A FRAMEWORK FOR

EFFECTIVE SITE PLANNING AND DESIGN

OF GREEN RESIDENTIAL BUILDINGS IN CHINA

HUO XIAOSEN

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HUO Xiaosen

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CERTIFICATE OF ORIGINALITY

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

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HUO Xiaosen

ABSTRACT

Green building is a development trend of current construction industry. Site planning and design (SPD), as a vital step in the early stage of green building development, is a key issue in forming a sustainable site. The importance of this concept in the field of sustainable development has been emphasized in previous studies. Some major green building rating tools (GBRTs) being used worldwide have included SPD-related items. Several site layout planning and optimization methods in SPD were also proposed. However, very few research studies have investigated the effective SPD in the development of green residential buildings.

This research aims to develop a framework for effective SPD in green residential buildings in China, which in turn boosts the development of green buildings and creates a sustainable built environment. The objectives of this research are summarized as follows:

1) to establish a theoretical framework for SPD of green residential buildings;
2) to generate a list of variables and items affecting the SPD of green residential buildings and to investigate the critical factors in the SPD process;
3) to develop a preliminary framework that can guarantee the effective SPD of green residential buildings based on the practical experiences; and
4) to improve and validate the effectiveness of this framework in supporting the SPD process.

These objectives are addressed by using quantitative and qualitative methods, containing literature review, questionnaire surveys, face-to-face interviews and case studies. Through the literature review, 13 variables affecting SPD of green buildings are identified and used to establish a theoretical framework. These variables include “land use”, “site assessment”, “passive building design”, “open space”, “green vehicle parking”, “reduced parking footprint”, “ecological value and protection”, “cultural heritage”, “landscaping and irrigation”, “microclimate around buildings”, “neighborhood daylight access”, “storm water management” and “environmental management plan”.

Based on this theoretical framework, a preliminary framework for effective SPD in green residential buildings was generated based on the practical experiences, in which 38 SPD items were abstracted from the 13 aforementioned variables. Afterwards, the perceptions of practitioners in green building development towards the importance of and difficulty to realize these items and variables were investigated through a questionnaire survey. Several techniques, including descriptive statistics, non-parametric tests, exploratory factor analysis, and content analysis were conducted to analyze the survey data. Five critical factors of SPD, namely, “environmental protection consideration”, “effective use of space”, “use of natural and existing resource”, “green parking and thermal environment” and “use of land resource”, were identified based on the importance of the 38 items. Twelve practitioners or researchers in the field of green building were interviewed to investigate other elements in the preliminary framework, such as the SPD process, sustainable principles, stakeholders’ relationship, and

approaches to SPD.

In order to improve and validate the preliminary framework in practice, case studies were conducted on two green residential projects in Mainland China and on one green public rental house in Hong Kong. Document analysis and face-to-face interviews with the relevant architects or engineers in these projects were also conducted to improve the proposed framework. Then an improved framework for SPD in green residential buildings was proposed. At last, a feedback questionnaire survey was eventually performed in Mainland China and Hong Kong. The results confirmed that the proposed framework can help the participants improve their understanding on SPD in green residential buildings and promote effective SPD in green residential building in China.

PUBLICATIONS

The following outputs are generated based on the work presented in this thesis.

Journal papers

Published:

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1. **Huo, X**., & Yu, A. T. W. (2017). A preliminary framework for site planning and site design in green buildings. In *Proceedings of the 22nd International Conference on Advancement of Construction Management and Real Estate Melbourne* (pp.870-877). CRIOCM 2017 Organising Committee.

The following outputs are generated during the period of my research study at PolyU.

Conference papers:

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1.1 RESEARCH BACKGROUND

Sustainable development is often defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). The energy consumption in the construction industry occupies over 40% of the total consumption around the world, and about 30% of the overall greenhouse gas emissions (Metz et al., 2007; Hong and Zhang et al., 2017). Under the impetus of large-scale urbanization and industrialization, the construction industry in China is approaching a rapid development as reflected in its energy consumption growth rate, which has exceeded 10% over the past decades (Chang et al., 2014; Hong and Li et al., 2017). Therefore, sustainable development must be promoted in the construction industry to improve the resource use efficiency and to minimize its harmful effects on the natural environment. Sustainable construction is a process of building a healthy built environment under the principles of efficient resource use and ecological conservation (Kibert, 2016). Meanwhile, Li et al. (2018) defined sustainable construction as a development which aims to mitigate the adverse impacts on the built environment caused by the construction industry whilst to promote the social productivity and the overall health of occupants in communities.

Green buildings, as parts of the "sustainable building" concept, refer to "the implementation of a sustainable design" (Montoya, 2010; Tam et al., 2017). The term "green" has several definitions. For instance, the U.S. Green Building Council (2003) defined green buildings as those "buildings that are designed, constructed, and operated to boost environmental, economic, health, and productivity performance over conventional buildings”. Some scholars, such as Glavinich (2008), Robichaud and Anantatmula (2010) and Kruger and Seville (2012), believed that green building is a practice designed to minimize the impacts on the environment caused by buildings. Green buildings exert minimal effects on the environment because of their excellent resource use efficiency, low energy consumption, efficient recycling of materials and minimal construction waste (Horman et al., 2006; Robichaud and Anantatmula, 2010; Nguyen et al., 2017; Huo and Yu, 2017). Green buildings are also known for their ability to use natural resources effectively and their capability to maintain the capacity of the ecosystem, improve the quality of human life and increase their working productivity. As stated by Robichaud and Anantatmula (2010) and Zhang and Wang et al., (2017), there are four major concerns of green buildings, namely, minimizing the environment impacts, improving the living conditions of the building occupants, enhancing the investment return of developers and local communities, and considering the lifecycle of buildings during the process of planning and construction. Therefore, the construction of green buildings can effectively promote the development of sustainable construction because of their environmental characteristics and their ability to improve social and economic efficiency.

In order to facilitate green building development from the early stage, site planning and design (SPD) is a vital step as it affects and reflects the costs in operating and maintaining a construction site (Mawdesley et al., 2002; Russ, 2009). SPD refers to “the art of arranging structures on the land and shaping the spaces between, an art linked to architecture, engineering, landscape architecture and city planning" (Lynch and Hack, 2014). It is an interdisciplinary application of science, technology and arts to create a sustainable site (Russ, 2009; Kibert, 2016; Huo et al., 2017). In residential buildings, the primary objective of SPD is to provide a desirable place to live for the occupants and residents. To minimize the disturbances on construction sites, site planners and designers may use checking systems based on the site layout rules to facilitate their site design (Zolfagharian and Irizarry, 2014). By adopting green site design strategies, relevant construction issues such as urban heat islands and excessive energy and water consumption can be concentrated on in the initial stage of a building project. According to Ozdemir (2008) and Calkins (2011), a sustainable site design requires the use of holistic and ecological strategies in developing projects that can repair and restore, rather than alter or impair the ecosystem. Sustainable SPD can also improve the connection between people and nature as well as blend the science of ecology and the art of design in any type of development. Gonzales and Romero (2014) highlighted the important roles of good site planning in promoting sense of community, providing easy access to the open space, and in maintaining a harmonious relationship between a building and its surrounding community.

SPD occurs at the smallest scale of urban development, and several variables need to be considered during this process. Wedding and Crawford–Brown (2007) identified 40 indicators, including environmental health, finance, liveability and socioeconomic factors, that determine the success of brownfield redevelopment. They also developed a partially automated tool based on these indicators, which facilitates stakeholders to assess the potential success of a redevelopment project on brownfields. Jeong et al. (2013) assessed several factors involved in the site selection process from the physical, environmental and economic aspects as well as evaluated the siting process of a new building by using Geographic Information System (GIS). Wang et al. (2014) identified a set of factors that affect site planning decisions of planners in urban renewal projects. Previous studies have generally emphasized the importance of SPD in the development of green buildings. Several green site strategies have been applied in building projects, such as low impact development (LID), and Sustainable Site Initiative (SITES). Besides, the site layout planning and optimization based on decision making models were also focused on (Guillette, 2010; Kabbes and Windhanger, 2010; Hammad et al., 2015; Spillane and Oyedele, 2017). To realize the full potential of green building development, it is necessary to start the process from the very beginning, namely the planning and design stage. The importance of the SPD has been realized in previous research, but the conducted research has focused on part of the SPD such as the site layout planning and optimization, storm water management, brownfield redevelopment. The concept of SPD has been developed in the early years, but as the green concept and green buildings was introduced, the emphasis and importance of SPD has changed. However, very few studies have comprehensively analyzed the SPD variables and items involved in green residential buildings, meanwhile the processes, stakeholders, principles and approaches related to SPD in green residential buildings are yet to be investigated. To fill with these research gaps, this research study develops a framework for effective SPD in green residential buildings that can provide major stakeholders, including developers, planners and designers, with a valuable resource that can help them comprehensively understand SPD and conduct related practices in the early stage of green building development.

1.2 RESEARCH SCOPE

To conduct a comprehensive and in-depth research study, the research scope must be defined clearly. Two major building types are considered in green building development, namely, new buildings and existing buildings. Based on the nature of their occupancy, these buildings can be further classified into agricultural, residential, commercial, government, educational, industrial, religious, military, transportation and power buildings. This research only focuses on new residential buildings.

There are several major stages in a green building project, such as siting, design, construction, operation, maintenance, refurbishment, and deconstruction. The planning and design stages is the realization of a vision. To implement a building project successfully, the effective on-site space arrangement and utilization of spaces are both critical concerns. Accordingly, this research mainly concentrates on the early stage of green residential building projects, i.e. planning and design, in the context of China to boost the development of green buildings from the early stage. In addition, this research focuses on site planning and design at the building scale within the site boundary.

1.3 RESEARCH AIM AND OBJECTIVES

1.3.1 Research Gaps

Very few studies have comprehensively analyzed the construction sites, social environments, ecological situations and sustainable development in the site development of green buildings. A well-defined SPD in green buildings is not yet developed, and its relationship with the surrounding environment is yet to be explored. Developing a framework for effective SPD of green buildings can establish a harmonious relationship between green buildings and the surrounding natural environment. According to the existing research on SPD in green buildings, three research gaps have been identified, which are summarized as follows:

Gap 1. A detailed list of variables and items that affects SPD in green residential buildings is yet to be identified.

Gap 2. A theoretical framework for SPD in green residential buildings that reflects the relationships of the involved variables is yet to be developed.

Gap 3. A framework for effective SPD in green residential buildings based on the practical experiences that includes the related processes, principles, stakeholders and approaches is yet to be constructed.

In order to fill with these gaps, the following research aim and objectives are proposed in section 1.3.2.

1.3.2 Research Aim and Objectives

This research study aims to develop a framework for effective SPD of green residential buildings in China, which can promote the implementation of green building and create a sustainable built environment.

In order to achieve this research aim, the following objectives are designed:

1) to develop a theoretical framework for SPD in green residential buildings (corresponding to Gap 2);
2) to generate a detailed list of variables and items that affects SPD in green residential buildings and to identify the critical factors in this process (corresponding to Gap 1);
3) to develop a preliminary framework for effective SPD in green residential buildings based on the practical experiences (corresponding to Gaps 2 and 3); and
4) to improve and validate the effectiveness of this framework in supporting SPD process.

1.4 RESEARCH METHODS

Four research methods, namely, literature review, questionnaire surveys, face-to-face semi-structured interviews, and case study, are applied in this research study to achieve the research aim and objectives.

A **literature review** is performed to provide a theoretical foundation for this research. Articles and books relating to green buildings and SPD are extracted from library databases and other electronic resources and are then comprehensively reviewed to determine the latest developments in relevant areas, such as in site planning, site design and green building development. The information extracted from these sources is summarized and analyzed to determine the contents of this research, guiding the questionnaire design and construct a theoretical framework for SPD in green residential buildings.

A **questionnaire survey** is designed and distributed to collect structured data from the participants in green building development. The view and attitudes of these participants towards SPD in green residential buildings can then be gathered from the collected information. A statistical analysis is conducted to provide a foundation for identifying the factors critical to green SPD. The target participants of the questionnaire survey include the government, developers, architects, engineers, contractors and consultants. In framework validation stage, a feedback questionnaire survey is adopted to validate the completeness, suitability and applicability of the framework and to elicit suggestions for further improvements. After the survey, the framework for effective SPD in green residential buildings in China is finalized.

Face-to-face interviews are conducted to solicit the viewpoints of specialists in green buildings. By participating in semi-structured interviews, the participants can share related cases and practices from their own experiences, thereby providing this study with additional practical information that can contribute to its development of a preliminary framework for SPD of green residential buildings in China. After the theoretical framework is developed, face-to-face semi-structured interviews are adopted to identify other essential components must be included in the framework.

Case studies are particularly useful for studies on various social phenomena. The theoretical limitations of a study can also be addressed by analyzing information from real cases. Three case studies in green building projects are performed in this research to improve and validate the preliminary framework, including two in Mainland China and one in Hong Kong. These case studies can improve and validate the usefulness of the proposed framework in practice.

