

Evaluation of Sustainable Factors in the Chinese Construction Process

Zhengong Wang*

Zhejiang Jiangnan Project Management Co. Ltd, Hangzhou, Zhejiang 310012, China

Abstract: The building sector plays a key role in the global economic, social, and environment development. The energy consumed during construction and operation processes accounts for around 40% of the global energy use. China is the largest developing country and its construction market is one of the largest markets in the world. Although the construction phase occupies only a short period over the entire life cycle of a building, it is still an essential aspect of the process. However, in China, the concept of green construction remains scarcely known among construction industry members. Green construction continues to experience a disparity in the Chinese construction industry. Therefore, the aim of this study is to appraise the concept of green construction in the Chinese construction industry and to consider how it could be applied in most Chinese construction projects.

Keywords: *China; green construction phase; entire life cycle; essential aspect*

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Corresponding author: Zhengong Wang,
tthbbs@outlook.com

1 Introduction

1.1 Background of the study

The concept of sustainable development has become increasingly significant in the construction industry across the world. This industry is one of the largest contributors of global environmental deterioration. On the positive side, the construction phase is a production process that allows for new places and facilities to be built to satisfy the work and leisure needs of humans. On the negative side, such a construction phase is also

a destructive process that has negative impacts. In this phase, the ecology and environment can be damaged. In addition, it can also consume a vast amount of natural resources and produce plenty of greenhouse gases. China is the largest developing country in the world, and the construction industry is one of the most significant industries within the scope of Chinese development. This is indicated as recently as 2014 when the construction industry provided around 50 million jobs and contributed 7.03% to the total gross domestic product of China. However, the energy consumption and waste from construction materials are more prevalent compared to other industries. Sustainability in the construction industry of China is in its infancy. It is far behind numerous developed countries such as the United Kingdom, the United States, and Australia. Hence, the Chinese construction industry should draw more attention and focus toward sustainable construction.

At present, in China, the term “sustainable development” in the construction industry is more focused on the building design phase. In this stage, it is ideas such as the application of new materials, location of building and attention to structural design that is considered to achieve the goal of sustainability. This may also ensure the protection of the ecology and the overall energy conservation during the whole life cycle of buildings, especially in the building construction stage. However, in this construction stage, the destructive elements to the environment and energy consumption throughout the process are still disregarded compared to the other stages of the construction process. In recent years, the concept of “green buildings” has become more popular in China due to increasingly heavy air pollution that is rampant in the largest conurbations. The overall construction

process should involve not only the design phase but also considerations required in the construction phase. Hence, “green construction” is part of a whole green building life cycle. This, then, concentrates on protecting the ecology and environment. Together with reducing the consumption of natural resources, this hopes to provide a healthy environment throughout the construction phase.

1.2 Aim and objectives

The aims of this study are to appraise the term “green construction” in the Chinese construction industry and to consider how green construction could be applied in most Chinese construction projects.

The objectives of this study are as follows:

- To review previous literature on the definition of green construction and provide a detailed review of its development in China. This includes the general characteristics and the current state of green construction;
- To investigate and evaluate the practice of green construction in China, outline the regulations within China’s green construction and consider the factors that are affecting the development of China’s green construction;
- To explore the main challenges found in green construction in China.

1.3 Organization structure of the study

This study contains five chapters as follows:

Chapter one considers the background of this topic and outlines the aim and objectives of this study. It concentrates on identifying the statement of its purpose and shows in more detail the problems found in this topic. Chapter two discusses the literature review by studying the source materials that are found in relevant books, academic journals, and articles on the topic. The prevailing theories of the pertinent literature will be organized and summarized here. The objectives of this paper are then considered in the context of this literature review.

Chapter three outlines the research methodology. It concentrates on explaining the methods that are applied in the research process. In addition, it will consider other available options and look at any issues or challenges as well as potential improvements found within the research process.

Chapter four elaborates on the results and discussion. It describes and analyses the total samples received

from the questionnaire responses. It also discusses the background information of the data and is framed within the context of the aim and objectives of this study.

Chapter five conveys the conclusion and recommendations. It summarizes the entire study and draws a clear statement from the results. There are also recommendations made in this research area for future and further studies that may progress beyond the scope of this study.

2 Literature review

2.1 History of sustainability

The concept of sustainability has developed progressively over the past 40 years. At present, in the 21st century, the concept has, particularly, developed rapidly across the world. Adams^[1] stated that the International Union for Conservation of Nature (IUCN) has adopted this relatively new idea of sustainability since 1963. Following this, in Stockholm, Sweden, in 1972, the Report of United Nations Conference on the Human Environment discussed that, along with economic growth, human environment should be protected and enhanced by humans themselves. This is a similar concept to sustainability^[2]. Following this, in 1987, the United Nations’ World Commission on Environment and Development (WCED) published a report entitled “Our Common Future,” also known as the Brundtland Report. This further developed the terms “sustainability” and “sustainable development”^[1,3]. Arguably, the Brundtland Report is widely accepted as the earliest official citation of both these terms.

“Our Common Future” (1987) defines sustainable development as “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*” Although this is an often accepted definition of sustainable development, it is still rather vague and general. This definition only includes two key elements that relate to basic human needs and environmental problems. Nowadays, there has not yet been a standard definition of sustainability since this concept was first created. Scholars and practitioners have interpreted various definitions from different fields such as environmentalism, economics, architecture, and engineering. Similarly, Agekum-Mensah *et al.*^[4] have pointed out that there is not a unified accepted meaning of the concept of sustainability. The sustainability comprises the activities that, for all practical purposes, can continue indefinitely. Hill and Bowen^[5] contended

that sustainability is the ability to sustainably operate natural resources. Furthermore, Mora^[6] has suggested an economical explanation of sustainability and that it could operate to describe sustainable development in economic terms. Nevertheless, according to McGraw Hill Construction^[7], sustainability is denoted by several common factors that involve economic, social, and environmental considerations. At present, sustainable development does not only concentrate on environmental issues but also covers economic and social aspects. The term “sustainable development” has been more broadly applied within development policies.

