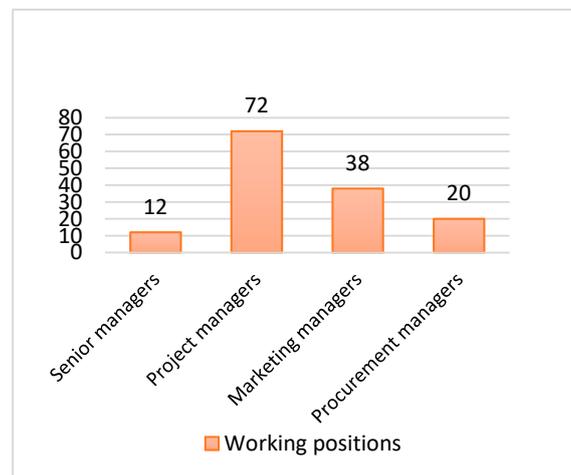


Figure 3. Working positions of the sample.

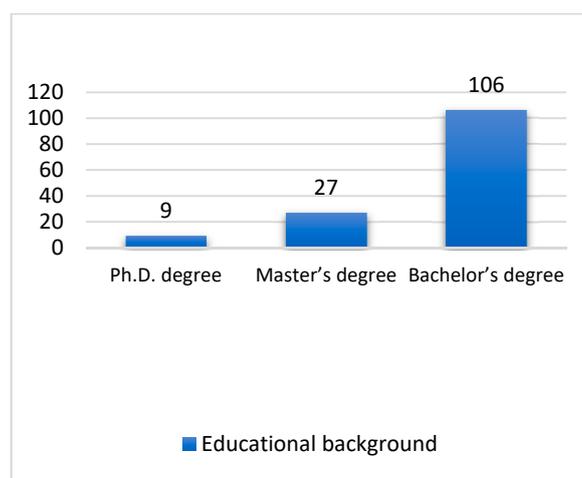


Figure 4. Educational background of the sample.

#### 4.4. Data Analysis Techniques

In this study, SEM a multivariate statistical analysis technique was conducted to test the hypotheses. A typical SEM consists of a set of measurement models and a structural model. SEM not only has the ability to test the relationships between constructs (i.e., latent variables) and their respective measurement items (i.e., observable variables) within the measurement models, but it also tests hypotheses among constructs (both independent and dependent latent variables) within the structural model. There are two approaches to SEM, namely, the covariance-based SEM (CB-SEM) approach and the component-based SEM (PLS-SEM) approach [67]. However, the present study adopted PLS-SEM as the method of analysis because of the following key reasons: (1) PLS-SEM can work well with small sample sizes, and nonnormal data [68], and (2) PLS-SEM is more appropriate for assessing the models that are more complex with a large number of latent and observable variables and include both reflective and formative constructs [69]. Additionally, PLS-SEM is also considered as an adequate alternative to CB-SEM if the studied phenomenon is relatively new and measurement models are newly developed and not yet validated before [70]. Literature shows that PLS-SEM was adopted by many previous studies (with small sample sizes) in the field of construction engineering and management; for example, Tran, et al. [55], Aibinu and Al-Lawati [68], and Leung, et al. [71].

After specifying the measurement and structural models, the individual item reliability, convergent validity, and discriminant validity were evaluated to ensure that the reflective latent constructs are accurately measured by their respective measurement items. The individual item reliability refers to the extent to which measurement of reflective latent constructs with a multi-item scale reflects the accurate scores of the constructs relative to the error [68]. It indicates the correlations of the items with their respective latent variables, and it was estimated by assessing the standardized loadings against a cut-off point of 0.70. Literature suggested that items with very low loadings should be considered to drop since they would provide very little explanatory power to the model. Convergent validity refers to the measure of internal consistency, and it was evaluated to ensure that the items only measure their respective latent construct rather than other latent variables. In PLS-SEM, the convergent validity of each latent construct was tested through assessing Cronbach's alpha coefficient, composite reliability (CR) scores and average variance extracted (AVE) values against the thresholds of 0.6, 0.7, and 0.5, respectively [68]. Discriminant validity refers to the extent to which a given latent variable is different from other latent variables in the model; and it was assessed by two tests: the analysis of cross-loadings and analysis of AVE. The analysis of cross-loadings was conducted by following the rule that loading of each measurement item on the latent variable that it is intended to measure should be greater than the cross loadings on any other latent variables in the model [69]. The analysis of AVE was conducted by following the criterion that the square root of AVE of each latent construct should be greater than the correlation of two latent variables [68].