1.5 STRUCTURE OF THE THESIS

Nine chapters are divided in this thesis, and the structures are summarized as follows:

Chapter 1 gives a overview of the research study, including the research background, research scope, research gaps, the specific research aim and objectives. The research methods are also outlined.

Chapter 2 comprehensively reviews the latest advancements in the field of green buildings. Six major themes are covered in this chapter, including general description of green building management, the benefits and obstacles of green building development, the actual performance of green buildings, behavior of green building stakeholders, green building strategies and development of GBRTs.

Chapter 3 reviews the related literature and documents on SPD to introduce the practical issues related to SPD in green buildings. This chapter discusses sustainability and SPD, SPD relevant issues in green buildings, site layout planning and optimization and SPD related requirements of GBRTs.

Chapter 4 elaborates the research methods and statistical techniques in this study as well as justifies their application. The research methods include literature review, questionnaire surveys, face-to-face interviews and case studies. The adopted statistical techniques include descriptive statistics, non-parametric analysis, exploratory factor analysis, content analysis and document analysis.

Chapter 5 develops a theoretical framework for SPD in green residential buildings. The 13 variables abstracted from 5 major GBRTs are also discussed and analyzed.

Chapter 6 develops a preliminary framework for SPD in green residential buildings. The perceptions of practitioners in Mainland China and Hong Kong towards the importance of and difficulty to realize SPD items in the development of green building projects was investigated based on a questionnaire survey. Factors that are critical to SPD in green buildings are identified by considering the importance of the variables obtained in the questionnaire survey through exploratory factor analysis. Semi-structured interviews with practitioners in green building area are also conducted to guide the development of the preliminary framework, which contains the variables, processes, relationships amongst stakeholders, and approaches in SPD of green buildings.

Chapter 7 improves and validates the proposed framework by conducting three case studies on green residential projects including two in Mainland China and one in Hong Kong. These case studies also aim to test the applicability of the framework in practice and to compare the different considerations in the framework and in practice. An improved framework is then developed based on the findings of these studies.

Chapter 8 further improves and validates the framework by conducting a feedback questionnaire survey to collect the perceptions and suggestions of practitioners in the industry. The framework for effective SPD in green residential buildings in China is then finalized considering their suggestions.

Chapter 9 concludes the thesis by summarizing its major findings, highlighting its significance and outlining its limitations. Some future research recommendations are also suggested.

1.6 SUMMARY

This chapter illustrates why this research study should be conducted and how to conduct it. Firstly, the research background is described, and the research scope, research gaps and objectives are introduced. Secondly, the specific research methods by which the research are conducted are introduced. Finally, the structure of the thesis is outlined.

CHAPTER 2 LITERATURE REVIEW-GREEN BUILDINGS

2.1 INTRODUCTION

2.2 GENERAL GREEN BUILDING MANAGEMENT

2.3 BENEFITS AND OBSTACLES TO GREEN BUILDING DEVELOPMENT

2.4 GREEN BUILDING PERFORMANCE STUDIES

2.5 STAKEHOLDER BEHAVIORS IN GREEN BUILDINGS

2.6 GREEN BUILDING STRATEGIES

2.7 DEVELOPMENT OF GREEN BUILDING RATING TOOLS

2.8 RESEARCH GAPS

2.9 SUMMARY

2.1 INTRODUCTION

The literature review is illustrated in the present chapter and chapter 3. This chapter gains some insights from previous studies that have been done relevant to sustainable buildings and green buildings. This chapter summarizes and presents previous research in the green building area including general green building development, benefits and barriers, green building performance, stakeholder behaviors, green building strategies, and the development of GBRTs. At last, the research gaps in green buildings are also introduced. In chapter 3 the definition of SPD and its importance in green buildings are described.

2.2 GENERAL GREEN BUILDING MANAGEMENT

2.2.1 Definitions of Green Buildings

Sustainable construction is a process which aims to create an environmentally friendly built environment leading by the concerns of efficient resource use and ecology protection (Kibert, 2016). Adler et al. (2006) stated that green building belongs to the larger category of "sustainable building", which is specifically considered as "the implementation of sustainable buildings". Researchers have provided various ways to define the term "green". As stated by one of the earliest organizations that have important roles in green building development, U.S. Green Building Council (2003), green buildings are "buildings that are designed, constructed and operated to boost environmental, economic, healthy and productive performance over that of conventional buildings". There are also definitions that focus on different elements of green buildings; for instance, Woolley and Kimmins (2000) focused on the design philosophy that the green building has less resource use and waste emission; Wang et al. (2005) thought that green buildings are designed to save resources, reduce the whole life cycle construction waste and costs, and build a healthy living and working environment for human beings; Robichaud and Anantatmula (2010) described green buildings as a practice which aims to minimize the total impacts on surrounding environment; Kibert (2016) regarded that green building is designed and constructed in a healthy way, with an efficient resource use manner, and under ecological-based principles. Overall, the green building development is a process that aims at improving environmental, economic, and social efficiency. Firstly, green buildings involve a commitment of minimizing disturbance on the natural environment and the ecological diversity through efficient natural resource use. Secondly, green buildings promote the economic development of the whole society as they save costs of the whole life cycle and increase the financial returns of the developers. Finally, green buildings improve the living quality and working productivity by providing better indoor environment. In this research study, green buildings refer to buildings that save resources in the whole life cycle, minimize the disturbance to the natural environment, and provide healthy and suitable space for human use.

2.2.2 Green Building Development

Dammann and Elle (2006) stated that to form well-functioned environmental indicators for green buildings, the environmental knowledge needs to be shared, and suggestions such as continuous learning, aggregation in different levels, siting and transport consideration were proposed to create a common language in green buildings. In order to build a green building management knowledge base, Hwang and Ng (2013) stated that the key knowledge areas include schedule management, stakeholder management, and communication management. In addition, the critical skills in this process include the ability in analysis, decision making, teamwork, and problem-solving. To frame a set of green building guidelines, several important elements should be considered. Potbhare et al. (2009) proposed that the green building guidelines should not be too complex and be easily understood by the adopters. It should synchronize with current construction practices. The adopters are able to preview the green requirements and to verify their choices of the green requirements in advance. In addition, their competitive advantages should be clear by the adopters, the relevant information is available, and the adopters have the flexibility in adopting green requirements. DuBose et al. (2007) presented a framework to illustrate that in public agencies a green building program contains four main components, including inspiration, motivation, implementation, and evaluation. Pearce et al. (2007) and Sentman et al. (2008) discussed green building promotion from the political aspect, who argued that in the public and private buildings green building policies should be adopted both on the local and the state level, which aims at reducing greenhouse gas emission and to regulate climate change, in which three basic categories of options should be considered: options for policies, programs, and evaluation methods. Zuo et al. (2017) proposed an integrated approach which combines life cycle assessment with life cycle costing to facilitate green building assessment, in order to reduce the uncertainty of green buildings in investment and operation decision making. Aktas and Ozorhon (2015) also emphasized that the main stimuli for converting existing buildings into green buildings are the strict environmental policies. Based on the previous research, it was found that the important concerns in achieving green building implementation included the commitment of the owners, the support of senior management, and the cooperation between different parties. In addition, to promote sustainable settlement, Ross et al. (2010) identified that the critical success factors were user support and acceptance, and adequate funding.

When considering whether the green building can be implemented successfully or not, management is another important issue (Li et al., 2011). In this process, the designers and contractors are coordinated, and the technical issues and innovation issues are integrated. Love et al. (2011) took the first energy-related Green Star certified (six-star) commercial office building in Australia as an example to reveal the key initiatives in gaining such a rating. It is revealed that except for the sufficient financial returns, another most important benefit is to reduce the use of non-renewable energy. Geng et al. (2013) investigated the case of a university in China and showed that to develop a green university, the critical and necessary elements include collaborating closely with the local government, strong leadership and comprehensive plans. To explore a green way to maintain historic masonry buildings, Forster et al. (2011) developed a model to evaluate the efficiency of maintenance interventions of green maintenance, and material data throughout the whole life cycle and “cradle to site” technologies are utilized to demonstrate CO_2 determination. Green retrofitting or renovation is economically attractive when applying to historic buildings which aims at enhancing their poor energy performance, because for such buildings a specific design approach is required. So Filippi (2015) suggested that applying the energy performance contracting to the retrofitting work. Wu and Issa (2014) and Inyim et al. (2014) stated that the coordination of Building Information Modelling (BIM) and environmental impact analysis can facilitate stakeholders to make decision during design and construction process. Therefore, such technology integration is beneficial to sustainable building development. Ruparathna and Hewage (2015) also explained that if there are more sustainability considerations before the construction stage or in the project procurement stage, the sustainability of the construction projects will be highly improved. In green building projects in Singapore, factors that will affect the construction productivity were identified by Hwang et al. (2016) by evaluating the likelihood, impact, and factor criticality. The results indicated that the top five critical factors are experience of workers, green technology, changing of design, skill level of workers, and planning and sequence of work. Gou and Xie (2017) provided suggestions for future green building development based on a literature review including expanding indicator systems of green buildings and changing the green building benchmark from reducing a negative development to increasing a positive development.

2.3 BENEFITS AND OBSTACLES TO GREEN BUILDING DEVELOPMENT

2.3.1 Benefits of Green Building Development

Tam et al. (2012) considered that green building development is environmentally friendly that is also conducive to social values, and its benefits are thus considered for economy, society, and environment. From the economic aspect, adopting green building development can reduce lifecycle costs, improve energy efficiency, taxation and market efficiency. Yudelson (2008) stated that the initial investment in green buildings is around 1% to 2% higher than that in conventional buildings, it provides long-term savings and a shorter payback period. Mathieson et al. (2008) added that investments in green materials and technologies, and the advanced identification of potential problems for building operations, all made it easier to operate and maintain green buildings. According to Yudelson (2008), green buildings were considered to be energy-efficient design in which 30% to 50% energy can be saved when comparing with conventional buildings and lead to significant energy efficiency improvement. Moreover, Kubba (2010) and Sillah (2011) showed that adopting green technologies like green roofs, passive design, low-e glass in design stage can meet the requirements of end users, and reduce energy use and save scarce energy resources at the same time. Kubba (2010) and Zhang et al. (2011) thought that many governments have tried to promote the development of green buildings by providing tax incentives or providing lower land prices and green materials. Yudelson (2008) reported that if a building is certificated as silver LEED green building in Nevada, a tact cuts is applicable. In addition, the sales tax rebates will be provided by the state government on the green materials used in that building. Therefore, private and public developers and owners prefer to build LEED-certified green building in order to gain financial support. Another example of green building benefits is highlighted by Sillah (2011), which showed that because of green buildings, the product differentiation has been promoted in the construction market. One significant social benefit is improving the health and working efficiency of occupants. Kubba (2010), Sillah (2011), and Ajilian (2014) argued that green buildings provide a better indoor environment, in which air quality is better, the thermal comfort is better, the lighting is more efficient, and the noise level is more acceptable, which is health beneficial to those who live and work in these buildings. Working and living in a comfortable environment also promotes greater efficiency.

Concerning the environmental benefits of green buildings, researchers such as Mathieson et al. (2008) and Ajilian (2014) found that green buildings have less environmental impacts and help to preserve ecosystems. As the design and construction of green buildings consider the environment protection, they seek to strike a balance between architecture and the ecosystem throughout their life cycle. Applying renewable energy and conducting proper waste management are helpful in decreasing energy consumption and limiting the exhaust gas emitted into the surrounding environment, thereby protecting the ecosystem. Via comparing post-occupancy evaluations in green and non-green buildings, Newsham et al. (2013) found that a better indoor environment is achieved by green buildings when it is related to the environment satisfaction and thermal conditions. Balaban and de Oliveira (2017) also indicated that green buildings have significant benefits when it is related to CO_2 and energy reduction, and improved environment for occupants in buildings.

2.3.2 Obstacles to Green Building Development

Except for the benefits of green building development, many obstacles exist during the green building implementation, such as higher green material costs, transportation costs, and design costs, lack of information, lack of green building regulations (Hwang and Tan, 2012; Mulligan et al., 2014; Darko and Chan, 2016). Kosheleva and Elliott (2006) discussed green building in the Russian context and summarized that the most widely recognized barriers include short-sighted decision making, high costs, lack of information, and imperfect regulatory system. As there are stricter green requirements, the initial investment in a green building could be higher. Tam et al. (2012) pointed out that the larger initial investment needs may be caused by the initial adoption of green methods and technologies and from the top-down construction method. In addition, it needs more time to implement green buildings, which in turn increase the costs (Richardson and Lynes, 2007; Sillah, 2011). Shi et al. (2016) investigated conflicts among various green building objectives and provided suggestions for solving major conflicts. To solve the problems caused by high cost of green certification in design and construction stage, high efficient building strategy that considering long-term building performance is suggested; and to solve the problems of high costs in maintaining green functions in operation stage, a comprehensive post occupancy evaluation system is suggested. In the research conducted by Balaban and de Oliveira (2017), they argued that the barriers to green building adoption in companies with scarce resources in Japan include the longer payback period of green building technologies and the complicated nature of policy framework.