2.2 Sustainable building

The construction industry is one of the largest energy consumers out of any industry worldwide and is also one of the largest contributors of environmental destruction. The term “sustainability,” when applied to built environment, might lead to a change in the traditional construction industry to become a more sustainable development industry. According to Hill and Bowen^[5], the initially proposed sustainable building was characterized by the accountability that is achieved in sustainability in the construction industry. Therefore, both scholars of architecture and building engineers have attempted to create this concept of sustainable building, which has been increasingly developed over the last few decades. Progressively, sustainable construction projects are being built in many developed countries such as the United Kingdom, the United States, and most European nations, and also recently in several developing countries such as China and India. Kibert^[8] proposed sustainable construction to be defined as a healthy built environment that is created by ecological ethics, which also includes considerations of being resource efficient, material efficient, and land efficient. Meanwhile, according to DETR, there are five objectives that are included in the three fundamental elements of sustainable construction that relates to the social, economic, and environmental aspects. These objectives are as follows^[9]:

- To ensure that construction projects are more competitive and cost-effective.
- To provide valuable buildings to clients and future users.
- To ensure the interests and respect of the investors.
- To protect the environment and improve efficiency.
- To maximize the reduction of carbon-based energy and the consumption of natural resources.

As mentioned previously, the concept of the sustainable building is an attempt to combine construction projects with considerations of wide-ranging environment problems to reduce the environmental impact of buildings. The aims are to reduce energy consumption, increase water conservation, reduce pollution, protect the environment and ecology and generally enhance the buildings’ productivity to benefit future generations.

Nevertheless, sustainability, when applied in built environment, could be customized according to different circumstances. Sustainable construction is increasingly being applied, and so it is essential to differentiate between “sustainable works constructed” and “sustainable construction activities”^[6]. This means that sustainability in construction projects could be associated with either building actions in the construction phase or the process as a whole construction project. In addition, sustainable sites may offer a good opportunity to create a built environment using renewable resources^[10]. This means that a building that is constructed in one of these sites may help reduce total carbon dioxide emissions. Moreover, construction projects use the concept of sustainable construction to describe environmental standards of construction. These standards comprise the construction process of buildings that include a building’s maintenance and repair or even demolition activities. Alternatively, Mora^[6] discussed that if construction projects want to attain the aims of sustainability when they are first conceived, they should employ renewable energy resources, renewable materials, or other kinds of environmental protection technologies.

2.3 Green building

Although the Chinese construction market is one of the largest markets in the world, green building in China has started relatively late. In the 1980s, residential buildings of northern China started to incorporate energy saving technology and by the beginning of the 21st century, it had spread to other types of building and in almost all other districts. According to Ye *et al.*^[11], the concept of green building was established from “*Residential Building of energy conservation and land-saving*” as required by the Chinese government in 2004. In 2006, the Chinese government announced the Evaluation Standard for Green Building (GB50378-2006), also known as the Three-Star Green Building Evaluation System. This system specifically comprises two key building phases and six categories. The two

phases are the design phase and the application phase. There are >300 labels in the design phase and only 22 labels in the application phase, respectively. The six categories include sustainable site and atmosphere, energy conservation and efficiency, water conservation and efficiency, materials conservation and efficiency, interior environmental quality as well as operation, and management of the buildings. Therefore, this evaluation system is far more focused on the designing phase rather than the building process as a whole. The construction phase is not even included in this system.

2.4 Green construction

2.4.1 Definition

There are various connotations of the definition of green construction that are given by scholars and government guide. In 2007, China's Ministry of Construction published the Green Construction Guideline. This indicated that the definition of green construction not only includes concerns regarding the quality and other basic requirements of buildings but also an application of scientific management and advanced technology on a construction site. This is an attempt to maximize the reduction of negative influences on the environment. Additionally, there is an aim to attain the "four items of energy-saving," which is related to energy, land, water and material conservation, as well as "one item of eco-friendly," which is related to environmental protection^[12]. Xiao and Feng^[13] indicated that green construction is based on sustainable construction projects and should involve the drawing design stage as well as the whole construction stage. In these stages, construction activities could ensure both quality and safety elements on a construction site. Through state-of-the-art management method and building technology, the aim is to achieve green goals such as energy efficiency, water efficiency, and being more environmentally friendly. In other words, green construction is the practice of construction activities in a building process; these activities are associated with the concept of sustainable development and also concentrate more on environmental protection.

2.4.2 Current state in other countries

Other developed countries have studied green construction much earlier than China. According to Zhao and Zhang^[14] and Li *et al.*^[15], it was an architect named Paolo Soleris who, in the 1960s, combined

architecture and ecology to create the idea of ecological building. At the year of 1969, another architect named Ian McHarg published a book called design with nature. This marked the introduction of the term "ecological architecture." Later in 1987, "sustainable development" was coined by the WCED^[1,4]. This concept gradually became mainstream in the construction industry. At the beginning of the 1990s, several developed countries started to research the term "green construction." These countries not only published laws and regulations but also created assessment systems to secure countenance and incentives of green construction practices.

The United Kingdom, as a leader in the construction industry globally, created the Building Research Establishment Environmental Assessment Method (BREEAM), the first green building standard in the world^[15,16]. BREEAM not only included the design phase of green building but also the construction phase. Its schemes were more specific as it directly covered topics such as "management, health and wellbeing, energy, transport, water, materials, waste, land use and ecology, pollution, and innovation"^[17]. Moreover, the British government promulgated a plan in 2008 called the Low Carbon Transition Plan. This plan was ambitious as it required all new construction projects to ensure zero greenhouse gas emission by the following year. From 2018 onward, all public construction projects, including both commercial office buildings and residential buildings, must include the installation of smart meters^[18]. Bulkeley *et al.*^[19] suggested that "all buildings should satisfy green building criteria from 2008 in Britain."

Since BREEAM was announced, there have been various green building rating systems published by organizations from various countries. One example is the Leadership in Energy and Environment Design (LEED) that was introduced in the United States in 1998. LEED rates green building according to land-saving, energy-saving, and water-saving capabilities as well as an interior surrounding. Green Globes is another rating system from the United States. Other examples include Australia's Green Star environmental rating system, Japan's Comprehensive Assessment System for Built Environment Efficiency in 2001, and Germany's Gesellschaft für Nachhaltiges Bauen from the German Sustainable Building Council in 2009^[20]. These rating systems assess almost all types of construction projects such as residential, institutional, and commercial projects. In addition, these systems have promoted

and developed green construction in these developed countries. However, although the above-mentioned green building rating systems offer an advanced model of operation and extensive practical experience, their structures are largely similar. Moreover, they might not be completely applicable in China. Therefore, in 2006, a Chinese assessment tool called the Green Building Label was published by the central government of China.