Regarding formative constructs, the analyses of multicollinearity, formative indicator weights and loadings, and nomological network effects were conducted. Collinearity is one of the main challenges to the predictive capability of formative constructs. If multicollinearity among indicators is high, the more likely indicators will have low or non-significant path weights [72]. Multicollinearity was assessed by a variance inflation factor (VIF), and according to literature, there is no concern on multicollinearity if the VIF value is less than the threshold of 3.33 [73]. It is also necessary to assess both formative indicators' weights and loadings. A particular indicator is considered to be not relatively important if both its weights and loadings are non-significant; and therefore, it should be deleted from the measuring scale [73]. Additionally, the issue of portability at the construct level of the theoretical model is crucial; and it is assessed following the rule that a particular formative construct has excellent portability if its weights change very little in different nomological networks [73].

After verifying the reliability and validity of the measurement models, the structural model was assessed next to determine the explanatory power of the model and to test the research hypotheses through assessing the squared multiple correlations ( $R^2$ ) for the dependent variables and the significance of the path coefficients [68]. In order to do this, the bootstrapping technique with 500 resamples

was used and conducted by SmartPLS 3.3.2. The analysis results are presented and discussed in the following sections.

### 5. Analysis Results

#### 5.1. Measurement Model Validation

We performed CFA using SEM as implemented in PLS to test the theoretical model’s reliability and validity (Figure 5).

##### 5.1.1. Individual Item Reliability and Convergent Validity

Table 2 shows that the Cronbach’s alpha coefficient, CR, and AVE of all the reflective constructs were greater than the thresholds of 0.6, 0.7, and 0.5, respectively. Table 3 shows that the factor loadings of all items were greater than the threshold of 0.7, with the exception of GMR1, GMR2, Ad3, Ad4; however, in this case, these items are still kept because of content validity matters; therefore, in general, the measurement scales have good convergent validity and internal consistency.

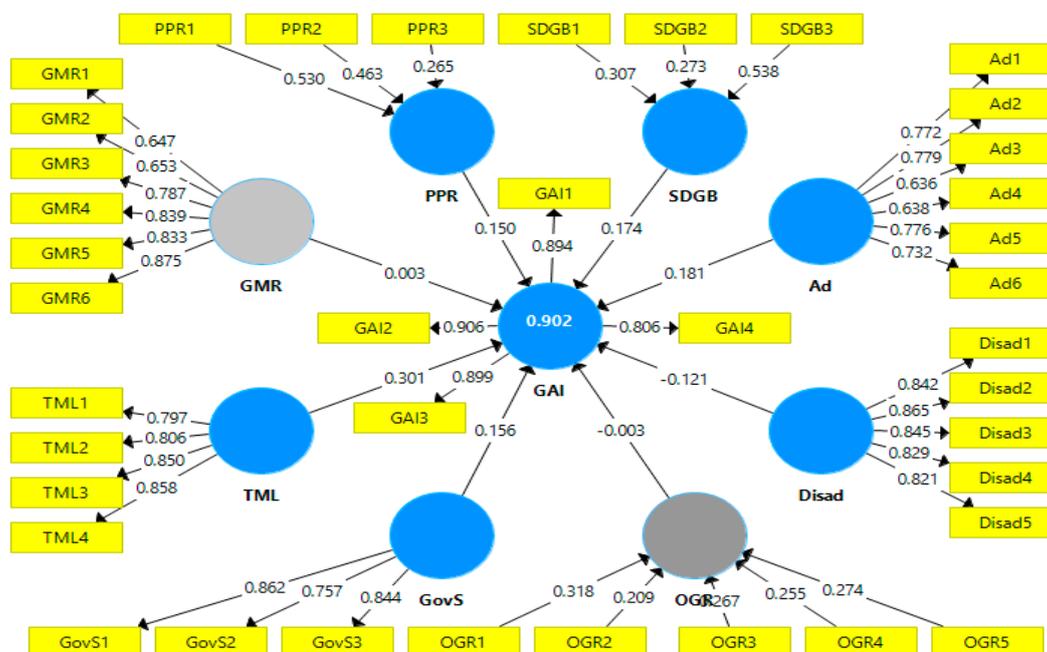


Figure 5. Factor loadings, weights, and R-squared (R<sup>2</sup>).

Table 2. Cronbach’s alpha, CR, AVE, and the square root of AVE of the reflective constructs.

	Ad	Disad	TML	GMR	GovS	GAI	Alpha	CR	AVE
Ad	0.725						0.820	0.868	0.525
Disad	-0.524	<b>0.916</b>					0.896	0.923	0.706
TML	0.636	-0.718	<b>0.910</b>				0.847	0.897	0.686
GMR	0.706	-0.629	0.768	<b>0.882</b>			0.866	0.901	0.605
GovS	0.624	-0.734	0.813	0.799	<b>0.939</b>		0.759	0.862	0.676
GAI	0.754	-0.763	0.890	0.832	0.852	<b>0.936</b>	0.900	0.930	0.770

Note: The bold diagonal values are the square root of the average variance extracted of each construct.

##### 5.1.2. Discriminant Validity Analysis

The analysis results are presented in Tables 2 and 3. Table 2 shows that the square root of AVE of each component (i.e., the bolded diagonal values) are all greater than the other values of correlations

amongst components. In Table 3, it can also be seen that each item had the highest loading in its corresponding structure. Thus, it indicates that there was no problem with discriminant validity.