Except for the higher initial investment, another obstacle in green building development is the lack of economic incentives and government support. Lam and Chan et al. (2009) claimed that the lukewarm attitude toward green building exhibited by the senior managers of many development firms may directly or indirectly reduce the efficiency of green building practices. The lack of management support further deprives contractors of incentives for achieving green building goals. At the same time, as Samari et al. (2013) showed, insufficient government support often hinders green developers from accessing low-risk and affordable financial resources. Zhao et al. (2016) evaluated green building risks in Singapore by using fuzzy synthetic evaluation approach in which the occurrence likelihood, impact magnitude and risk criticality were considered, and cost issues such as "inaccurate cost estimation" and "cost overrun risk" were considered as the most important issues in risk factors and risk groups separately.

In addition, Hwang and Tam (2012) showed that there is insufficient information about green products and sustainable building systems to guide the implementation of green buildings. Besides, there are not enough case studies which convince developers that for green buildings the operating and maintaining costs are lower while the environmental efficiency is higher than conventional buildings. Therefore, as explained by Sillah (2011), in the mainstream construction market, the superior performance offered by green buildings has not yet fully achieved. Meanwhile, when it concerns to green principles and technologies, the public awareness and knowledge is insufficient. Shi et al. (2014) assessed the effects of applying green building policies based on an approach of fuzzy impact matrix, and the results indicated that only about 50% of the policies were considered as effective. Despite the steady growth in the number of green buildings in the past few years, green building development is still a relatively new field. The green building strategy implementation are hindered by insufficient expertise in green technologies and methods, and insufficient awareness of green tools and materials. Hwang et al., (2017) took the green residential buildings in Singapore as an example to investigate critical risks in these projects, and the most important five risks were identified as "complex procedures to obtain approvals", "overlooked high initial cost", "unclear requirements of owners", "employment constraint", and "lack of availability of green materials and equipment".

2.4 GREEN BUILDING PERFORMANCE STUDIES

2.4.1 Resource Use Efficiency

Green buildings are regarded as the integration of sustainable products and maintenance systems. Through this integrated system, the overall energy footprint of the buildings id reduced by achieving energy saving through every part of the system (Goldberg, 2008). Sharma et al. (2011) and Mao et al. (2015) pointed out that life cycle assessment (LCA) is effective in green building assessment which can quantitatively evaluate the material use, energy flows, and their environmental impacts. LCA can be used to systematically assess the effects of each material and process involved in. Besides, Chalifoux (2006) and Kim et al. (2014) pointed out that the energy simulation of a building and the linear regression are applicable to predict the energy use savings of green buildings throughout their whole life cycle. Besides, Xu et al. (2015) identified the key issues that will affect the project management, including the technology availability, the organizational strength of team leadership, the degree of trust, the technical skills of team members, and the accuracy of measurement and verification. Decision makers should therefore focus more on these aspects in managing energy retrofits for buildings.

As evidenced by previous studies, applying green building methods has made a significant contribution to reducing energy use in buildings. Pan et al. (2008) evaluated the energy cost savings of green buildings through an energy simulation model and showed that they have much better energy performance. Issa et al. (2011) took a green school as an example and conducted a case study in an eight-year period, and the results showed that comparing with conventional buildings, green buildings consume less energy and cost less. A case study in a retirement village in Australia conducted by Zuo et al. (2014) demonstrated that green buildings can effectively reduce long-term energy costs, which may be an important selling point for developers. Azizi et al. (2015) conducted a questionnaire survey and the results indicated that green buildings performed better than conventional buildings in energy saving. They also suggested strategies to encourage energy-saving behavior, such as raising awareness through education on energy efficiency or assigning active building managers to energy-related matters. Though green buildings are supposed to have better greenhouse gas emission reduction performance, sometimes it is not that situation when considering the whole life cycle because the criteria for greenhouse gas emission performance are not involved in GBRTs, which should be improved in future research (Wang et al., 2016).

2.4.2 Cost-benefit Analysis

Whole life costing is an effective way that helps to evaluate the cost-effectiveness of a building project. As two mainstream tools for such integrated costing, BREEAM and ENVEST was studied by Bartlett and Howard (2000), which can help managers make more suitable choices and eliminate the misunderstanding that “green buildings involve more capital costs.” In addition, there are also several tools can be used in green building cost premium forecast such as artificial neural networks and multiple regression analysis (Tatari and Kucukvar, 2011).

When it concerns the construction costs and economic benefits of green buildings, researchers and practitioners have some different considerations. Issa et al. (2010) investigated the views of practitioners on the potential long-term savings in building projects, and the cost factors were ranked as follows: energy, waste, water,, productivity and health, operation and maintenance, and gas emissions. By comparing the building costs between conventional office buildings and green office buildings, Rehm and Ade (2013) stated that green buildings had a lower cost as the sustainable materials and systems application. The financial performance of 14 LEED-certified hospitals was compared with that sorts of non-green facilities by Sadatsafavai et al. (2014), the results indicated that in spite of the higher inpatient revenues made by green hospitals, the operating costs of LEED-certified hospitals is higher than the non-green ones, as the increased income were not enough to compensate for the additional operating costs.

Overall, the results of cost-benefit analysis indicate that green buildings have economic value. Especially when a building is invested and long-termly operated by the government, green building is an economical choice which can save taxpayers a lot of money (Gabay et al., 2014). While Zhang et al. (2014) pointed out that because of the huge initial investment of green buildings, there are more uncertainties for the developers, owners, and end-users, which leaves them incentives to develop green building projects. Therefore, Zhang et al. (2015) developed an energy performance contracting based framework which helps to transform “green” investments into “gold” economic benefits. In addition, Deng and Wu (2014) indicated that the premium is larger for green buildings during resale transactions, but smaller during the pre-sale stage, so that developers should capture sufficient financial benefits in the pre-sale stage.

2.4.3 Health and Efficiency of Occupiers

Post-occupancy evaluation is an effective way to evaluate the building performance after the green buildings are built and put into use for a period of time. Pei et al. (2015) explained how the evaluation can be used to compare the design goals and the actual operations of the green buildings. Bearg (2009) also highlighted the significance of such evaluation and feedback, as it can reduce the operation risks and uncertainties of the buildings, thus to achieve a healthy green building.

In previous studies, various case studies have shown that green buildings are beneficial to improve employee performance. Ries et al. (2006) noted that in green buildings, the performance is better as the provision of outdoor landscapes, expansion of work areas, and provision of suitable temperature and relative humidity. Abbaszadeh et al. (2006), Leaman and Bordass (2007), and Gou et al. (2012) conducted a comparison of the comfort and satisfaction levels for those living in green and conventional buildings. Their research indicated that green buildings perform better in the overall performance. Notably, green buildings are highly satisfied with the air quality and lighting, and the acoustics scores in green buildings are lower. Armitage et al. (2011) explored evaluations of green workplace environments in Australia and indicated that green certificated buildings perform better in overall satisfaction levels and in improved health and productivity. These results indicate a number of incidental benefits from green buildings. The weaknesses of Green Star certified buildings are that employees feel that they lack thermal comfort and privacy and that the buildings have greater internal noise issues. The employees also reported that they had little knowledge concerning the features of green buildings. Rashid et al. (2012) found that the occupants in green buildings were satisfied with the individual work space and department spatial characteristics of the certified green buildings, but they assessed the private space features negatively. In evaluating the indoor environmental quality of green buildings, Liang et al. (2014) showed that the occupants of green buildings assessed the overall indoor environmental quality favorably, but the conventional buildings were rated better in terms of relative humidity and sound level. MacNaughton et al. (2016) studied the objective impacts of green buildings on the health of occupants by tracking indoor environmental quality, self-reported health status, and heart rate before and after relocating to a green building. The results suggest that occupants in green buildings felt that they have better indoor environments and the occupant health is impacted by psychological perception and physiological pathways.

Some doubts remain about green building performance. For example, Paul and Tylor (2008) made the comparisons of the occupants' comfort and satisfaction in green and conventional buildings, while these results are not enough to support a better aesthetic and tranquil effect of green buildings. Rajendran et al. (2009) completed a comparison survey concerning about the safety and health issues of construction workers and found no significant difference. By considering the improvement of green building acoustic environment, Hodgson (2008) suggested several ways to reduce reverberation and noise, such as strengthening external-internal noise isolation, increase working place isolation, and adopting adequate noise absorption methods. By considering the improvement of indoor environmental quality, Ravindu et al. (2015) regarded that green buildings should to be designed responding to the climate that are locally relevant. Huang et al. (2015) also claimed that the use of passive design methods in green buildings improves the comfort of indoor environment. The passive design features include appropriately determine the size and distribution of the fenestration positions, providing adequate shade by installing exterior sunshades for window openings, and creating deep corridors. Steinemann et al. (2017) summarized that overall indoor air quality (IAQ) in green buildings is higher than that in conventional buildings, and as products and activity indoors have the primary influence on IAQ, the source reduction and control should be focused on to improve IAQ in green buildings, and incentives that will improve IAQ and benefit building occupants, owners, and employers should be developed to create higher recognition of IAQ in green buildings.

2.5 STAKEHOLDER BEHAVIORS IN GREEN BUILDINGS

2.5.1 Stakeholder Interrelationship

Stakeholder refers to "any group or individual who can affect or is affected by the achievement of the firm's objectives" (Freeman, 1984). Yang et al. (2009) and Gluch et al. (2014) studied on the stakeholders in green buildings and revealed that there is a wide range of stakeholders involved in green buildings and they play important roles. These various parties include financial stakeholders and knowledge-intensive or communicative actors.

Stakeholders in buildings usually focus on uncertainties and risks in design and management. Generally contractors regard that adopting a proactive environmental strategy may make them have risks in the financial well-being. Qin et al. (2016) elaborated on the risk awareness of green building participants in the context of China, and they conducted a questionnaire survey to assess risk factors of green buildings throughout the life cycle, in which the importance of risks is considered by combining the occurrence probability and the influence degree, and the most important risk factor is identified as “government bureaucracy and complicated approval procedures”. Yang et al. (2016) modelled stakeholder risk networks in green buildings based on social network analysis (SNA) in the context of China and Australia. Results show that in both countries, reputation risk is a serious issue. Furthermore, in China the government is critical in raising public green knowledge and the green technology adoption. By contrast, in Australia, the organizational reputation in sustainable building development is built based on self-motivation. Son and Kim (2015) showed that at the very early stage of green building projects, prediction models are beneficial to stakeholders in evaluating the potential green building performance. As the effectiveness of SNA on analyzing the relationships among stakeholders, Shen and Yang (2010) applied SNA in analyzing the impacts of projects that were resulted from stakeholder relationship networks and thus promoted the stakeholder management in building projects. Yang and Zou (2014) analyzed the risk of internal stakeholders being relatively central to the project. Yang et al. (2014, 2016) established an interactive risk network model that affect various stakeholders and revealed that the critical risks of green buildings in China are relevant to the behavior of the clients, the government, and the end users. There have been several research studies that highlighted the stakeholders’ behavior in green buildings. For instance, Xu et al. (2013) developed a multi-objective model to balance the interests of developers and contractors in a complicated environment. Hojem et al. (2014) regarded that social learning is critical to stakeholders because it expands their ambitions and inspires them to pursue goals that improve energy efficiency and achieve a broad range of environmental goals. Olubunmi et al. (2016)

reviewed common themes on green building incentives in previous research, such as incentive categorization (external and internal incentive), the effectiveness of incentive measures for green building development, criticization on the current implementation of green building incentives (defects in government management incentive), and strategies to improve green building incentives (redirection of the incentive approaches for the government). The perspectives of certain previous studies related to core stakeholders are as follows in section 2.5.2 to section 2.5.6.

2.5.2 Perspective of Developers

There are many third-party standards or labels that can be applied to evaluate and measure the state of green buildings. As Bo (2009) pointed out, when developers in the construction industry decide whether to seek a green building label, their decision-making process can resemble a replicator dynamic evolutionary game. Only when the numbers of identified green real estate developers reach a certain range can scale benefits be achieved. Ma et al. (2007) found that for developers who aim to maximize their benefits, the features of green buildings are regarded mainly as promotional tools for selling buildings, and the developers are not concerned too much about the technical aspects. Some developers are reluctant to have investment in green buildings because its initial costs are higher than conventional buildings. Sun et al. (2015) found that small builders are often an obstacle in promoting green building development because they are reluctant to provide extra payment in the short term for long-term benefits. Thus, various mandatory and incentive policies should be emphasized to promote sustainability in construction projects. Olanipekun et al. (2017) explored the relationships between motivation and owners' commitment and its effects on the green building performance through confirmatory factor analysis conducted by structural equation modelling (SEM). Results showed that there is a direct positive correlation between the intrinsic motivation of the owners and the sustainable performance. Vyas and Jha (2017) used data envelopment analysis to help developers measure the attributes of green building costs and provide available investment suggestions. Seven major green building attributes that help to get more green points with lower costs are identified including utilization of recommended waste materials, improvement of environmental awareness, service facilities, universal accessibility design, low impact design (LID), construction management practice, and low-volatile organic compounds paint application.