2.4.3 Green construction

In the early 1980s, due to the central government's realization that the national construction industry was heavily and increasingly consuming more energy, the first edition of the Civil Building Energy Efficient Design Standard (for Residential Building Heating) was published by the Ministry of Construction in 1986^[12]. The aim of this criterion was to achieve a saving of 30% in energy consumption in residential buildings. 10 years later, a revised edition the Civil Building Energy Efficient Design Standard (for Residential Building Heating) was issued. The aim of this edition was to increase the saving of energy consumption to 50%^[15]. In 2001 and 2003, respectively, the Ministry of Construction also promulgated the Residential Building Energy Efficient Design Standard in Hot Summer and Cold Winter Area, as well as its' revised edition.

In 2005, the Ministry of Housing and Urban-Rural Development (MOHURD) published a standard called the design standard of public green building. This criterion demanded that construction projects drop half of their total energy consumption each year. The renewable energy law was formally implemented in January 2006. The following year, the MOHURD announced the Green Construction Guideline. Although there were some criteria published by the central government in the past few decades, the concept of green construction remains a relatively new idea. Shi *et al.*^[21] proposed that the construction projects for the Beijing Olympic Games allowed for practical experience of green construction in China. These projects were mainly supported by the government. Other government standards were referred to in the rating exercise such as design standard for energy efficiency in public buildings (GB50189), thermal design code for civil buildings (GB 50176), and code for indoor environmental pollution control in civil buildings (GB 50325)^[21].

Since the green construction guideline was published, the development of green construction has been

promoted across China. In this circumstance, there are more Chinese scholars that have started to research green construction associated with the national conditions. For instance, green construction seems to represent the specific utilization of the concept of sustainable development in the construction process. Liu (2010) analyzed the state of green construction management and issues in China and asserted that the scientific management associated with construction technology improvement could be the primary approach to achieving green construction. Moreover, most construction supervisors or engineers believe that green construction technologies could be acquired due to them being more popular rather than being compelled by the central government or its regulations^[12]. According to Li *et al.*^[20], the effective elements of green construction include the option of construction management and approach, the operation of construction machinery and green materials as well as the recycle operation of construction waste. Although green construction is more popular than the Green Construction Guideline that was previously published, the backward outlook of the construction management system and methodology seems to still restrict the development of green construction in China.

3 Research methodology

3.1 Overview of types of research methodology

Qualitative research is regularly applied in social science research. The purpose of this form of research is to gather an insight into human behavior and the reasons behind them. This approach is subjective since it investigates reasons and methods of decision-making. Conversely, quantitative research involves the organization of data collection and empirical testing techniques for analysis and later use in statistics and mathematics^[22]. Here, an investigator might ask specific questions to participants and collect their mathematical results. These collected results are evaluated in the context of particular participants. In addition, mixed-method research combines both qualitative and quantitative techniques by applying multiple methods to collect data. However, this approach is quite difficult to operate and is generally reserved for advanced studies^[23].

3.2 Research methodology of the study

This study adopts predominantly quantitative research. Both primary data and secondary data were collected

through a questionnaire and literature review, respectively.

Data collection was accomplished through a questionnaire intended to survey the circumstances of green construction in China. It was related to the factors that affect green construction development in China and the challenges involved, all of which were based on the wide literature review. The questionnaire consisted of 10 questions in total, a few of which were related to basic information about the respondents. The other questions were associated with the study's aim and objectives. The questionnaires were delivered through e-mail and also through a website to help collect the primary data. The data were subsequently analyzed and discussed. Moreover, survey software was used to help with the data collection.

3.3 Issues and challenges of the study

There were a number of issues and challenges that were found in the data collection process. First, there was the issue of translation between English and Chinese languages. This study was directed at the Chinese construction industry, but most Chinese architects, engineers, or supervisors could not speak English. Therefore, the questionnaire was translated into Chinese language. After receiving the completed questionnaires, the data content was promptly retranslated into English language. Second, the geographical constraint further challenged the data collection process. The initial data collection process was slow as there were only 14 responses after approximately 1 month. The large distance covered by the study also hindered alternative data collection methods such as interviews or postal delivery of the questionnaires. This issue was eventually solved with the use of a professional survey website.

4 Results and discussion

This chapter first presents the questionnaire results, analyses, and discussion. In total, there were 110 respondents from a varied geographical pool, covering 20 provinces, and four municipalities in China. The data were collected through the internet, and the respondents include a wide range of members of the construction industry such as engineers, developers, managers, and builders. Both Figures 1 and 2 show the locations of respondents and their numbers by area, respectively. Beijing, Shanghai, and Guangdong [marked red in Figure 1] are the most developed areas in China, and

these districts saw the highest number of respondents in this study.

4.1 Results

4.1.1 Generation information of respondents

Figures 3-5 present information, respectively, about the respondents' length of work experience, the nature of the projects they have been involved in, and phases of construction process they tend to be involved in.

Figure 3 reveals the respondents' length of work experience. In this survey, around 85% of respondents have been working for <10 years. This might be because the questionnaire was delivered through modern techniques such as website and social media. Younger people are more active in such communication methods and are, therefore, more likely to respond through these channels. On the other hand, this might also reveal that there are numerous participants with plenty of work experience in the Chinese construction industry but are not skilled in modern communication methods. Figure 4 indicates that most respondents are working or have worked on residential and commercial projects. This seems to be accorded with the Chinese construction market as, in the last decade, numerous houses, apartments, and office buildings have been constructed by property developer companies in China. Furthermore, Figure 4 also shows that approximately only one-third of respondents are working or have worked on other institutional projects. However, there are no civil engineering projects such as highways and railway projects in which these respondents have worked. Figure 5 shows information about what phase of the construction process that respondents were working in. It clearly indicates that the majority of respondents are working in the design phase (59.09%) and the construction phase (60%). It is presumed that these two phases are significant and provide plenty of occupations in construction projects.