**Table 3.** Cross Loadings of the Reflective Constructs.

	Ad	Disad	TML	GMR	GovS	GAI
Ad1	<b>0.772</b>	−0.377	0.492	0.681	0.521	0.544
Ad2	<b>0.779</b>	−0.296	0.403	0.640	0.390	0.506
Ad3	<b>0.636</b>	−0.237	0.308	0.440	0.312	0.381
Ad4	<b>0.638</b>	−0.266	0.361	0.518	0.348	0.463
Ad5	<b>0.776</b>	−0.506	0.599	0.625	0.575	0.689
Ad6	<b>0.732</b>	−0.502	0.517	0.570	0.491	0.609
Disad1	−0.460	<b>0.842</b>	−0.605	−0.520	−0.577	−0.649
Disad2	−0.399	<b>0.865</b>	−0.611	−0.491	−0.616	−0.629
Disad3	−0.515	<b>0.845</b>	−0.646	−0.620	−0.683	−0.680
Disad4	−0.429	<b>0.829</b>	−0.601	−0.527	−0.608	−0.659
Disad5	−0.391	<b>0.821</b>	−0.549	−0.474	−0.595	−0.582
TML1	0.409	−0.639	<b>0.797</b>	0.588	0.614	0.713
TML2	0.525	−0.628	<b>0.806</b>	0.636	0.691	0.731
TML3	0.533	−0.546	<b>0.850</b>	0.620	0.670	0.735
TML4	0.631	−0.570	<b>0.858</b>	0.695	0.716	0.767
GMR1	0.528	−0.496	0.565	<b>0.647</b>	0.594	0.557
GMR2	0.542	−0.284	0.396	<b>0.653</b>	0.432	0.521
GMR3	0.664	−0.434	0.506	<b>0.787</b>	0.622	0.570
GMR4	0.637	−0.576	0.718	<b>0.839</b>	0.722	0.737
GMR5	0.631	−0.509	0.666	0.833	0.677	0.701
GMR6	0.741	−0.585	0.671	0.875	0.650	0.748
GovS1	0.527	−0.564	0.695	0.706	<b>0.862</b>	0.722
GovS2	0.456	−0.554	0.619	0.528	<b>0.757</b>	0.648
GovS3	0.552	−0.688	0.690	0.726	<b>0.844</b>	0.729
GAI1	0.632	−0.753	0.755	0.699	0.748	<b>0.894</b>
GAI2	0.737	−0.671	0.846	0.775	0.766	<b>0.906</b>
GAI3	0.690	−0.686	0.832	0.778	0.837	<b>0.899</b>
GAI4	0.575	−0.560	0.677	0.661	0.626	<b>0.806</b>

For the formative constructs Organizational GBT Resource (OGR), Project Partner GBT Readiness (PPR), Social Demand for Green Building (SDGB), the issues related to multicollinearity, weights, loadings, and nomological network effects were tested.

### 5.1.3. Multicollinearity

Table 4 shows that all VIF scores were less than the threshold of 3.33; the exception was the indicator SDGB3 with its VIF = 3.651, but it was still included in the analysis for content validity.

**Table 4.** Variance Inflation Factor (VIF), *p*-Values of Outer Loadings, and Weights.

	Loadings	<i>p</i> -Values	Weights	<i>p</i> -Values	VIF
OGR1->OGR	0.892	0.000	0.318	0.001	2.619
OGR 2->OGR	0.738	0.000	0.209	0.036	2.031
OGR 3->OGR	0.800	0.000	0.267	0.028	2.152
OGR 4->OGR	0.657	0.000	0.255	0.001	1.368
OGR 5->OGR	0.661	0.000	0.274	0.001	1.390
SDGB1->SDGB	0.873	0.000	0.307	0.000	2.738
SDGB 2->SDGB	0.785	0.000	0.273	0.000	1.793
SDGB 3->SDGB	0.963	0.000	0.538	0.000	3.651
PPR1->PPR	0.881	0.000	0.530	0.000	1.747
PPR 2->PPR	0.877	0.000	0.463	0.000	1.808
PPR 3->PPR	0.479	0.000	0.265	0.000	1.070

### 5.1.4. Formative Indicators' Weights and Loadings

This study performed a bootstrap analysis with 500 subsamples by SmartPLS 3.3.2. The analysis result in Table 4 showed that all the formative indicators had significant weights and loadings.

### 5.1.5. Nomological Network Effects

In this study, a new nomological network is built by removing GAI and replacing it with another construct, namely “enterprises’ attitude toward GBTs” (ATG). The three questions on enterprises’ attitudes toward GBTs were asked at the beginning of each survey. Generally, GAI and ATG are positively correlated. Figure 6 shows no significant change in the relative magnitudes of the indicator weights in the formative constructs OGR, PPR, and SDGB.