2.5.3 Perspective of Designers

In green building development, management is an important issue. It enables designers and contractors to coordinate and integrate innovation-oriented factors and green technologies (Li et al., 2011). To provide decision-making support for planners and designers in site layout planning, Abdul–Rahman et al. (2011) developed a Tacit-based Decision Support System through extracting key issues of on-site planning primarily in the acquisition process of tacit knowledge. Jun et al. (2015) proposed the establishment of a BIM based green template for the green building certification system. This template will help designers establish eco-friendly design strategies, operators to offer reliable advice for users and managers to construct systematic databases. To help designers in green buildings to apply proper technologies based on previous successful experiences, an integrated system was introduced by Shen et al. (2017), in which the application of text mining allowed the extraction of textual features from case reports, which increases the effectiveness of similar case selection.

2.5.4 Perspective of Contractors

In the field of green building construction, Ladhad and Parrish (2013) showed that the contractor has an essential position in detailing the project, identifying and implementing cost savings, and communicating with sub-contractors. Mokhlesian and Holmén (2012) indicated that for those construction units that would like to adjust to green building development should regulate their business model, for instance their value allocation, cost structures and capabilities. Qi et al. (2010) investigated green innovation drivers for contractors and summarized two significant driving forces, including the management issues and government supervision forces. Ahn and Pearce (2007) explored the behaviour of contractors and indicated that most of them would like to acquire green building skills and knowledge. In addition, some contractors refer to green building conferences and related industry publications to obtain professional green building knowledge. Through a qualitative study on contractor practices in green building development, Ofori et al. (2012) concluded that successful contractor project management should involve collaboration with consultants, application of engineering expertise and provision of incentives to employees.

2.5.5 Perspective of End Users

Research shows that market demand has a significant impact on the development of green buildings. Hewitt et al. (2016) emphasized that understanding end users and their behavior is crucial to the success of green facilities. Vives–Rego et al. (2015) showed that sustainable architecture relies not only on passive technology but also on the behavior of occupants, which is no less crucial an element. Steinberg (2009) pointed out that in green buildings, the adoption of new systems and technologies requires different kinds of thinking and behavior from the occupants. Increasing the willingness of the occupants to change their behavior requires providing them enough information about green building standards and energy saving behaviors impacts. Chau et al. (2010) explored the issue of end users and their behaviors in green building development, such as their knowledge and awareness of green development, their willingness to pay for green building elements, and the influence of individual socioeconomic background on their preferences. Leaman and Bordass (2007), Monfared and Sharples (2011) and Deuble and Dear (2012) have conducted some post-occupancy evaluations in green buildings, in which the users were found that they prefer to ignore and accept suboptimal conditions than those in non-green facilities. That is, end users are lenient to green buildings, indicating that the attitudes of the users affect the performance and sustainability of the buildings. Holmgren et al. (2017) revealed that the physical characteristics of the indoor environment (i.e. temperature) interacts with psychological associations of environmental certification (i.e. the green label), affecting the occupant perception of green buildings. Results indicate that green label has a positive impact on occupants' perception of indoor environment when temperature is within acceptable limits specified in the green building guidelines.

2.5.6 Perspective of the Government

The government departments that is related to construction industry are in charge of the formulation and implementation of housing programs. The government often plays the role of catalyst, educator, reformer, regulator and innovator in promoting green building implementation and sustainable development. Like mentioned by Theaker and Cole (2001), the Hong Kong government formulates and implements public housing programs to promote green building development in Hong Kong. As the initial investment of green buildings are higher than conventional buildings, it will hinder the enthusiasm of many stakeholders. Therefore, Chan et al. (2009) and Qian et al. (2015) had highlighted the role of the governments that they need to provide additional incentives to other stakeholders and to enhance the expected effects of green buildings in order to achieve green market transformation. Cupido et al. (2010) conducted case studies and indicated that the government policy is an important issue for sustainable building development and green building certification. Ross et al. (2007) also suggested that in order to promote green building development, some municipal policies should be modified such as reducing tax rate and increasing financial returns in green buildings.

2.6 GREEN BUILDING STRATEGIES

By applying green building strategies in construction industry, the growing economic benefits and great income growth were led to, and the benefits are summarized as economic returns, risk reduction, brand promotion, extensive sense of payback and benefits of early access to new markets (Lu et al., 2013). Jaillon and Poon (2008) concluded that in terms of sustainable construction, the adoption of a prefabrication approach in a dense urban environment could reduce construction waste, the requirement for on-site labour, construction time and accident rates, to varying degrees. Cronin et al. (2011) suggested that green marketing strategies should include the themes of green innovation, green organization, and green alliances. Safety management strategies in green building implementation was highlighted by Dewlaney and Hallowell (2012), and a decision-making support tool which can help practitioners improve the safety of the construction workers has been proposed. Darko et al. (2017a) identified five major categories of drivers for green building practice based on a comprehensive literature review. These categories include external drivers (such as mandatory requirements and regulatory incentives), corporate-level drivers (such as corporate image and marketing benefits), property-level drivers (such as increased property values, high rental income and risk reduction), project-level drivers (such as right design decision-making and off-site production approach) and individual-level drivers (such as personal motivation and self-identity).

Kang et al. (2013) and Son and Kim (2015) stated that developers should focus more on the project planning from the very early stage to reduce the possibility of cost overruns. It is because that the prediction of green building design performance at the very beginning is a key issue in achieving effective and high-performance green buildings. Furthermore, Williams (2010), Kats (2003) and Gultekin et al. (2013) highlighted that due to that the forward thinking can have a significant impact on cost savings, the green issues are suggested to be involved in the early design stage, and contractors are encouraged to participate in from the pre-design stage. Zhang et al. (2014) also recommended the participation of teams with multiple design experiences, third-party environment consideration representatives and efficient communication teams in order to ensure that each part in the building project has a unified goal of environment protection, thereby realizing sustainable project management. A number of technical tools and systems have been provided by researchers for application in green management strategies. Mohamad et al. (2011) explained that such strategies include applying industrialized buildings systems in green construction to protect the environment, reduce dependence on foreign labours and improve economic sustainability. Rawai et al. (2013) recommended the use of cloud computing in the early stages of green construction to help develop collaborative and integrated environments for construction management. Whang and Kim (2014) also proposed sustainable design management which involving passive design elements. Lee et al. (2015) advised that this approach is an effective technique for improving the aesthetic and spatial design of a green building and can enable improved decision-making during the schematic design phase. Darko et al. (2017b) identified the driving forces for the application of green building technologies in Ghana through a questionnaire survey. The most important driving force is "setting a standard for future design and construction". Moreover, the underlying forces were summarized as environmental, company, economic and health and industrial issues.

There are still some obstacles that limited the effects of the numerous sustainable development strategies. As stated by Du (2007), these obstacles and constraints include the integration with major decision systems is insufficient, the foundation of the participation is narrow, the links between the policy and practical situation are weak, or there is lack of clear priorities and achievable targets. For green strategy implementation, the most significant barriers have been named by Williams and Dair (2007) and Zhang et al. (2011) as the insufficient design of green technologies, the high price of energy-saving materials, insufficient stimulation of customer demand, and lack of policy enforcement. Hoffman and Henn (2008) tried to solve these barriers from the perspective of social and psychological, they pointed out that the effective strategies should be focused on education, structural reforms and incentive promotion, risk compensation, tax incentive, and green building rating tools optimization. To solve the economic and behavioral barriers to sustainable architecture, Shi et al. (2013) advised building a cooperative interests alliance among governments, industry associations and enterprises which helps to enhance communication and collaborative work. To solve investment uncertainties faced by developers and insufficient economic return in implementing green technologies, Zhang et al. (2014) developed a framework by concerning energy performance contract in which the “green” investment can be transformed into “gold” economic benefits. In addition, Wong and Abe (2014) tried to promote the environmental evaluation in building projects and recommended prioritising education and promoting public understanding of the green buildings from regional to national levels, which would develop strong business environment for green building and improved communications between local building professionals and owners.

2.7 DEVELOPMENT OF GREEN BUILDING RATING TOOLS

Green Building Rating Tools (GBRTs) are effective techniques to measure the design and construction performance of a green building. The evaluation standards vary in different rating tools considering different regional conditions and green requirements around the world (Zuo and Zhao, 2014; Ding et al., 2018). GBRTs can be used as a guide to evaluate the green building performance and whether the listed requirements are met. The corresponding certificate will be issued based on the assessment scores. A certified green building is regarded as performing well in improving energy efficiency and providing comfortable living environment than a conventional one (U.S. Green Building Council, 2013).

A number of GBRTs have been drawn up worldwide, such as Leadership in Energy and Environmental Design (LEED) in USA, Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, Green Star (GS) in Australia, Green Mark (GM) in Singapore, Building Environmental Assessment Method (BEAM) in Hong Kong, Ecology, Energy Saving, Waste Reduction, Health (EEWH) in Taiwan, Green Building Index (GBI) in Malaysia, Evaluation Standard for Green Building (ESGB) in China. (Huo et al., 2017; Mattoni et al., 2018). The development process of these major GBRTs in the world is listed in Figure 2.1.

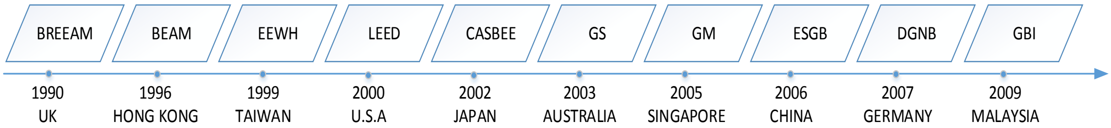

Figure 2.1 Development process of GBRTs worldwide

2.8 RESEARCH GAPS

The literature review showed that in green building development, the application of green technologies in the construction stage and green building performance evaluation have gained increasing attention. Certain researchers proposed a framework for green building evaluation, and the importance of planning and design in green building development has been recognized by other researchers in their studies. One obstacle in green buildings has been identified as short-sighted decision making. There is still a lack of comprehensive study in the early stage of green building development.

2.9 SUMMARY

As an effective practice to construct sustainable living environment, the importance of green buildings has been widely recognized on a global scale. This chapter summarizes current status of green building development. For green building management in general, researchers focus on definitions of green buildings, green building policy, critical factors for green building management, integration of information technology in green building, and retrofitting of existing buildings. In benefits and obstacles in green building development, the green building benefits are analyzed from economic, social and environmental aspects, and obstacles in green building implementation are also addressed. Current green building performance is analyzed from resource use efficiency, cost-benefit analysis, and health and efficiency of the occupiers. Stakeholders' interrelationships and behaviors of various stakeholders are summarized as well, including developers, designers, contractors, end-users, and government organizations. In addition, green strategies for marketing, safety management, building guidelines, green technical tools, green strategy implementation obstacles are concluded, and the development of GBRTs worldwide is introduced. The research gaps in previous green building studies were also mentioned.

CHAPTER 3 LITERATURE REVIEW-SITE PLANNING AND DESIGN

3.1 INTRODUCTION

Site planning and design (SPD) is an early stage in a construction project. To apply effective SPD can lay an important foundation to sustainable development. In this section, SPD process, sustainable development and SPD, SPD in green buildings, site layout and optimization in previous literatures, and SPD relevant items in GBRTs are explored, which gives a general understanding of SPD in the field of green buildings. The research gaps in SPD of green buildings are also identified.

3.2 SITE PLANNING AND DESIGN PROCESS

The location of a project is the basis for sustainable development, and site planners should minimize construction site disturbance. Site planning is defined by Lynch and Hack (2014) as "the art of arranging structures on the land and shaping the spaces between an art linked to architecture, engineering, landscape architecture and city planning". Russ (2009) stated that site design reflects the value of the society through the work of the designers.

As a multi-stage activity, the qualified professionals in SPD must make sure that the site is developed in a way of functionally efficient, aesthetically pleasing and environmentally (LaGro Jr, 2011). In residential SPD, the focus is to balance the development volume and costs with the interests of the community and the environments. The process of SPD is shown in Figure 3.1. Programming is an integral part in SPD, which determinines the objectives and functional requirements in the project based on the information of previous experience, user needs and site conditions. Site selection has important effects from the design stage to construction stage, including organizational and functional properties, the harmony of operation and economic benefits, and safety and aesthetic features in a building (U.S. General Services Administration Public Buildings Service, 2016). Through site inventory, the characters of the site can be mapped from the perspectives of physical, biological, and cultural (such as soils, topography, hydrology, climate, vegetation, human use), which help the designers better understand the site and its surrounding landscape. In addition, site analysis is also an important step based on the information provided by the site map. By analyzing the opportunities and constraints on site, the suitability of the programmed use can be investigated and summarized. In the design stage, the conceptual design explores and compares the possible spatial organization of the basic components in the project, and the design development process refines and details the conceptual site plan. Construction documents include construction drawings and construction specification, which confirm the design and facilitate the project implementation.