4.1.2 Results of respondents' green building knowledge

The respondents' knowledge of sustainable building or green building is very important for the following sections of the questionnaire as it might affect the quality of its results. Figures 6-8 indicate respondents' attitudes toward green building, the extent of acquired knowledge of Chinese sustainable building and green

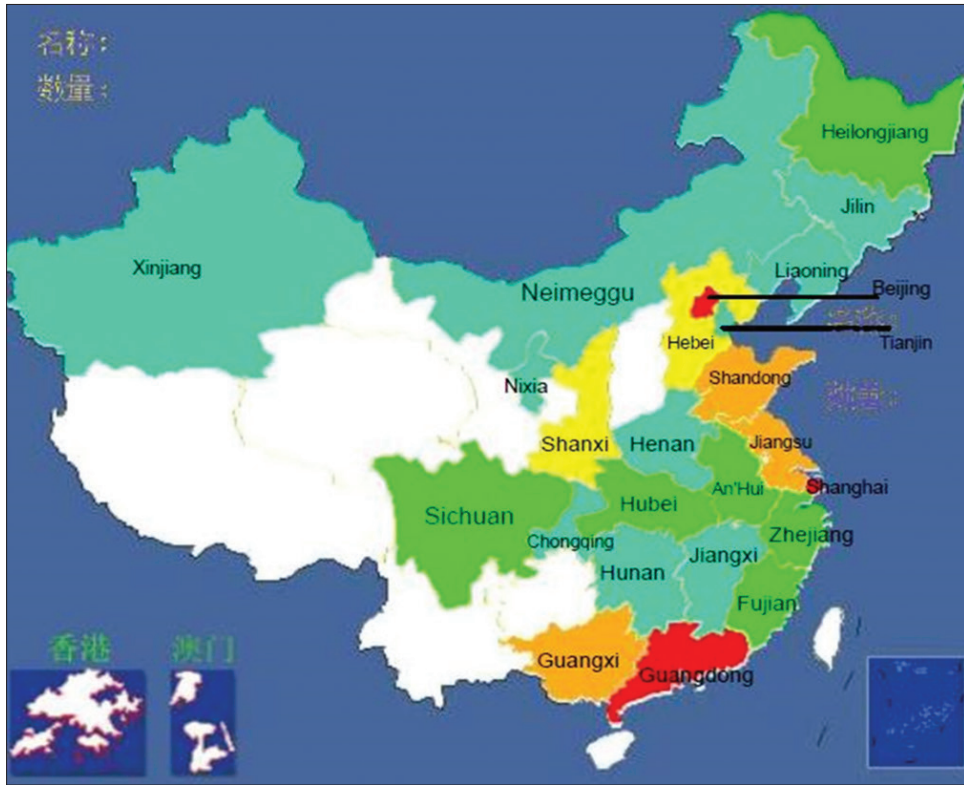


Figure 1. Location of Respondents

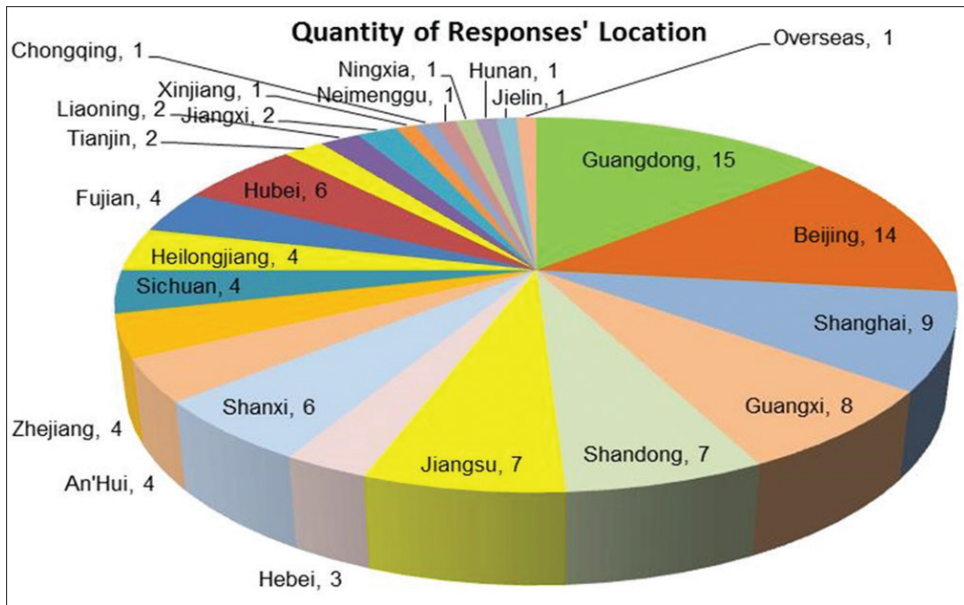


Figure 2. Number of respondents by location

building market as well as knowledge of the various international rating systems of green building. Based on Figure 6, 60% of respondents either strongly agree (13.64%) or agree (46.36%) that China's contribution in green construction is less than that of other developed countries. The reason for this data might be due to the Chinese green construction market that started relatively later than those of developed

countries. Figure 7 shows that most respondents have acquired a degree of information on green construction from higher education courses. There is 10% of respondents did not study about green construction throughout their higher education. On the other hand, >50% of respondents possess little knowledge about green construction. As is shown in Figure 8, LEED, BREEAM, and Green Globes are the three most