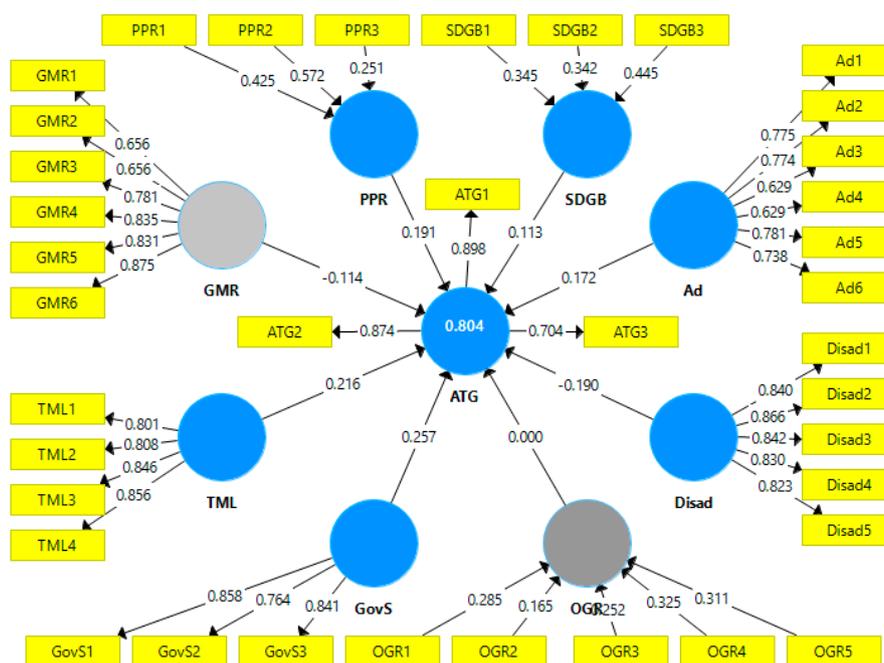


Figure 6. Factor loadings, weights, and R-squared ( $R^2$ ) of the revised model.

## 5.2. Empirical Analysis

Figure 2 presented the analysis result of the model. In this study, the  $R^2$  of GAI is 0.902, meaning that about 90.2% of the changes to GBT adoption intention by construction developers are due to the examined eight latent variables. F-test was conducted to assess the significance of the  $R^2$  value [68]. The following formula calculates the F value:

$$F = \frac{R^2/k}{(1 - R^2)/[n - (k + 1)]} \tag{1}$$

where n is the total number of the sample size ( $n = 142$ ); k is the number of latent variables ( $k = 9$ ); F is the distribution with degrees of freedom k and ( $n - k - 1$ ) (9 and 132). The study has  $F = 134.99$  for  $R^2 = 0.902$ . The table of F-test critical values provides  $F_{0.01, 9, 132} = 2.544$ ; therefore, it can be said that the explanatory power of the model is statistically significant.

The impact of a particular latent variable on the latent dependent variable was also assessed by performing effect size ( $f^2$ ) analysis. The effect of a predictor variable is considered to be small or medium or large at the structural level if  $f^2$  is 0.02, 0.15, and 0.35, respectively. Table 5 shows the inference on the  $f^2$  estimate for the eight independent latent variables.

**Table 5.** Results of effect size ( $f^2$ ) analysis by SmartPLS 3.3.2.

Dependent Variable	Independent Variable	Effect Size ( $f^2$ )	Inference
GAI	Ad	0.104	small to medium effect
	Disad	0.060	small to medium effect
	OGR	0.000	not effect
	TML	0.187	medium to large effect
	SDGB	0.052	small to medium effect
	GMR	0.000	not effect
	GovS	0.055	small to medium effect
	PPR	0.074	small to medium effect

### 5.3. Paths of the Structural Model

The sign, size, and statistical significance of the path coefficient between the independent and dependent variables are used to assess each hypothesis. Table 6 presented the result of bootstrap analysis in SmartPLS3.3.2 with 500 resamples; accordingly, six out of eight paths were statistically significant. This means that hypotheses H1, H2, H4, H5, H7, and H8 are supported. Accordingly, perceived GBT advantages, perceived GBT disadvantages, top management leadership, social demand of a green building, government support, and project partners' green building readiness have significant impacts on GBT adoption intention by construction developers. Whereas, organizational GBT resources and GBT market readiness have no significant influence on GBT adoption intention by the developers.