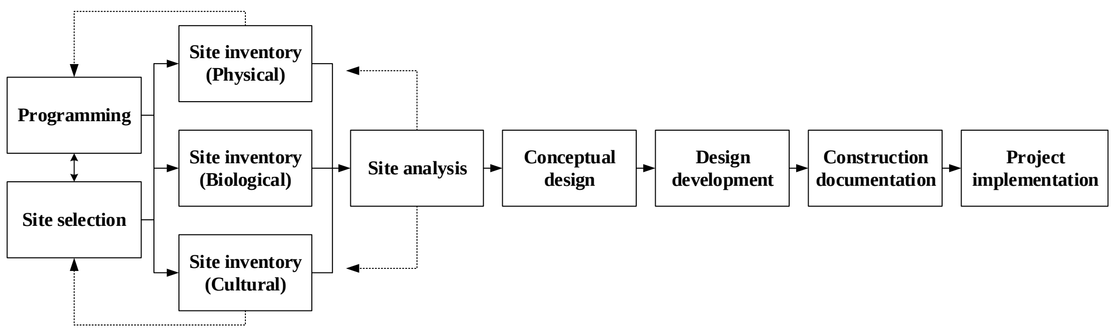

Figure 3.1. Site planning and design process (Source: LaGro Jr, 2011)

3.3 SUSTAINABILITY, SITE PLANNING, AND SITE DESIGN

Within the project site, a poorly designed site may lead to vehicle-dominated development that neglects the demands of pedestrians. This situation may cause conflicts in the circulation of vehicles and increase human exposure to natural risks (LaGro, 2011). A sustainable site considers and plans land use density, civil planning, landscape, water use and other issues that can reduce the ecological footprint of a new or renovation construction (Hendee, 2006). The key issue in forming a sustainable site in green buildings is SPD, and the costs of operating and maintaining the site is affected and reflected by SPD (Russ, 2009; Mawdesley, Al-Jibouri et al., 2002). In terms of sustainability and site, Kabbes and Windhanger (2010) introduced Sustainable Site Initiative (SITES), a rating system that considers the sustainability of site planning. SITES identified the importance of ecosystem services in sustainability. Ozdemir (2008) illustrated how sustainable site design practices can be a useful tool for policymakers, planners and designers concerned with the natural risks at the early stages. Certain sustainable site design principles and approaches were concluded as follows: evaluating site resources during site selection and assessment, combining with existing topography, identifying existing vegetation situation, designing appropriate plantings for site engineering, understanding terrain conditions to avoid excessive earthwork, minimizing disturbance to terrain and drainage modes and reducing the paving area. In urban areas, sustainable sites are crucial in providing habitats, protecting ecosystem, creating productive places, and maintaining natural and cultural features (Calkins, 2011). Sustainable site design is an information gathering, investigation and composition of creative and analytical process, in which art and science are combined to connect natural and construction environment (Venhaus, 2012). Venhaus (2012) stated that three pillars of sustainability have relationships with site development. In the planet aspect, the sustainable site helps society in building an environmental ethic by providing opportunities for people to connect with nature. In the profit aspect, sustainable sites consider economic merits, and the environmental and social costs and benefits are also concerned about. Thus, sustainable sites bring about economic profits, as well as encourage social and environmental responsibility. In the people aspect, sustainable sites benefit human health and create opportunities for site users to improve their physical, mental and social well-being. A sustainable SPD can benefit not only the economy by reducing long-term costs but also the society and environment. LaGro Jr (2011) listed the benefits of sustainable planning and design in Figure 3.2.

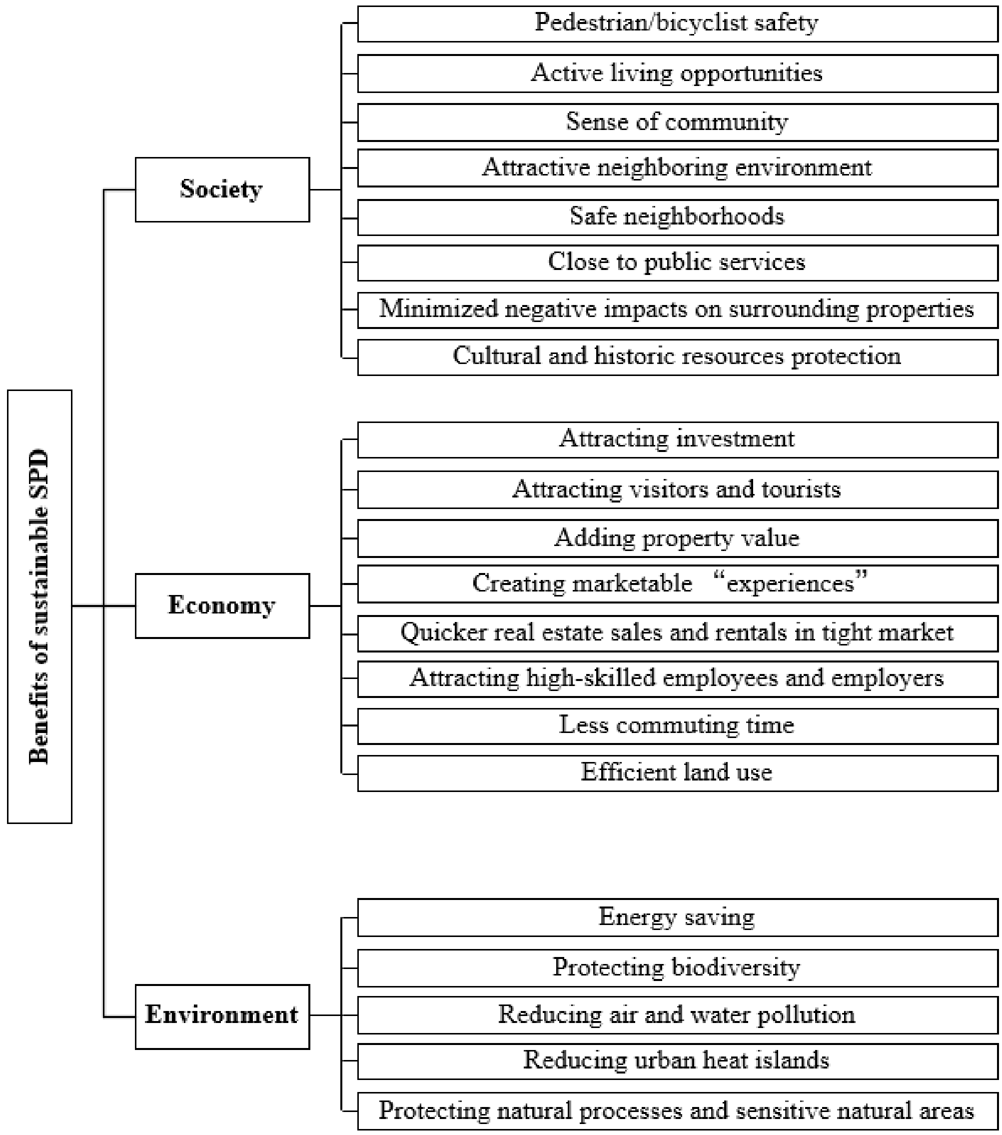

Figure 3.2 Benefits of sustainable site planning and design
(Source: LaGro Jr, 2011)

Complex and crowded construction site planning affects construction safety and construction performance on site (Gore et al., 2011). A photo modelling method was proposed for capturing the construction conditions for space planning, which proved to be feasible and effective in industrial case study. Wang et al. (2014) developed a group of factors that influence the sustainable land use planning decision-making process in urban renewal projects. By comparing factors involved in literature review and in real cases, it showed that certain factors considered in sustainable site planning have not yet been implemented completely, such as air and water quality in environmental concern, community characteristics and landscape uniqueness in social and cultural indicators, and slope or relative elevation in physical concern. In sustainable efficient residential site design, identifying factors that significantly affect access to facilities and daily essential services is important, including development diversity, non-residential land use, land diversity, and the employment (Maleki and Zain, 2011). Location relationships or accessibility suggests a guide to planning or designing because it affects other planning standards. Landscape and ecosystem is formed by the smaller concept, namely the site in green building projects. In sustainable site design, the environmental role of the site must be considered broadly, as well as the project plans and intents. This approach requires a comprehensive, ecology-based strategy to develop projects that do not change or damage the site environment but help to repair and restore existing ecological systems (Ozdemir, 2008; Russ, 2009). Sustainable and environmentally sensitive site planning, as an analytical and creative process, requires comprehensive understanding of the suitability of the site for the proposed program, which normally starts from site selection and briefing/programming (LaGro, 2011). To maintain a favourable microclimate, sustainable site planning is regarded as an effective strategy to be integrated in green building projects (Srivastava et al., 2017). Chen et al. (2017) stated that site planning and building orientation will affect building performance through stressing the shading, ventilation and daylight access conditions. Ustinovichius et al. (2017) proposed a site and building planning model by applying BIM, and a simplified application example was presented using MATLAB and artificial neural network. Mikaelsson and Larsson (2017) applied integrated planning in site management of sustainable buildings, wherein four critical factors were considered including enhancing leadership, improving health and safety, increasing quality management and focusing on the impact on surrounding environment, which helps site manager have improved knowledge and understanding.

3.4 SITE PLANNING AND DESIGN IN GREEN RESIDENTIAL BUILDINGS

To develop an environment-friendly site, various studies have been conducted concerning green building and construction site. Jaques (2000) focused on the reduction of waste generation on site and concluded that "attention at design stage" can be effective in reducing waste on site, following by "drawing complete" and "modular construction". Moreover, to reduce waste material, "smart design" and "total design involvement" are the most popular methods employed. Based on green planning, design and construction strategies proposed by Gwaze and Woolliams (2001), site design strategies in green buildings are involved. In green site design strategies, protection of the biodiversity, reduction in water consumption and urban heat island and multiple transportation provision should be given careful attention, to reduce disturbance on site (Glavinich, 2008; Montoya, 2010). When selecting a new construction site for green buildings, providing sufficient water resources and access to other renewable energy sources such as solar, wind, and geothermal energies should be among the considerations (Sillah, 2011). Proposal reasonable site planning is important in meeting the desirable requirements in sociocultural aspects in a green community, such as community awareness open-space and outdoor activity needs (Gonzales and Romero, 2014). When assessing the brownfield redevelopment on site-level and incorporating it with green building development, Wedding and Crawford-Brown (2007) found that applying Analytical Hierarchy Processes (AHPs) will facilitate to develop an indicator framework and develop a sustainable brownfield redevelopment tool. Stormwater management has been considered in previous research on green site design. For example, Cook (2007) proposed green site strategies such as green roof, green parking space, pervious paving, and alternative paving systems. Furthermore, LID is also regarded as a sustainable stormwater management strategy that prevents groundwater quality degradation, efficiently manages stormwater and protects potable water supplies. LID strategy is dynamic and adaptable and has been proved helpful in minimizing operating and maintenance costs and improving the project marketability (Guillette, 2010). Nizarudin (2010) took GRBT in Malaysia as an example and identified site related items in sustainable site planning, including site selection, access to public transport, community services and heat island effect, construction system and site management, storm water management, brownfield redevelopment, avoidance of development on environmentally sensitive land, and establishment of building user manuals. Ahzahar et al. (2016) investigated the applicability of GBRTs for site planning and management in mountain areas as development zone by using a case study in Malaysia. The scores of the selected case for site planning and management in three major GBRTs (i.e. GBI, LEED and GM) were calculated and the results indicated the GBI in Malaysia is suitable for the hill land development area when rating site planning and management criterion.

3.5 SITE LAYOUT PLANNING AND OPTIMIZATION

Site layout planning is the execution of SPD during the construction process. As stated by Sadeghpour et al. (2006), good site layout planning helps to minimize the efforts spent on processing materials, increasing construction productivity, and enhancing site safety. Actually, it is a multi-objective optimization issue to conduct a site layout planning. Optimizing the construction site layout involves the combination of two conflicting objectives, namely, maximizing construction safety and minimizing material transport cost while meeting all practical layout constraints (Mawdesley, 2002). El–Rayes and Khalafallah (2005) established a powerful model for site layout planning that can balance the construction safety and resource transport costs of resources on sites while satisfy construction constraints. The application of BIM was considered by Albahri and Hammad (2016) to provide information on construction site. Moreover, a framework for estimating travel frequency parameters for site layout was presented, wherein the estimated parameters can be integrated in optimization models to enhance site layout planning. In construction site layout planning, the decision-making process includes four stages, namely, design, evaluation, selection and output. Ning et al. (2016) presented a multi-attribute decision-making model in which the cardinal class method is involved by using predefined qualitative attributes in identifying the basic preferences of a site layout scheme.