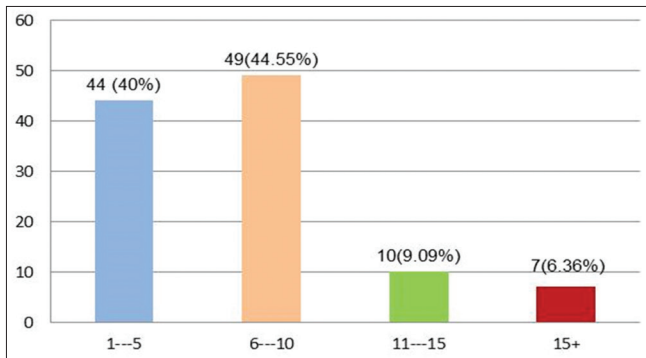


Figure 3. Length of work experience of respondents

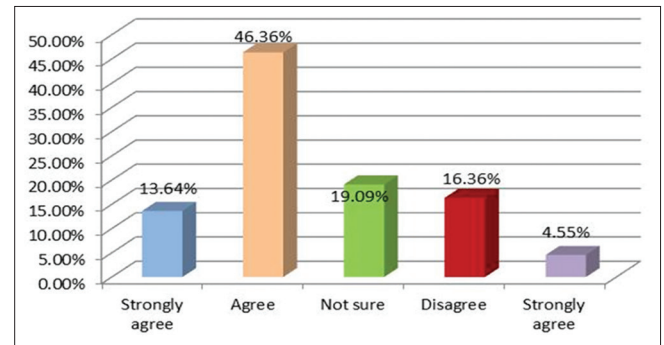


Figure 6. Respondents' attitudes towards China's continued contribution to green construction

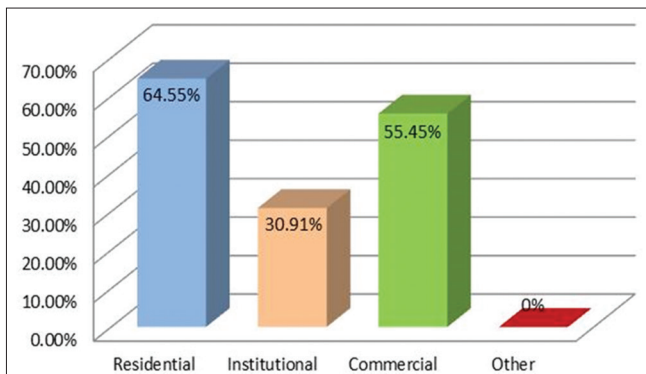


Figure 4. Type of projects involved by respondents

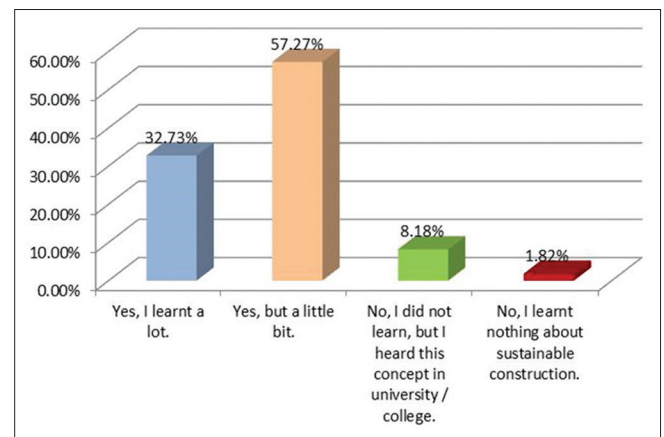


Figure 7. Acquired knowledge of green construction in higher education

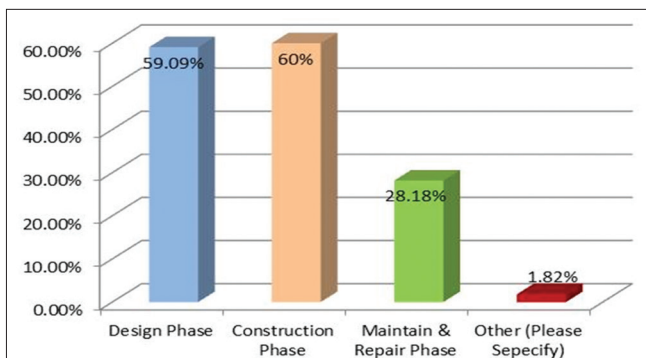


Figure 5. Phases of construction project involved by respondents

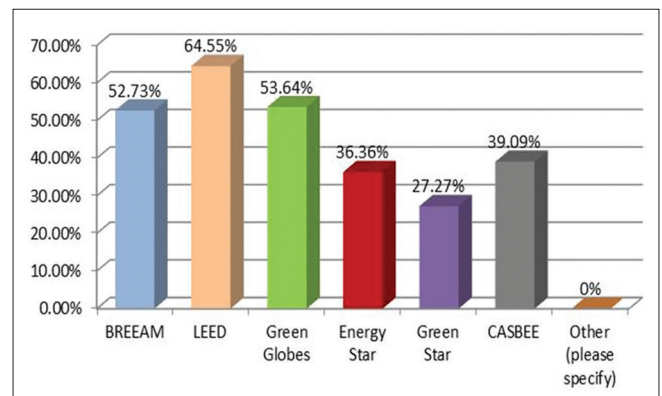


Figure 8. Knowledge of international green building rating systems

commonly known green building rating systems. A significant 64.55% of respondents know of the LEED system, which is the highest figure in this survey. Although the United Kingdom's BREEAM standard is the first green building system throughout the world, the United States' green building standards seem to be the most recognized in China.

4.1.3 Results of factors that affect construction projects in China

According to Table 1, the most important of factors that affect Chinese construction projects are "To Create a Healthy Environment on Site," "Resources are Used

Effectively," and "Reduce Pollution." The average score of these three factors is the same, which is 4.15. However, "Resources are Used Effectively" is the most difficult to control in the construction phases, which is revealed to be 4.83 in Table 2. In addition, the other two factors, "To create a healthy environment on site" and "reduce pollution," follow behind "resources are used effectively." On the satisfaction scale, "innovations" ranks as the second most significant factor in construction projects. "Innovations," which

Table 1. Level of importance given to construction projects in China

Objectives/options	1	2	3	4	5	Average score
Stewardship of projects (%)	0 (0)	2 (1.82)	19 (17.27)	60 (54.55)	29 (26.36)	4.05
Support communities (%)	0 (0)	5 (4.55)	18 (16.36)	57 (51.82)	30 (27.27)	4.02
Enhance biodiversity (%)	1 (0.91)	3 (2.73)	23 (20.91)	42 (38.18)	41 (37.27)	4.08
To create healthy environment on site (%)	0 (0)	2 (1.82)	15 (13.64)	58 (52.73)	35 (31.82)	4.15
Resources are used effectively (%)	0 (0)	2 (1.82)	17 (15.45)	53 (48.18)	38 (34.55)	4.15
Reduce pollution (e.g., noise pollution, greenhouse gas emissions, and so on) (%)	0 (0)	4 (3.64)	20 (18.18)	41 (37.27)	45 (40.91)	4.15
Innovations (%)	0 (0)	4 (3.64)	17v15.45)	52 (47.27)	37 (33.64)	4.11