**Table 6.** Path coefficients and  $p$ -values.

	Path Coefficients ( $\beta$ )	Standard Deviation	T Statistics	$p$ Values	Inference
H1: Ad->GAI	0.181	0.054	3.365	0.001 **	Supported
H2: Disad->GAI	-0.121	0.032	3.756	0.000 **	Supported
H3: OGR->GAI	-0.003	0.047	0.070	0.944	Non-supported
H4: TML->GAI	0.301	0.058	5.218	0.000 **	Supported
H5: SDGB->GAI	0.174	0.068	2.557	0.011 *	Supported
H6: GMR->GAI	0.003	0.067	0.040	0.968	Non-supported
H7: GovS->GAI	0.156	0.051	3.068	0.002 **	Supported
H8: PPR->GAI	0.150	0.048	3.096	0.002 **	Supported

\*\* Highly significant; \* Significant; critical t-value: 1.96,  $p < 0.05$  and 2.58;  $p < 0.01$ .

## 6. Discussion

The results of this study revealed three notable points: (1) construction developers' GBT adoption intention is significantly affected at the same time by technological, organizational, and environmental factors; (2) top management leadership, perceived GBT advantages, social demand of the green building, government supports, project partners' green building readiness, and perceived GBT disadvantages are the factors significantly affecting the developers' intention to adopt GBTs; (3) both organizational GBT resources and GBT market readiness have no impact on GBT adoption intention by developers. Presently in Vietnam, the green building market is at the initial stage of its development process; therefore, in order to improve GBT adoption, it is essential to implement systematic and comprehensive solutions from the three perspectives. Additionally, it is essential to have the participation of all stakeholders within the green building supply chain; specifically, government, leading developers, constructors, GBT suppliers, and research and education centers to take necessary actions to improve GBT adoption and diffusion. These findings are now discussed in detail.

## 6.1. Technological Factors

### Perceived GBT Advantage vs Disadvantage

The result shows that the perceived advantages of GBTs emerged as the second most significant contributor to the construction developers' GBTs adoption intention ( $\beta = 0.181$ ,  $t = 3.365$ ). This means that the developers who have better cognition of the potential advantages of green building can promote GBT adoption. This result is consistent with previous studies, such as Darko, et al. [17], Zhang, et al. [7], Ozorhon and Oral [74]. For example, Darko, et al. [17] empirically revealed that company image and reputation, and increased building value were two of the key factors that have a significant positive influence on GBT adoption in the Ghanaian construction industry. Ozorhon and Oral [74] provided empirical evidence that improved corporate image, culture, and vision through green building practices influence the decisions of stakeholders to implement green building practices.

The analysis result also revealed that perceived GBT disadvantages have a significantly negative influence on the developers' GBT adoption intention ( $\beta = -0.121$ ,  $t = 3.756$ ). This implies that the developers who believe that there are more potential risks facing GBT-adopting building projects will likely hesitate to adopt GBTs. The findings are consistent with previous studies, such as Chan, et al. [43], Potbhare, et al. [62], Zhang, et al. [7], and Hwang and Tan [63]. Wang, et al. [4] empirically discovered that the defects of GBTs were the second most important factor affecting GBT adoption by designers. Moreover, relevant technological and managerial complexity in adopting GBTs can easily create a situation of "knowing but not implementing."

By implication, in order to promote the adoption of GBTs by construction developers, it is essential to conduct appropriate measures to enhance the awareness of GBTs' advantages as well as decrease potential disadvantages/challenges related to GBTs and green building practices. First, both relevant government departments and the leading construction developers should actively take a more responsible role in forming a demonstration of green building projects and spreading information about the gained benefits across the industry. Second, it is exceptionally vital to upgrade early the system of relevant legal regulations as well as technical standards/guidance and codes on green building. Additionally, it is necessary to speed up the investment in R&D activities to develop the market of more reliable and innovative GBT products, so as to enhance the perceived advantages of GBT adoption by developers. Finally, establishing GBT-focused research funding foundations led by the government should also be considered to strengthen research activities.

## 6.2. Organizational Factors

### 6.2.1. Top Management Leadership

The result indicated that top management leadership is the most significant contributor to GBT adoption intention by developers in Vietnam ( $\beta = 0.301$ ,  $t = 5.218$ ). This finding implies that the Vietnam construction developers whose top managers have a good sense of community, a positive attitude on sustainable construction, a good awareness of the green building market, and are innovative will be more likely to take initiatives to integrate the green building goals into their business strategy and adopt GBTs early into their building projects. These results are consistent with previous empirical findings [24,29,75,76]. Wang, et al. [1] also revealed that the managers who have a stronger sense of community belonging and social responsibility are more likely to adopt GBTs due to their environmentally friendly features.

As commonly recognized, in Vietnam, most managers tend to be less willing to accept changes; and the green building sector is still at the early stage of its development [13]. According to the evolutionary perspective, adopting innovations by the early adopters will play a key role in improving the awareness of, and attitude towards the innovations, and thus, promote the adoption by potential adopters. Therefore, it is important that the Government needs to play a pioneering role as an early adopter by adopting GBTs into its public building projects. Besides, the Government should also

establish specific incentive policies to promote several leading developers to invest in green building project models. Through such demonstration projects, the awareness and attitude of green building and GBT adoption will be improved gradually across the market. Finally, the legal regulations and appropriate measures to develop and encourage corporate culture with social and environmental responsibility should also be considered within the industry.