The complexities of construction sites such as the interrelationship among materials, labour and surrounding buildings influence the smooth flow of resources. Tawfik and Fernando (2001) designed a simulation environment for the modelling, visualization and optimization of construction site layouts, with the aim of supporting site planning task that satisfies the criteria of safety, efficiency and cost. To solve problems in construction site layout planning, a number of useful methodologies are explored and applied. In the initial stage of site layout planning when only inaccurate information can be provided, the non-structural fuzzy decision support system is a suitable tool to help to achieve rational and multi-objective decision-making. Furthermore, the repeated evaluation and selection process is suitable for major facilities at the site (Tam et al., 2002). Ant Colony Optimization (ACO) is found useful especially in medium sized project in determining the optimal site layout. As in site layout planning, the certain key facilities would be assigned at first, using the ACO algorithm, thereby improving the effectiveness of the site layout planning (Lam et al., 2007). Through interviews with professionals in the construction industry, Freitas (2009) validated that the computational tool SAP-LCO Virtual (Virtual Support System for Planning Construction Site Layout) is important in the construction site planning process. Lam and Ning et al. (2009) combined Max-Min Ant System (MMAS) with Genetic Algorithm (GA) as MMASGA to optimize the construction site layout planning. With the application of MMAS–GA, heuristic and pheromone information are used to converge immediately by reducing searching space of optimal solution. Abotaleb et al.

(2016) developed a site layout optimization model concerning about various new algorithms to stimulate the regular and irregular free-form shapes of site facilities. Razavi Alavi and Abou Rizk (2016) introduced a genetic algorithm simulation framework to facilitate solving site layout problem and evaluating layout quality. This framework is composed of three phases, namely, functionality, cost, and value evaluation. The framework is suitable for sites that have crucial subjective constraints and cost-effectiveness for layout. To realize the multi-objective optimization in site layout planning, Hammad et al. (2015) presented a novel multi-objective model in which the objectives are noise control and improved transportation function. To conduct effective material logistics management for closed construction sites, Spillane and Oyedele (2017) explored four major strategic management themes on construction site based on SEM.

3.6 SITE-RELATED REQUIREMENTS IN GREEN BUILDING RATING TOOLS

3.6.1 Site-related Requirements in BREEAM

As the earliest established GBRT in 1990, BREEAM is the leading sustainability assessment tool around the world that guides projects, infrastructure and buildings. By adopting BREEAM in building assessment, the environmental impacts caused by buildings can be evaluated and minimized, which helps to create high-value and low-risk assets. There are ten categaries involved in BREEAM: “energy”, “health and well-being”, “innovation”, “land use”, “materials”, “management”, “pollution”, “transport”, “waste”, and “water”. When evaluating the building performance, if the building fulfils the relevant requirements, the corresponding scores will be achieved. Finally, the total scores will decide the ranking and certification of the building. By considering the final score percentatge, six levels are divided in BREEAM certification, namely, Outstanding (≥85%)， Excellent (≥70%), Very Good (≥55%), Good (≥45%), Pass (≥30%), Unclassified (＜30%＝.

SPD involves two categories of BREEAM, i.e. “transport” and “land use and ecology”. To reduce traffic-induced pollution and congestion, construction and development should be encouraged in proximity to reliable transport networks. When considering the location of the site, the proximity to facilities that facilitate occupants or residents to local services should be attributed as it helps to reduce emissions caused by the expansion of the footprint of the occupants. Furthermore, when selecting a construction site, development on previously occupied or contaminated land is encouraged to reduce the footprint of construction development on the undisturbed land. To protect the existing ecological functions, it is also encouraged to develop on the land of low ecological value. When constructing new buildings, their impact on existing ecological environment should be minimized by reducing changes in the ecological value of the site. To strengthen site ecology, qualified ecologists should be designated at an early stage, and proposals for strengthening site ecology should be proposed. To mitigate the the long-term impacts of the building on the surrounding biodiversity, it is necessary to comply with the relevant legislation on ecological conservation and protection during the design and construction process. It is recommended that during the first five years after the project is completed, appropriate landscape and habitat management and preservation plan on site should be proposed.

3.6.2 Site-related Requirements in LEED

LEED is a rating tool that aims at "evaluating and accrediting energy efficiency and sustainable design features of new and renovated buildings" established by the U.S. Green Building Council (Barnes, 2012). There are 8 sustainable categories in LEED, namely, "location and transportation", "sustainable site", "water efficiency", "energy and atmosphere", "materials and resources", "indoor environmental quality", "innovation" and "regional priorities". In the evaluation, the prerequisites have to be met before calculating the total points, and the total possible points are 110. According to calculated total points in the scorecard, buildings of new construction can be divided into four levels, namely, Certified (40 to 49 points), Silver (50 to 59 points), Gold (60 to 79 points), Platinum (80 to 110 points).

Two categories in LEED, namely, "location and transportation" and "sustainable sites", contain SPD relevant items. To protect environmentally sensitive lands, the development activities should be placed on already developed land or should be insensitive to the environment. Developing construction projects in areas with existing infrastructure and facilities helps conserve land, protect farmland and wildlife habitat, encourage daily physical activities, and improve public health. Moreover, if a construction site is well-located, then walkability can be promoted, transportation efficiency can be improved, and vehicle travel distance can be reduced. New construction must meet the minimum multimodal transportation options to reduce greenhouse gas emission, air pollution, and other environmental and public health hazards caused by private vehicles use. Encouraging bicycle use and increasing transportation efficiency can also help reduce vehicle travel distance. Reducing parking footprint helps to reduce environmental hazards caused by vehicle dependence, and to reduce land occupation, and to better manage storm water runoff. Promoting green vehicles use can also reduce pollution resulting from motor vehicle use. Moreover, among the total parking space, 5% of them should be researved for green vehicle parking. Alternative fuel station should also be installed such as electric vehicle charging and liquid, gas, or battery installation. Erosion and settlement plans must be made and implemented before new residential buildings are built. Before conducting site design in green buildings, an assessment should be conducted to investigate the site conditions, which shows the site conditions and characteristics and their impacts on site design. In site development, to provide ecological habitat and promote biodiversity, there is a need to preserve the current natural areas, and restore damaged areas by planting native or adapted vegetation. Outdoor space should be designed for the interaction between the environment and society, entertainment and physical activities. Appropriate rainwater management on construction site can effectively reduce the runoff and improve water quality. In oder to reduce heat islands and mitegate their impacts on surrounding microclimate, human being and wildlife habitats, measures such as high-reflectance roof and covered parking areas should be adopted on site. In addition, to reduce light pollution and increase nighttime visibility, backlight, up light and glare can be applied on site.

3.6.3 Site-related Requirements in BEAM Plus

In 1996, the HK-BEAM was established, which was the second earliest implemented system except for Europe. After several amendments, Hong Kong now has four major GBRTs including BEAM Plus New Buildings, BEAM Plus Existing Buildings, BEAM Plus Interiors and BEAM Plus Neighborhood. The weights for the five categories in new buildings are assigned as site aspects (25%), material aspects (8%), energy use (35%), water use (12%) and indoor environmental quality (20%). By considering the achieved credits in each category and the weightings of the category, the overall certified grade of the building can be divided into Platinum (75%), Gold (65%), Silver (55%) and Bronze (40%).

In site design appraisal section, planners should consider the physical and environmental factors around the construction site. Clients and design team should collaborate to achieve the integration of the development with the surrounding environment. Habitat conservation is an efficient way to protect the ecological value and conserve the natural environment. Reconstruction of the local ecosystem needs additional time and effort. Thus, it is encouraged to develop buildings at brownfield sites that are of low ecological value. Protecting cultural heritage is another important concern. Hence, there is a need to pay attention to the protection measures to ensure that cultural heritage features on and around the site are protected and that the cultural sustainability is maintained. Landscaping strategies are effective in improving the microclimate and reducing damage to site ecology by providing efficient irrigation and controlling surface runoff. Microclimate conditions of the site should also be designed by considering the thoroughness and balance of wind, sunlight, and temperature and air quality. For sensitive adjacent buildings, the impacts of the newly developed buildings on their sunlight exposure should be analyzed. Furthermore, to reduce the environmental impacts of the building projects during the construction and demolition stage, there is a need to formulate an environmental management plan that involving environmental monitor and audit on construction site.

3.6.4 Site-related Requirements in GM

GM was founded in Singapore in January 2005 to encourage the construction industry develop towards green buildings. All relevant prerequisites for the specific GM rating should be met to achieve the GM Award. In addition, the framework also involves two major parts, one is about energy-related requirements, in which the achieved score should be no less than 30, the other part is other green requirements, in which at least 20 points should be achieved. Four categories of GM rating are included according to the GM score, namely, Green Mark Platinum (90 and above), Green Mark Gold ^{PLUS} (85 to < 90), Green Mark Gold (75 to <85) and Green Mark Certified (50 to <75).

In GM, SPD-related items are involved in “water efficiency” and “environmental protection” parts. In terms of irrigation systems and landscaping, rainwater or other non-potable water are suggested to be used for landscaping irrigation. Automatic irrigation systems with rain sensor help to save water, and planting drought-tolerant plants are also effective in reducing water consumption. Increased green space is encouraged such as on-site restoration or conservation of trees and relocation of existing trees to reduce the heat island effects. High-quality and environment-friendly transportation methods are also encouraged to reduce air pollution by using private vehicles, including providing easy access to and covered walkway to surrounding public transport stations, providing green electric vehicles charging facilities, and designing covered or sheltered non-motor vehicle parking lots. Furthermore, proper stormwater runoff treatment is encouraged before the stormwater on site is discharged into public drains. The treatment methods include bioretention swales, rainwater gardens, constructed wetlands, cleansing biotopes and retention ponds.

3.6.5 Site-related Requirements in ASGB

In China, the Evaluation Standard for Green Building (ESGB) was firstly established by the National Ministry of Construction in 2006, and was revised and issued as ASGB in 2015. This system has five major indicators for residential buildings at the design evaluation stage, including “land saving and outdoor environment” (weighting of 0.21), “energy saving and energy utilization” (weighting of 0.24), “water saving and water resource utilization” (weighting of 0.20), “material saving and material resource utilization” (weighting of 0.17) and “indoor environment quality” (weighting of 0.18). For each indicator, the total points are 100, wherein two types of items need to be considered, i.e. prerequisite items and scoring items. Buildings that pass the evaluation are divided into three levels, including One Star (≥50 points), Two Stars (≥60 points), and Three Stars (≥80 points), respecting the building performance levels from low to high. Among them, all prerequisites should be met, and the scoring items for each indicator must be no less than 40 points.

In ASGB, the categories of “land saving and outdoor environment”, “energy saving and energy utilization” and “promotion and innovation” have mentioned SPD-related items. Encouraging intensive land use means controlling residential land per capita within a reasonable range. Moreover, the reasonable use of greenery land and underground space is also suggested in green buildings. For the outdoor environment, effective measures should be taken to reduce environmental noise, improve outdoor wind environment and control urban heat island intensity. When considering transport facilities and public service, the evaluation considers easy access to public transportation facilities, wheelchair-friendly sidewalks, reasonable parking spaces and convenient public services. The site topography should be taken into consideration to protect the original ecological features during site design and layout. In rainwater management, the site space should be used completely to design for green rainwater infrastructure. The amount of storm water outflow on site can be controlled by planning the surface and roof rainwater runoff properly. For site greenery, reasonable green plants and greening methods, such as vertical greening or green roof, should be selected. Combining architectural scheme with site features and building function and locating construction on brownfields reasonably contribute to green building assessment.

3.6.6 Comparison of SPD-related items in GBRTs

To compare the different considerations in these GBRTs, the significance score (SS) of SPD items in major GBRTs was calculated by the Equation (1), (2) and (3).

In BREEAM and BEAM Plus, the section weightings were considered when calculating the achieved credits. Therefore, Equation (1) is applied to calculate the SS of SPD-related items.

$$SS = \sum SPDC_i / C_j * W_j \tag{1}$$

Where $SPDC_i$ means the maximum credits of the SPD-related item i, C_j represents the maximum credits of the corresponding section j. W_j means the weight of the corresponding section j.

In LEED and GM, there is no consideration about the section weights. So Equation (2) is adopted to calculate the SS of SPD-related items.

$$SS = \sum SPDP_i / TP \tag{2}$$

Where $SPDP_i$ refers to the maximum points of the SPD-related item i. TP means the total points in this system.

In ASGB, expect for considering the section weights, the bonus scores in promotion and innovation are involved separately. The SS of SPD-related items is calculated by Equation (3).

$$SS = \sum (SPDS_i * W_j + SPDSI\ ) / TS \tag{3}$$

Where $SPDS_i$ means the maximum score of the SPD-related item i. W_j represents the weight of the corresponding weighted section j. $SPDSI$ refers to the maximum score of SPD-related items in the section of promotion and innovation. TS means the maximum total scores of the system.