Table 2. Factors considered difficult to control in construction phases in China

Options	Score
Enhance biodiversity	4.83
Resources are used effectively	4.83
To create healthy environment on site	4.1
Reduce pollution (e.g., noise pollution, greenhouse gas emissions, and so on)	3.94
Stewardship of projects	3.77
Support communities	3.57
Innovations	2.96

scored 2.96, is the easiest to control compared to all the other factors. In contrast, although “enhance biodiversity” scored the highest in Table 2, this factor is almost the least significant in construction projects, scoring an average mark of 4.08 and closely followed by “stewardship of projects” (4.05) and “support communities” (4.02). In addition, the respondents’ result of “enhance biodiversity” confirms that most members of the construction industry in China do not really realize the importance of protecting the natural environment. However, environment protection is an essential factor in green construction. This point will be discussed in detail in Section 4.2.

4.1.4 Factors affecting green construction development in China

As is described in Table 3, both “Government Developing Strategy” (scoring 3.75) and “Client’s Awareness” (scoring 3.71) are the most significant factors affecting the development of green construction in China. Although the average score of these two factors as a whole is only slightly different, the composition of this score varies significantly. For instance, the percentages of respondents who were neutral toward these factors

vary. Only 8.18% of respondents were neutral toward the “Government’s Developing Strategy” whereas 20% were neutral toward the “Client’s Awareness.” On the other hand, the “Construction Cost” was the smallest affecting factor, scoring 3.57. These influencing factors will be discussed further in the following section.

4.1.5 Challenges facing green construction in China

Table 4 illustrates some challenges facing the further development of Chinese green construction. On examining the average scores, “Local Government Regulation” appears to be the main challenge for green construction in China. The scores of “Social Responsibility” (3.59) and “Shareholder’s Strategy for Sustainability in Construction Phase” (3.58) are nearly the same, marking the second and the third largest challenges, respectively. However, the percentage results reveal something more for Option 4: “Shareholder’s Strategy” account for 65.45% of the respondents’ result. This factor is considered to be a significant challenge for the development of green construction, making it the most significant factor. Moreover, 63.63% of respondents believe that the current “Local Government Regulation” posed a significant challenge to the said development.

4.2 Discussion

4.2.1 Evaluation of factors affecting green construction development in China

Green construction has been thriving in the construction industry in China after the government announced the Green Construction Guideline. However, since green building and green construction started relatively later, there are several constraints on its development across China. They are as follows:

Table 3. The factors that affect green construction development of China

Objectives/options	1	2	3	4	5	Average score
Construction cost (%)	11 (10)	14 (12.73)	16 (14.55)	39 (35.45)	30 (27.27)	3.57
Construction technology (%)	9 (8.18)	8 (7.27)	29 (26.36)	33 (30)	31 (28.18)	3.63
Client's awareness (%)	5 (4.55)	8 (7.27)	22 (20)	54 (49.09)	21 (19.09)	3.71
The concept of construction management (%)	6 (5.45)	11 (10)	21 (19.09)	49 (44.55)	23 (20.91)	3.65
Government's developing strategy (%)	7 (6.36)	14 (12.73)	9 (8.18)	50 (45.45)	30 (27.27)	3.75

Table 4. Challenges facing green construction in China

Objectives/options	1	2	3	4	5	Average score
Social responsibility (%)	9 (8.18)	14 (12.73)	18 (16.36)	41 (37.27)	28 (25.45)	3.59
Customer demands (%)	7 (6.36)	15 (13.64)	28 (25.45)	34 (30.91)	26 (23.64)	3.52
Shareholder's strategy for sustainability in construction phase (%)	8 (7.27)	12 (10.91)	18 (16.36)	52 (47.27)	20 (18.18)	3.58
Local government regulation (%)	8 (7.27)	14 (12.73)	18 (16.36)	42 (38.18)	28 (25.45)	3.62
Lower sustainable construction technologies (%)	12 (10.91)	8 (7.27)	21 (19.09)	48 (43.64)	21 (19.09)	3.53

4.2.1.1 Government developing strategy

As mentioned earlier, >70% of respondents believe that the government's development strategy is the largest factor affecting green construction development in China. The achievement of green construction requires various subjects, such as the government, clients, developers as well as construction companies, to cooperate in its implementation. However, this cooperation, if supported by government strategy, could succeed. For instance, if the government's development strategy does not carry out green construction and construction company was to implement green construction in their project, the cost of building materials would be higher, the availability of necessary technologies would be lower, and this would increase the total cost of the project. This loss of profit for the company could, in turn, mean that it may never consider green construction again. Therefore, government strategy plays a significant role in this essential industry cooperation. If the government was to implement policies that support green construction development, the organizations, developers, and clients might implement green construction. Hence, green construction might never been achieved without government backing.

The central government should announce systematic, sustainable policies on both the macroeconomic and microeconomic levels for the operation of construction projects. Although the green building standard was announced in China in 1986, Shi *et al.*^[21] remarked that the concept of green construction was mentioned by

China's Agenda 21, which was published in 1994 by the State Council, China's highest executive body. This means that the Chinese government only completely adopted green construction as a state developing strategy in 1994. Nevertheless, the Chinese government could encourage industry members such as developers, clients, or engineers to take on green construction projects. It could compile reports about the concept of green construction and issue statements supporting the economic, environmental, and social interests of green construction. Liu *et al.*^[24] have argued that these industry members already have a positive attitude toward adopting the technologies and criteria of green construction. Furthermore, the implementation of green construction would inevitably encourage construction companies to compete in this market and increase social prestige. Moreover, many innovative technologies in China are still in their research stages and have not been commercialized. This is primarily due to the lack of an effective platform to promote, demonstrate, and communicate these new technologies. The government should continue to support research into these technologies, alongside their development, and work to promote technical communication.