### 6.2.2. Organizational GBT Resource

Organizational GBT resources were found to have no significant effect on the construction developers' intention to adopt GBTs ( $\beta = -0.003$ ,  $t = 0.047$ ). This result implies that organizational resources, such as the GB capability of the project team, GB expertise of staff, GBT database, technical standards and procedures on GB, and availability of budget are not the critical factors promoting GBT adoption intention by construction developers in Vietnam. This result is consistent with the empirical result of Venkatesh, et al. [77] that confirmed that facilitating conditions are non-significant in predicting technology adoption intention but to be significant in predicting technology use behavior. Darko, et al. [17] also empirically discovered that the unfamiliarity with GBTs, lack of professional expertise on GB, and lack of GBT databases were not significant obstacles to GBT adoption. This finding can be explained by the fact in Vietnam that legal regulations, as well as technical codes and standards on green buildings are not well-developed, and they become a more overwhelming challenge than anything else. However, this finding should also be reconfirmed by future studies.

## 6.3. Environmental Factors

### 6.3.1. Government Supportive Policies

Government supportive policies were found to have a significant positive impact on the developers' GBTs adoption intention ( $\beta = 0.156$ ,  $t = 3.068$ ). According to Darko, et al. [17], government-related barriers, such as lack of government incentives and lack of green building policies and regulations were statistically significant factors of intended GBT adoption in Ghana. The finding is also very consistent with the empirical result of Wang, et al. [1] in China, where government incentive policies influence significantly positively the construction developers' perceived ease of use of GBTs, and the government plays an imperative role in promoting the adoption and diffusion of GBTs. The result empirically confirms the argument by many researchers that financial incentive schemes for the development of green buildings are very crucial in driving construction stakeholders to adopt GBTs [2,54]. In Vietnam, Quangdung, et al. [20] pointed out that although the government has a strong commitment to green building, governmental support of GBTs is still weak and unclear. Therefore, by implication, it is crucial that the government needs to promulgate early effective incentive policies or programs to promote developers more willing to adopt GBTs. Such a good supportive policy environment is not only limited to technical standards or guidance but also financial incentives (e.g., tax deductions and direct grants) [78] and non-financial incentives (e.g., expedited permitting and density bonus or gross floor area incentive) [2,40]. The role of the government is not only indirect as a policy provider but is also direct as a client, designer, supervisor, and producer in the green construction chain [2,13].

### 6.3.2. GBT Market Readiness

GBT market readiness has no significant positive impact on GBT adoption intention by the developers in Vietnam ( $\beta = 0.003$ ,  $t = 0.040$ ). Contrary to expectations, this finding is supported by the empirical result of Darko, et al. [17] who also found that GBTs' market-related barriers, such as the unavailability of GBT suppliers, lack of GBT databases, and unavailability of GBTs in the local market did not have any significant influence on GBT adoption in Ghana. However, this finding is not consistent with several previous empirical results. Lam, et al. [29] revealed that immaturity in the green supply market has a negative influence on GBT adoption within the entire green building supply chain. This result does not empirically confirm the results of Potbhare, et al. [62], Hwang and

Ng [25], Aktas and Ozorhon [51], and Darko, et al. [17]; they found that many GBT market-related factors, such as lack of local institutes and facilities for GBT R&D, unavailability of reliable green products, lack of a green building rating system, as well as demonstration projects, were barriers to GBT adoption. This finding can also be explained by the fact that in Vietnam, legal regulations, as well as technical codes and standards on green buildings, are not well developed, and they become an overwhelming challenge.

### 6.3.3. Project Partners' Green Building Readiness

Project partners' green building readiness was found to have a statistically significant effect on GBT adoption intention by the Vietnamese developers ( $\beta = 0.150$ ,  $t = 3.096$ ). This is consistent with several previous empirical studies. For example, Wang, et al. [1] revealed that relevant stakeholders have a significantly positive impact on the developers' perceived ease of use of GBTs in China. This finding provides the empirical evidence to support the claims by many researchers (that have not yet been empirically tested) that proactive roles and availability of green materials manufacturers/suppliers, designer, and contractors' GB capacity, and the dependability of the green supply chain as a whole are major factors influencing a decision of GBT adoption by stakeholders [12,79,80]. In fact, although the industrial awareness of GB is significantly improved, Vietnam construction developers still claim that delivering green building projects faces many challenges due to a lack of competent contractors, designers, and consultants (including supervisors, inspectors, green consultant specialists) [20,81].