The detailed SPD-related items and scores in the major five GBRTs are summarized in Table 3.1, in which the column of score indicates the highest score of the related item in that GBRT. By calculating the SS in the selected five GBRTs, the distribution and importance of SPD in each GBRT can be investigated. Out of the five GBRTs, in BEAM Plus the site aspect requirements were considered more with 25% of the weightings. Then LEED has assigned up to 23.6% of the total credits for site aspect, which is similar to the situation in ASGB, in which the site aspect requirements account for 23% of the total marks. In addition, in BREEAM, about 13% of this rating system is related to site aspect. While in GM, only around 7% of the total credits are relevant to site aspect requirements.

Table 3.1 SPD-related requirements and scores in selected GBRTs

(Source: Huo et al., 2017)

GBRT	Section	Item	Score	SS
BREEAM	Transport	Public transport accessibility	5	**9/10*0.07+ 10/10*0.07 =13.3%**
		Proximity to amenities	2	
		Alternative modes of transport	2	
	Land us and ecology	Selection of previously occupied or contaminated land	3	
		Protection of ecological features	2	
		Enhancing site ecology	3	
		Minimization of long-term impact on biodiversity	2	
LEED	Location and transportation	Sensitive land protection	1	**26/110=23.6%**
		High-priority site	2	
		Surrounding density and diverse use	5	
		Access to quality transit	5	
		Promotion of bicycling and transportation efficiency	1	
		Reduced parking footprint	1	
		Promotion of green vehicles	1	
	Sustainable sites	Site assessment	1	
		Protection or restoration of habitat on site	2	
		Creation of exterior open space	1	
		Rainwater management	3	
		Heat island reduction	2	
		Light pollution reduction	1	
BEAM Plus	Site aspect	Remediation of contaminated land	1	**20/20*0.25 =25%**
		Reduction of private vehicle use	3	
		Integration of neighborhood amenities	3	
		Proactive approach in integrating site planning issue	2	
		Reduction of ecological impact	1	
		Protection of cultural heritage	1	
		Proper landscaping and planters on site	3	
		Ensure microclimate around buildings	4	
		Preservation of neighborhood daylight access	1	
		Environmental management plan	1	
GM	Water efficiency	Irrigation system and landscaping	3	**18/242=7.44%**
	Environmental protection	Greenery provision	8	
		Green transport	4	
		Storm water management	3	

ASGB	Land saving and outdoor environment	Economic and efficient land use	34	**(0.21*100+0.24*6+3) /(100+10) = 23%**
		Outdoor environment	18	
		Transport facilities and public services	24	
		Site design and site ecology	24	
	Energy saving and energy utilization	Architecture and envelope structure	6	
	Promotion and innovation	Promotion and innovation	3	

3.7 RESEARCH GAPS

Through this chapter, it can be observed that previous studies have stressed the importance of SPD in sustainable development. SPD-related items have been mentioned in major GBRTs around the world. However, no comprehensive and systematic analysis of these items including their importance and difficulties when realizing in green buildings have been conducted.

The focus of site planning in previous literature was site layout planning and optimization. Hence, a number of planning and optimization methods were applied. Limited research has mentioned the framework related to the entire process of SPD in green buildings, including the principles, factors, stakeholders' relationships and approaches. Thus, these research gaps were identified and studied in this study.

3.8 SUMMARY

A sustainable site helps to minimize the disturbances in a construction site. This chapter summarizes the previous literature concerning SPD in green buildings. The concept and process of SPD were introduced first, and the combination of SPD and sustainability were elaborated, followed by the introduction of SPD in green buildings. Several strategies in SPD of green building development were presented, such as development in brownfield, low-impact development and storm water management. Site layout planning, as the implementation of SPD in the construction process, was given attention in previous studies. Moreover, various models and framework were developed to solve this optimization problem. In addition, SPD considerations in five major GBRTs around the world were summarized, which showed that SPD issues have gained increasing attention. Finally, the research gaps in SPD of green buildings were stressed, which served as basis for the research study.

CHAPTER 4 RESEARCH METHODOLOGY

4.1 INTRODUCTION

4.2 RESEARCH DESIGN

4.3 DATA COLLECTION METHODS

4.4 DATA ANALYSIS METHODS

4.5 SUMMARY

4.1 INTRODUCTION

This chapter summarizes the research methods and process, the data collection methods and the data analysis techniques, which are further discussed in Sections 4.2 to 4.4, respectively.

4.2 RESEARCH DESIGN

4.2.1 Research Methodology Overview

The Concise Oxford Dictionary of Current English defined research as “the systematic investigation into and study of materials, sources etc. in order to establish facts and reach new conclusions”, whilst Fellows and Liu (2015) defined research as “a careful investigation” and “contribution to knowledge”. Researchers generally rely on quantitative or qualitative methods to collect and report information.

Quantitative methods are applied to collect factual data, to examine the relationships amongst facts and to determine whether the findings of one study are in line with those of previous research. Some of these methods include surveying a large number of participants to describe a certain phenomenon and employing several statistical techniques to summarize the characteristics of different groups or to establish relationships amongst them.

Qualitative methods investigate the understanding, views, insights and opinions of various individuals or groups towards certain subjects. The unstructured data collected by using these methods can help researchers investigate things in their natural settings and explain certain phenomena based on the meaning that people ascribe to them (Mertens, 2014). Qualitative methods allow researchers to collect empirical materials based on case studies, personal experiences, life stories, interviews, artefacts, cultural texts and production, observations, history, interactions and visual texts (Denzin and Lincoln, 2011).

Each of the above methods has its benefits and limitations and is suitable for answering certain types of questions. Table 4.1 lists the benefits and limitations of quantitative and qualitative methods (Punch, 2013).

Table 4.1 Benefits and limitations of quantitative and qualitative methods

Characteristics	**Quantitative methods**	**Qualitative methods**
Benefits	● Collect information from a large number of participants ● Measure data by statistical analysis ● Study relationships between variables in detail objectively	● Allows new and unrecognized phenomena to be identified ● Gains rich and more detailed data ● Allows in-depth study of small group
Limitations	● Limited outcomes in a quantitative research ● Difficulty in obtaining kinds of data through structured data collection instruments	● Challenges in statistical methods application ● Time consuming

Nevertheless, researchers can combine quantitative and qualitative methods to exploit their benefits whilst addressing their limitations (Punch, 2013). Accordingly, triangulation studies that adopted a combination of these methods were conducted in this work to gain powerful insights and findings. According to Jick (1979) and Fellows and Liu (2015), triangulation aims to enhance the external validity of a study, whilst seeks to enhance internal validity and reliability within the methodology.

4.2.2 Research Process

A proper research design must include methodological approaches that can facilitate to construct research questions and to achieve the research aim and objectives which are illustrated in Chapter 1. The research framework is illustrated in Figure 4.1.

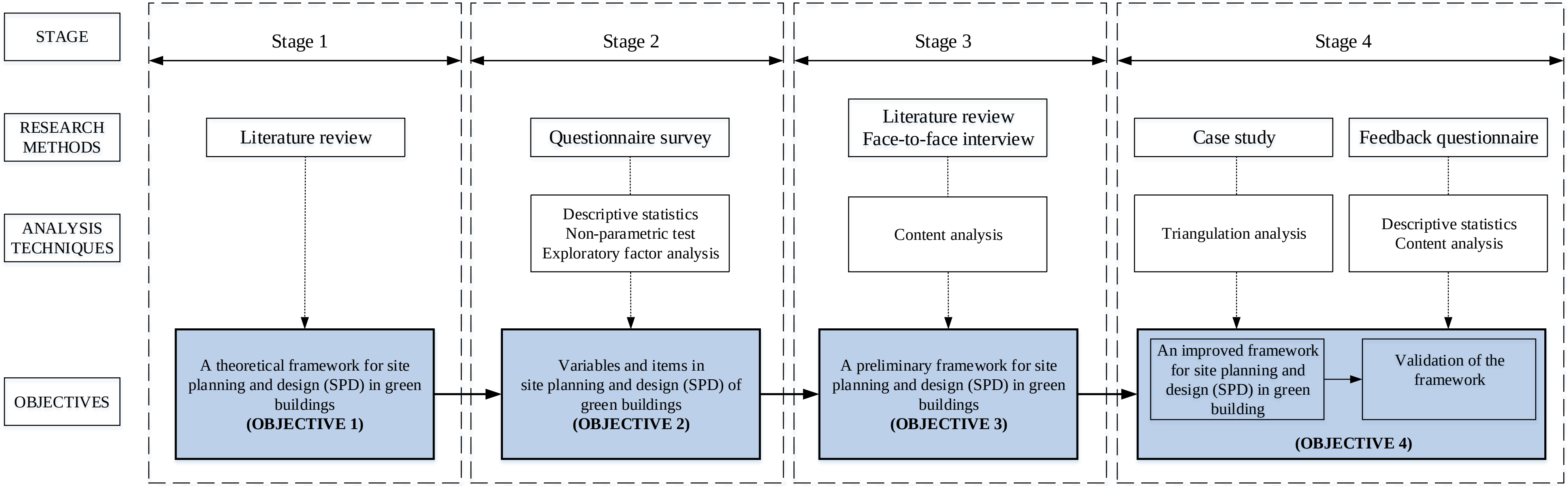

Figure 4.1 Research Framework

Several qualitative and quantitative methods are also applied in each of the following stages for data collection and analysis:

Stage 1: A theoretical framework for SPD in green buildings

The literature on green buildings and the aspects of their construction sites was reviewed to understand the extent of the present knowledge in this area and to identify the research gaps and research problems in these studies. By conducting a comprehensive and in-depth evaluation of the SPD issues in major GBRTs being used around the world, the variables and items in SPD of green residential buildings were summarized and a theoretical framework for SPD in green buildings was developed.

Stage 2: Variables and items in SPD of green buildings

The variables and items included in the theoretical framework lay a foundation to the questionnaire design. This questionnaire survey aimed to study the perceptions of green building participants towards the importance of and difficulty to realize these variables and items in SPD of green residential buildings and to identify critical factors in SPD of green buildings. Descriptive statistics, non-parametric test, and exploratory factor analysis were performed to analyze the questionnaire survey data and to identify the potential critical factors.

Stage 3: A preliminary framework for SPD in green buildings

A preliminary framework for SPD in green residential buildings was then developed by inviting the researchers and industry practitioners to participate in the semi-structured interviews. These interviews explored the SPD process in green buildings and the design principles, the relationships amongst different stakeholders, and the effective planning and design approaches. The collected interview data was analyzed by content analysis and coding. The variables and items identified based on the theoretical framework were then summarized to construct a preliminary framework for SPD in green residential buildings.

Stage 4: Improvement and validation of the improved framework

Firstly, case studies were conducted in Mainland China and Hong Kong to strengthen the preliminary framework. Major stakeholders, such as engineers and architects, were invited to the interviews, through which different considerations in the preliminary framework and in real practice were identified and analyzed. By conducting case studies, the preliminary framework was then refined to an improved framework for SPD in green residential buildings. A feedback questionnaire survey was performed afterwards to validate the improved framework and to test whether participants agreed with its contents. The framework was then improved based on the suggestions and comments provided by these participants. Both descriptive statistics and content analysis were applied to analyze the feedback questionnaire survey results, and the summarized suggestions were used to improve the developed framework.

4.3. DATA COLLECTION METHODS

4.3.1 Literature Review

The purpose of conducting literature review is to outline important research findings that were published in relation to the research problem being investigated (Fink, 2013). Before conducting a research study, the first step is to search related research studies and to determine the extent to which the topic at hand has been investigated in the past. This process also determines the major research in previous studies, their contributions to the literature development, the research gaps and the potential directions in future research (Jesson et al., 2011).

In this study, those mainstream journal papers and books on green buildings and SPD were identified from various academic databases, such as Scopus and Google Scholar. After a brief reading of the research titles, those articles and books that included the keywords “green building”, “sustainable building” and “green construction” were downloaded for further consideration. Those works with the keywords “site planning”, “site design” and “construction site” were also collected for further review. After comprehensively reviewing the obtained literature, the current status of green building development and SPD research was determined and the research gaps in existing studies were identified. Five major GBRTs being used around the world were also selected to form the foundation of a theoretical framework for SPD in green residential buildings.

4.3.2 Questionnaire Survey

4.3.2.1 Introduction to the Questionnaire Survey

Questionnaires objectively collect information about the beliefs, attitudes and behaviors of people from different backgrounds (Boynton and Greenhalgh, 2004). A questionnaire survey not only gathers large amounts of information within a relatively short period and in a relatively cost-effective manner but also generates results that can be quickly and easily quantified by researchers or some statistical software. Questionnaire surveys often employ two types of questions, namely, open and closed questions (Rossi et al., 2013). Given that open questions are easy to ask yet difficult to answer and analyze, respondents tend to ignore and skip these types of questions. Meanwhile, closed questions allow researchers to provide their respondents with several options from which they must choose the most proper response. Given that these types of questions limit the potential answers artificially, researchers need also provide their respondents with the additional option, “others”, where it is applicable. A questionnaire may ask more closed questions considering that the they are easier to answer than the open questions.