4.2.1.2 Construction technology and the concept of construction management

The improvement of construction technology is primarily dependent on the transfer and penetration of other industries' technologies into the sector. For example, new material techniques, new energy

technologies, and equipment manufacturing technologies all feed into the construction industry. In this sense, the degree of development in construction technology could be determined by other industries' technologies. As a developing country, China has an under-developed technology sector. Although those green technologies such as solar panels or heating pump systems are relatively advanced in China, most technologies for green building are developing slowly or have not yet been combined as a complete set of systems. For example, there is no unified standard for solar panel application until recently, and this application is not made an essential feature of green buildings.

Furthermore, achieving green construction requires technological progress and scientific management. The improvements of these two aspects are one way to attain green construction. The fundamentals of green construction management are the establishment of a health management system and the formulation of a strict management institution, thereby assigning responsibilities to different management layers and implementing dynamic management. The final stage of effective management is the establishment of a green construction evaluation system. This is at the core of green construction management. Moreover, establishing practical measures of green construction technologies are the safeguard and mode of green construction management. Therefore, a green construction evaluation system and the development of its technology that assists in the growth of green construction not only complement each other but also are indispensable for a completely green construction management system.

4.2.1.3 Citizen's awareness of the lack of green construction

At present, most participants, such as government officials, clients, designers, construction engineers, builders, and public, lack awareness of environmental protection in general. The level of environmental protection awareness should be improved. For example, most respondents in this survey selected "Enhance Biodiversity" as a factor that was the most difficult to control rather than selecting a factor of higher significance in the construction phase. On the other hand, due to the characteristics of the construction industry, entry-level employees in China, generally, have lower education qualification. Hence, they might not pay enough attention to environmental conservation

and low energy consumption. They seem to have adapted to conditions of high volumes of serious wastage. In addition, developers and clients tend to concentrate on the criteria of green construction rather than consider the issues of environmental sustainability found in different types of construction projects^[21].

A fundamental component of green construction is to enhance effective resource application. First, it is imperative to consider protecting the natural surroundings and to ensure that construction activities are efficient, environmentally friendly, and energy conserving, while balancing these principles to satisfy the basic building elements such as quality, cost, safety, and civilization^[11]. Arguably, the citizens' participation in the development of green is summarized as being more or less feasible; the environmental problems are more concerning to scholars and government administrators, while citizens, in general, are less considerate with such issues. For instance, approximately 95% of all Chinese buildings are high energy consumers. The energy consumption per unit area of these buildings is 3 times higher than those of developed countries. However, as contractors are driven by profits, they might not want to utilize green construction technology.

4.2.1.4 Construction cost

It is commonly accepted that the cost of green construction is higher than traditional construction, which could affect its development. An example is that most developers are unwilling to operate new green technologies, citing concerns of increased costs and risks when applying new green technologies or systems^[25]. However, Kats^[26] surveyed >100 green buildings in 10 countries and concluded that the average construction cost of green construction projects was only 2.5% higher than traditional constructions. Furthermore, Li^[27] did survey results showed that the demand for green buildings has increased in recent years, with >35% of respondents willing to purchase a green building if the price was controlled at 6% higher than normal buildings. In fact, green construction appears to more effectively utilize natural resources within economic means. In addition, the goal of most developers is the pursuit of profit. The implementation of green construction projects has to face numerous barriers. The extra cost of green construction technologies has become one of the primary barriers of its implementation in the Chinese market. In contrast, consumers care more about the cost

of the performance of the building, which must support their comfort and well-being.

4.2.2 Evaluation of green construction challenges in China

4.2.2.1 Government regulations

Currently, in China, the regulation systems that govern the construction of green buildings are inadequate, and various laws are imperfect. More specifically, the green construction legal enforcement is lacking. The position of green construction within construction law is not clear; neither is its position within energy law and energy conservation law. A green construction management system has not been established. This management system should control the planning, design, construction, operation, and demolition of an entire lifecycle of green construction. In general, the government emphasizes the performance of building design and construction, rather than emphasizing on the construction process such as the supervision of construction materials and construction waste recycling. Furthermore, the current incentive policies for green construction promotion are inadequate. These policies only include aspects of finance, taxation, as well as economy. There are no policies to inspire developers to demand that green construction principles are applied in their projects. There is a lack of incentive measures that encourage construction companies to adopt green construction management methods or green materials. Therefore, a shift in legislation seems to be the fundamental approach in promoting green construction. Furthermore, the power of administrative supervision over green construction is weak in China. The existing regulatory system emphasizes energy conservation over water, land, and material conservation as well as environmental protection. Since the announcement of the Evaluation Standard for Green Building and Green Construction Guideline by the MOHURD in 2006, many items have not been affected in the implementation process. The main reason for this is the lack of regulation by the local governments. Thus, most investors or construction companies may not implement the standard items. This means that the relevant laws and regulations for promoting green construction are limited.

4.2.2.2 The social responsibility of construction industry members

There are some misunderstandings of the green construction process among most members in the

construction industry. They tend to believe that green construction entails high cost and high-tech construction methodologies. The promotion and population of green construction have been limited by this misunderstanding. A significant number of architects, engineers, and supervisors have not been acquainted with the connotations of green construction. Similarly, most builders and consumers do not recognize the profound influence of green construction.

Both of these factors could affect the demand for green construction within the construction market. Moreover, the public believes that it is the government's responsibility to uphold environment protection, not their personal responsibility. Some developers do not consider distinguishing between the natural environmental conditions prevailing in China and other developed countries, preferring to directly apply other countries' green construction assessment tools without customizing to China's environment. Some contractors do not take into account the entire lifecycle of construction projects, piling up a number of high-paying technologies.

Furthermore, since contractors tend to focus on construction cost and green construction technology is generally more costly, the latter is often not considered. In addition, China is a developing country, and its construction industry members are unsure of the expected returns on their green construction investment. This may affect their decision to consider a green construction project.

4.2.2.3 Fewer green construction technologies

There is not enough supporting capacity for green construction technology in China. The fundamental research required for green construction is weak. This means that the significant and difficult elements of green construction technology have not yet been analyzed or resolved. A technology system befitting Chinese local characteristics and construction functions has not yet been formulated. Furthermore, the development of green construction materials is slow, while the extent of integration between the materials and construction industry is low. The construction industrialization in China is in its initial stage, so relevant government policies, regulations, and technologies have to be improved. At present, the construction industrialization only accounts for approximately 5% of the construction industry in China. In contrast, the average construction industrialization of developed countries accounts for

around 65%, especially in Sweden where the figure is as high as 80%.