The finding implies that it is essential to implement appropriate integrated measures from the government, industry associations, non-governmental organizations, and educational centers to improve the competency and readiness of construction stakeholders. For instance, the government should formulate mandatory policies and regulations on green public procurement and adopting GBTs into public building projects. This is necessary because it motivates or exerts pressure on the industry practitioners in improving their GB capability to be able to take part in public projects. Implementing educational programs on GB for contractors, design units, and consultant units is also considered to be very necessary to raise their knowledge and competency level, especially in the context of developing economies such as Vietnam, in which the GB sector is just at its initial stages of development [2]. Besides, establishing green building rating systems and labeling programs by industry associations or third parties is also considered to be helpful in enhancing the GB readiness of project stakeholders through providing relevant technical guidance, as well as nurturing green consultant specialists [2].

### 6.3.4. Social Demand for Green Building

The result showed that the social demand for green building emerged as the third most significant contributor towards GBT adoption intention by developers ( $\beta = 0.174$ ,  $t = 2.557$ ). This finding is consistent with the results of previous studies. For example, Zhang, et al. [7] found empirically that the absence of customers' demand negatively influences green building strategies in the Chinese construction industry. Zhao, et al. [82] argued that the public attitudes and awareness of environmental sustainability could be translated into social demand for GB; and also revealed that the social demand has a significant effect on the promotion of GB.

In order to boost the social demand for GB, it is necessary to combine the educational, legal, and policy measures [5,13]. Public education on environmental sustainability and GB should be considered as an effective strategy to enhance the attractiveness of GB and GBTs in the entire society [2]. The strategy can be implemented through public and professional activities, such as media programs, talk shows, and scientific conferences. Additionally, the government should also be more responsive to the trend of sustainable construction by promulgating strong legal regulations and appropriate incentive policies (e.g., grants or loans) to stimulate the social demand of GB [13]. This could start with issuing technical codes and guidelines on GB for different types of buildings, establishing building labeling systems, and developing a reliable national or regional database for GBTs in terms of specification, cost, and benefits [2,13].

## 7. Conclusions

Promoting GBT adoption is an imperative approach to realize the green and sustainable construction industry. At present, the rate of GBT adoption is still low because many obstacles exist in the construction market in Vietnam. Construction developers play a key role in GBT adoption, and also in the development of the green building market. Based on the evolutionary and resource-based theoretical perspectives and the related literature on GBTs, this study proposes a research model to explore the factors that affect GBT adoption intention by developers in developing countries.

### 7.1. Theoretical Implications

The study makes important theoretical contributions to the GBT literature. First, using data from 142 respondents, the study further examines the empirical validity of the integrated utilization of DOI, RBV, and RDT for studying GBT adoption. The combination of these three theories helps to overcome the limitations of the relevant theories of innovation adoption (e.g., DOI) against the unique characteristics of the GBTs adoption process, and especially it helps to investigate the effect of the resource interdependency within the green project supply chain as a whole on the developers' GBT adoption intention. Secondly, this study provides the existing literature on GBT adoption with reliable empirical evidence in a developing economy such as Vietnam—the context has not yet received much attention from scholars. Consequently, these empirical results will be more valuable for the theory building of GBT adoption.

### 7.2. Practical Implications

This study provides some important practical implications.

- (1) First of all, the most important strategies to promote GBT adoption intention by developers in Vietnam should focus mainly on improving management leadership and the development of social demand for green building.
- (2) Second, in the current economic and social conditions, it is necessary to maintain close collaboration between government, local agencies, industry stakeholders, and other economic stakeholders where government intervention is key, by utilizing a combination of incentive policies and regulatory tools. Accordingly, the government and its local authorities should actively play a key role as controllers as well as leading promoters in fostering GBT adoption in Vietnam. First, the government is needed to be more responsive to the sustainable trend in the industry by promulgating mandatory legal regulations and technical codes/standards and guidelines to control and regulate the environmental performance of buildings. Furthermore, the government should also take responsibility as a key promoter by selecting and providing direct financial and non-financial incentive policies in the form of awards, deficit subsidies, direct grants, discounted development application fees, tax reliefs, low-interest loans, gross floor area, and concession schemes.

### 7.3. Limitations and Further Research

The first limitation of this study is the small sample size. Although the PLS approach can largely solve the relevant problem, future studies should use a larger sample size to retest the results in similar economies. Secondly, the generalization of the findings is limited due to the data having been collected in Hanoi and Ho Chi Minh City only. Future research should expand the scope of the investigation to validate and generalize the current findings. Finally, this study only focuses on GBT adoption intention from the construction developers' perspective; it would also be worth carrying out future research on relevant stakeholders in order to promote further GBT adoption and diffusion more comprehensively.

**Author Contributions:** Conceptualization draft, writing—original draft preparation, Q.T.; review and editing, Q.T., S.N.; resources, Q.T., N.-K.H. and T.-H.N., investigation, data collection, M.-H.N. and Q.-K.P., visualization, T.-S.K., providing feedback, T.-H.D. and V.-P.N., project administration, Q.T. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research is funded by the Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number 502.02-2018.39.

**Acknowledgments:** The authors are thankful to the reviewers and editors for their valuable feedback and suggestions.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Variables and measurement items

Latent Variables	Items	References
Perceived GBT Advantage (Ad)	Ad 1: Improved company image/reputation and impressing regulators and the public through an improved commitment to social responsibility Ad 2: Enhanced marketability Ad 3: Increased building value Ad 4: Higher return on investment Ad 5: Improved quality of building projects Ad 6: Improved competitive advantage	Self-developed based on Low, et al. [41], Chan, et al. [43], Devine and Kok [44], Abidin and Powmya [45]
Perceived GBT Disadvantage (Disad)	Disad 1: Increased initial costs of GBT-adopting building projects Disad 2: Increased technical complexity in terms of testability, trialability, installation Disad 3: Low compatibility with existing traditional construction practices Disad 4: Increased managerial complexity when delivering building projects Disad 5: Increased risk of delay in building projects	Self-developed based on Wang, et al. [4], Chan, et al. [9], Robichaud and Anantatmula [47], Ying Liu, et al. [46], Koebel, et al. [12]
Organizational GBT Resource (OGR)	OGR 1: We have qualified project teams to successfully deliver green building projects. OGR 2: Other staff members from the relevant units also have good knowledge of GBTs to provide assistance as required OGR 3: We have well-defined technical standards and procedures for green construction OGR 4: Availability of appropriate GBT database OGR 5: We have an ensured budget specific for green building project	Self-developed based on Wang, et al. [4], Darko, et al. [17]; Chan, et al. [11]; Chan, et al. [9], Nguyen, et al. [13], Lam, et al. [50], Hwang and Ng [25]
Top Management Leadership (TML)	TML 1: Our managers have good knowledge and awareness of green building's benefits and the current green building market trends, as well TML 2: Our managers have a positive attitude towards green building TML 3: Our managers have an innovation-oriented leadership style TML 4: Our managers have a strong sense of community belonging	Self-developed based on Darko, et al. [52], Chan, et al. [11], Aktas and Ozorhon [51], Häkkinen and Belloni [49], Shi, et al. [83]

Table A1. Cont.

Latent Variables	Items	References
Government Support (GovS)	<p>GovS 1: The government and its agencies have a strong commitment to green building and sustainable development in general</p> <p>GovS 2: The government and its agencies provide incentives/support to promote green building and GBTs in both the public and private sectors</p> <p>GovS 3: Codes and regulations/legislation on green building and GBTs are well-defined, sufficient, and available</p>	Self-developed based on Qian and Chan [53], Potbhare, et al. [62], Koebel, et al. [12], Darko, et al. [30], Darko, et al. [3]
GBT Market Readiness (GMR)	<p>GMR 1: There are tested and reliable GBTs in the local market</p> <p>GMR 2: The GBT market is steady in terms of price</p> <p>GMR 3: There are available laboratories and equipment/tools specific for testing and assessing GBTs in the local market</p> <p>GMR 4: There exist easily accessible technical guides/handbooks for implementing GBTs</p> <p>GMR 5: There are many examples of GBT-adopting projects</p> <p>GMR 6: There exist good alternatives for green building rating systems and labelling programs</p>	Self-developed based on Potbhare, et al. [62], Hwang and Ng [25], Aktas and Ozorhon [51], Koebel, et al. [12], Darko, et al. [3], Darko, et al. [17]
Project Partner GBT Readiness (PPR)	<p>PPR 1: Contractors with good expertise and skills on green building practices are available and ready to cooperate with us to deliver GBT-adopting projects OK</p> <p>PPR 2: Consultants (including design units, supervision units, green consultant specialists . . . ) with good expertise and skills in green building practices are available and ready to cooperate with us to deliver GBT-adopting projects</p> <p>PPR 3: GBT product suppliers are available and ready to supply green technology products as required</p>	Self-developed based on Berardi [26], Hwang and Tan [63], Li, et al. [64], Wang, et al. [1]
Social Demand for Green Building (SDGB)	<p>SDGB 1: People's increased demand for green and smart residential buildings</p> <p>SDGB 2: Government's increased demand for green public building projects</p> <p>SDGB 3: There is a lot of different types of building markets to develop green building; for example, resorts, condotel, officetel, shophouse, industrial buildings, etc.</p>	Self-developed based on Djokoto, et al. [65], Rodriguez-Nikl, et al. [66], Zhang, et al. [7], Koebel, et al. [12], Wang, et al. [1], Baek and Park [58]
GBT Adoption Intention into Building Projects (GAI)	<p>GAI 1: Green building will be integrated into their business strategy.</p> <p>GAI 2: GBTs have been adopted more and more in terms of type and quantity.</p> <p>GAI 3: They have a clear plan to open different categories of building projects that will adopt GBTs</p> <p>GAI 4: Green building culture has been becoming one of the key characteristics of their organizational culture</p>	Adapted from Wang, et al. [1], Venkatesh, et al. [77]

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