The evaluation criteria for measuring green construction are currently imperfect. There are some unreasonable indicators within these criteria. Most current green building evaluation systems are not intended for assessing construction works. These tools merely concentrate on assessing and reporting information that can be assessed, rather than reporting on what architects, engineers, or clients really want to know. The green construction evaluation systems mostly concentrate on assessing aspects. In particular, there is a lack of quota standards that are associated with green construction. This is difficult to lead and restrict effectively within green construction practice. Furthermore, a number of aspects and subjects are related to the planning of green construction. Although various professional subjects have developed their own standards, there is a lack of cooperation between them. At present, there is a lack of green construction specialists such as consultants, planners, architects, engineers, and appraisers. This is mainly because most higher education institutions in China utilize traditional building models when training construction students. Consequently, most construction companies seem unwilling to invest financial and energy resources into the fostering and development of green construction engineers. Therefore, to consider this point of view, green construction specialists are unlikely to develop their career in the short term.

5 Conclusion and recommendations

5.1 Summary and review of chapters

5.1.1 Chapter one: Introduction

This chapter has described the proposal of this study. It described the background information and identified a gap in the research area that this study aims to fill. It also laid out the aims and objectives of this study as well as the organization structure of this thesis. The aims of this study were to appraise the concept of green construction in the Chinese construction industry and to consider how green construction could be applied in most Chinese construction projects. In addition, the core topic of this study is green construction, which is based on the overall construction phase and consists of the drawing design stage and the entire construction stage. However, the concept of green construction is in

its initial stage in China and is still rather scarce among construction industry members.

5.1.2 Chapter two: Literature review

This chapter has looked into the study's source material found in relevant books, academic journals, and articles that are relevant to the topic. The literature collected has been organized and summarized into four main sections, which are the history of sustainability, sustainable building, green building, and the concept of green construction, on which the notion of sustainability is based. These sections fulfilled one of the objectives of this study, which was to provide a detailed review of past literature on the development status of green construction across the world as well to reveal the current status of green construction in China.

5.1.3 Chapter three: Research methodology

This chapter has explained the methods that were applied in the research process. It first introduced the various forms of research methodology. Second, it showed that the questionnaire survey method was employed to collect data on the status of green construction in China. Finally, the issues and challenges of the research process were revealed. The main issue was the difficulty of translation between the English and Chinese languages. The main challenge was the geographical constraint of reaching respondents. This led to finding a solution to the limitation of data collection method.

5.1.4 Chapter four: Results and discussion

This chapter has summarized and organized the questionnaire responses and discussed their results. It analyzed a total of the 110 completed questionnaires, which were answered by construction industry respondents across a vast geographical area in China. The data have been discussed and framed within the context of the objectives of this study. The results of the 10 questions posed to the respondents were presented, respectively. The discussions fulfilled two key objectives of this study, which were to examine the factors that affect the development of green construction in China and the challenges of implementing green construction in China.

5.2 Key findings of the study

5.2.1 The current state of green construction in China

At present, the broad literature review reveals that in China, green construction studies concentrate more

on the environment, which involves greenhouse gas emission reduction, energy consumption, and the development of assistive technologies such as solar panels. However, the study of green construction management methodologies and systems that aid green construction are relatively weak. In addition, two-thirds of respondents agreed that China's progress in green construction was less than that of other developed countries. Furthermore, most higher education students in China acquired little to no awareness of the concept of green construction than those who completed university or college. In addition, a range of green construction assessment tools, protocols, guidelines, and standards have been developed over the past 20 years. However, the ability to implement these criteria seems to be weak.

5.2.2 Factors that affect the development of green construction in China

This study has evaluated and analyzed the effects of selected factors on the development of green construction in China. There are four main factors that affect the development of China's green construction. The first factor is the government's development strategy. The construction industry members who apply green construction management methodology or green construction technology in their projects could be affected by this factor. The government's development strategy could do more to encourage the utilization of green construction methodologies and technologies by promoting their existence. The second factor is the current state of construction technology and construction management. Arguably, the progress of construction technologies depends on the degree of progress found in other related industries. The current industrial capacity as a whole is relatively underdeveloped in China. In addition, green construction is dependent on scientific management, but the concept of a scientific management system remains in its initial stage in China. Therefore, outdated construction technologies in general and groundless assumptions of management could also affect the development of China's green construction.

Furthermore, public awareness of green construction and the comparatively higher construction cost are two other influencing factors for the development of green constructions in China. Most citizens do not realize that green construction could improve the quality of the environment and preserve various resources. Some clients, developers and contractors are tempted

by short-term profits and worry that the cost of green construction is higher than traditional construction, resulting in their reluctance to implement the concept of green construction.

5.2.3 Challenges found in green construction in China

There are three main challenges of green construction in China. The first is government regulations. Although the Chinese central government has announced a number of evaluation standards, such as a guideline and laws and regulations associated with green construction, their implementation still faces major barriers in the Chinese green construction market. The second major challenge is that most construction organizations try to evade their social responsibilities of attempting green construction. The final significant challenge is the general lack of developed green construction technologies to support the construction industry. As mentioned earlier, China's green construction technology, which is aimed at aiding green construction, is in its initial stage of development. In addition, the lack of specialists in green construction might also hinder improvement in green construction technologies.

5.3 Recommendations

Overall, this study investigated the general status of green construction in China. It is based on the findings of the survey and associated with circumstances specific to China. The recommendations put forward for future research are as follows:

- Future research on this area should apply different methods of data collection. This is to avoid limitations of the groups of respondents. In addition, the questionnaire can be more specialized. An example would be Question 5 of the survey (Did you learn the concept of sustainable construction in university/college?). This question did not consider whether the university or college attended was overseas, affecting the results' accuracy.
- It is imperative for further research to be conducted on more specific green construction technologies found in China. Such studies are not mentioned in this study.
- The industrialization of the construction industry is the main technology that achieves the aim of green construction activities in China. The construction industry's industrialization could become a primary trend in the future development of China's construction industry.

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