Before designing a questionnaire, the research objectives and the information included in the questionnaire must be clarified (Brace, 2018). A complete questionnaire should include four major elements, namely, title, preface, main body and closure (Wu, 2016a). A proper title should provide clear information about the topic and contents of the research. The preface needs to briefly describe the research background, outline the research objectives and provide the respondents with a guarantee that their responses will be kept private. The main body of a questionnaire collects the background information of the respondents to facilitate the data analysis. To ensure their intelligibility, each survey question must be clearly stated and focus only on a single issue. Questionnaires need to end with a closing statement where the researchers thank their respondents for their participation and contribution in the data collection.

4.3.2.2 Pilot Study

A newly developed questionnaire cannot be directly employed in a formal survey. Before conducting the survey, the questionnaire must be tested in a pilot study involving a small sample (Fellows and Liu, 2015) to test the answerability, clarity, and intelligibility of its contents. The feedback of the participants in the pilot study can also be used to clarify any ambiguity in the wordings of the questions and to guide the revision of the entire questionnaire (Van Teijlingen and Hundley, 2001).

4.3.2.3 Questionnaire Design

In this research study, a total of 13 variables and 38 items for SPD in green residential buildings were identified based on the theoretical framework. In order to measure the perception of participants in green building development about the importance of and the difficulty in realizing the aforementioned items, a questionnaire survey in the context of China was conducted. There are three major parts in the questionnaire. The first part briefly introduced the research aim, guaranteed the anonymity of the participants, and clarified that their responses will be only used in academic research. The second part is about the background information of the participants. In the third part, the opinions of these participants were investigated towards the importance of and difficulty to realize the SPD items. At the validation stage, a feedback questionnaire survey was also designed to verify whether the developed framework can be regarded as a reference in practice.

4.3.3 Face-to-Face Interviews

Interviews can be divided into structured interview, semi-structured interview or unstructured interview. The differences among them mainly depend on the constraints that they place on the respondent and the interviewer (Fellows and Liu, 2015). In structured interviews, a list of questions is raised by the interviewer and the answers of the respondents to each item are recorded simply without asking supplementary questions. In unstructured interviews, the research topic is introduced briefly by the interviewer at the beginning of the interview, recording the responses of the participants and allowing them to elaborate their answers. Semi-structured interviews fill the scope between structured and unstructured interviews by allowing the interviewer to administer a questionnaire and probe the responses.

Semi-structured and face-to-face interviews were selected in this research to allow the interviewers to share their ideas, to smoothly ask questions and to record the reactions of their respondents easily. To determine the components that should be included in the preliminary framework, 9 face-to-face semi-structured interviews with 12 experienced green building practitioners were conducted in both Mainland China and in Hong Kong. Table 4.2 showed the profiles of these interviewees and their respective organizations. The interview duration ranges from 30 minutes to 1 hour depending on the discussions with the interviewees and their understanding of the research questions. The interviewees were guaranteed that their responses would be only for academic use and that their personal information would remain confidential. Five major issues were discussed with each interviewee, including 1) how do they perceive the differences of SPD in green buildings and in conventional ones; 2) how do they perceive the SPD process of green buildings; 3) how are major stakeholders involved in the SPD process of green buildings; 4) what are the sustainable principles in the SPD process; and 5) what effective planning and design approaches can be applied in the SPD of green buildings.

Table 4.2 Profile of the interviewees participated in the face-to-face interviews

No.	**Position**	**Organization characteristic**	**Region**	**Experience (Year)**
1	Architect	Government	Hong Kong	5
2	Associate (Sustainability)	Company	Hong Kong	12
3	Professor	University	Mainland China	8
4	Architect	Company	Mainland China	9
5	Architect	Company	Mainland China	5
6	Technical consultant	Company	Mainland China	10
7	Architect	Government	Hong Kong	21
8	Engineer	Company	Mainland China	11
9	Engineer	Company	Mainland China	4
10	Architect	Company	Mainland China	17
11	Architect	Company	Mainland China	5
12	Associate professor	University	Mainland China	8

4.3.4 Case Study

Case studies are often applied in social sciences when investigating real-life phenomena. These studies usually examine individuals, groups or events in depth to determine their causes or underlying principles (Yin, 2017). According to Yin (2017), a case study has three major characteristics: 1) adopt context-based methods; 2) focus on non-specific contextual conditions; and 3) utilize a combination of several methods. The data used in case studies are usually collected by using several techniques, such as interviews, archival data, questionnaires and observations (Fellows and Liu, 2015). Case studies usually generate in-depth yet narrow results and are particularly useful in testing theoretical models in real-world contexts. Theoretical limitations can also be addressed by analysing information from real cases.

Three case studies were conducted in this research after the preliminary framework was developed based on the questionnaire survey results and the face-to-face interviews. Case studies were performed in Mainland China and Hong Kong to further develop this framework and explore its issues in practice. The background information of the three case studies is summarized in Table 4.3. Face-to-face interviews with engineers or architects who were involved in the selected green residential building projects were conducted during the case studies. These respondents received a case study guide before participating in the interviews to ensure that they clearly understand the process and contents of the interview. This guide contains three sections. The basic information about the selected project is included in the first section. The second section briefly describes the 13 variables related to the SPD of green buildings. The interviewees were also asked which of these variables were involved in their projects and how they were involved. The third section included open-ended questions that could help the interviewees describe more detailed information of SPD process in their projects.

Table 4.3 Background information of the three cases

Cases	Characteristics	Region
Case one-A green residential project	This project has been awarded as two-star green building in design assessment according to ASGB in China in December 2015.	Mainland China
Case two-A green residential project	The second selected project was awarded two-star green building design label in June 2015.	Mainland China
Case three-A public rental house	It was started from about 2008 and completed in 2015, which is the first public estate in Hung Shui Kiu. The Hong Kong Housing Authority project the won the Grand Award in the New Buildings category (Completed Projects - Residential Building) in 2016.	Hong Kong

4.4 DATA ANALYSIS METHODS

4.4.1 Descriptive Statistics

Descriptive statistics is a brief descriptive coefficient to summarize a given data set, which can be either a sample or a representative of the entire population (Goyal, 2017). Descriptive statistics serve two main purposes, that is, to provide basic information about the variables in the database and to highlight the potential relationships amongst these variables. Typically distinguished from inferential statistics that attempt to reach conclusions beyond the immediate data, descriptive statistics simply describe the data or what they show. Therefore, inferential statistics extrapolate the analyzed data to general conditions, whilst descriptive statistics merely describe what is happening in these data. Descriptive statistics also help to simplify large amounts of data in a reasonably.

Descriptive statistics present quantitative description in a manageable form by using several measures. Two major types of measures, namely, central tendency and variability, are often used to understand the analyzed data. Central tendency describes the centre position of a distribution for a data set by using mean, median or mode, whilst variability describes how spread-out the distribution of the data set by using range, standard deviation and quartiles.

After the questionnaire survey, descriptive statistics analysis was used to summarize the background information of the respondents via graphic analysis. Mean values were also summarized to identify the perception of the respondents towards the items and variables in the SPD of green buildings.

4.4.2 Non-Parametric Test

Non-parametric tests, which are also regarded as distribution-free tests, as only few assumptions are needed to conduct the tests (i.e. it does not need to gain normally distributed data) and they can be applied on all types of data (Pallant, 2013). Non-parametric tests are also applicable in small samples that require a relatively simple calculation process. Parametric tests are often conducted to test the group means, whilst non-parametric tests aim to test the group median. Moreover, parametric tests usually involve t-test and ANOVA. Correspondingly, in non-parametric test, the alternative of independent samples t-test is Mann-Whitney U test, the one-way ANOVA and two-way ANOVA correspond to Kruskal-Wallis test and Friedman test respectively.

During the analysis of the questionnaire data, Kendall's coefficient of concordance aims to test whether the respondents in a certain group agree with the importance and difficulty rankings of the SPD-related items. Mann–Whitney U test was performed afterwards to examine the differences of the responses in Hong Kong and Mainland China in terms of their importance and difficulty rankings for these items.

4.4.3 Exploratory Factor Analysis

Factor analysis is a statistical method that describes unobserved factors by using few observed and correlated variables. According to Kim and Mueller (1978), factor analysis is particularly a suitable statistical tool in variable reduction, which is achieved by calculating the scores of each underlying dimension. The variables were grouped into relatively few factors to represent the relationships amongst various interrelated variables (Comrey and Lee, 2013). Cronbach's alpha (α) was calculated to test the goodness of fit of those variables that are believed to be combined to form a certain construct. Cronbach's alpha is the most commonly used reliability measure in a survey to determine the internal consistency or average relevance of the variables (Santos, 1999). Generally, if in a survey the Cronbach's alpha coefficient of each item is greater than 0.7, it means that the variables have a satisfactory individual reliability (Fellows and Liu, 2015). Whilst evaluating the appropriateness of the extracted factors, the Kaiser–Meyer–Olkin (KMO) value was computed to test whether the correlation matrix is an identity matrix. The value range of KMO is 0 to 1. A value close to 0 indicates that there are large partial correlations compared to the sum of correlations, thereby indicates that it is not appropriate to apply factor analysis within this data set. Meanwhile, a value close to 1 implies a compact correlation pattern and applying factor analysis will produce reliable factors. According to Field (2009) and Hou et al. (2014), KMO values of larger than 0.5 are acceptable. Bartlett's test of sphericity was also performed to examine whether the original correlation matrix is an identity matrix (Field, 2009). In this test, a level of significance that less than 0.05 indicates that the correlation matrix is not an identity matrix, thereby highlighting that the applicability of factor analysis (Pallant, 2013). In factor extraction, principal components analysis was adopted to transform the original sets of variables into smaller and conceptually more coherent sets of variables. The "principal components" refer to the linear combinations of these variables (Mooi et al., 2018). To easily interpret the results of factor extraction, the varimax method was employed to rotate the principal components matrix.

Factor analysis has been widely applied in the construction industry and green building domain (Mao et al., 2013; Chan et al., 2016). After listing the variables and items related to the SPD of green buildings, the importance of and difficulty to realize these items in practice was identified in a questionnaire survey. Afterwards, exploratory factor analysis was employed to investigate those critical factors in SPD of green buildings by identifying the common trends in the aforementioned items and establishing a relatively small number of factor groupings.

4.4.4 Content Analysis

Content analysis (or textual analysis) is "a research technique used to make replicable and valid inferences by interpreting and coding textual material" (Krippendorff, 1980). Duriau et al. (2007) claimed the importance of content analysis in reviewing the subtle differences amongst organizational behaviors, stakeholder perceptions, human resources and societal trends. Content analysis can also link purely quantitative research methods with purely qualitative ones in two ways. On the one hand, content analysis can analyze social cognition and perceptual structure, which are difficult to be examined by using the traditional quantitative archiving methods. On the other hand, content analysis allows researchers to collect large samples, which cannot be easily achieved by using purely qualitative research methods. Coding, which is a process of segmenting and labelling text to form descriptions and board themes in the data, can also be combined with content analysis to produce better results. Specifically, coding divides the text data into segments that are labelled with codes and then collapses these codes into broad themes.

In qualitative research, content analysis is performed by documenting the communication between the researcher and his/her subject. This communication is often documented in interview records, observation records, videotapes and written documents. The eight major steps of content analysis are summarized as follows (Miles et al., 2013):

- collecting and preparing data, defining the choice of “content” and transcribing all data;
- selecting the unit of analysis and classifying the themes based on the research objectives;
- developing a sub-classification and coding scheme for the analysis from the original data, related theories and empirical studies with similar topics;
- pre-testing the coding scheme for the qualitative data and coding a sample of existing data to ensure consistency;
- applying the coding process to all the text;
- testing the validity and reliability of the whole dataset;
- drawing inferences based on the codes and generated categories and exploring the relationships, dimensions and properties; and
- presenting the results under each theme and generating conclusions that can be easily understood by readers.

According to Zuo et al. (2014), content analysis is a typical method for summarizing emerging themes from the collected data, and in previous built environment studies it is commonly used. In the face-to-face interview, some of the interviews were recorded by record pen which permitted by the interviewees, so audio data were collected. However, some interviewees refused to have their interviews recorded on audio. In this case, the key words and sentences mentioned by these participants during the interviews were written down, and a timely recall was performed after the interview to generate written data. Coding was also conducted to analyze the textual data. NVivo is one of the most commonly used tools for coding and is specifically built for qualitative and mixed methods research (Bazeley and Jackson, 2013). NVivo 11 was employed in this research given its capability to import and analyze various sources of data including text, audio, video and images.

4.4.5 Document Analysis

Bowen (2009) defined document analysis as a type of qualitative research in which the researcher interprets documents to gather opinions and meanings about the topic being evaluated. As a manageable and practical resource, document analysis has often been employed to effectively collect data. Several types of documents can be used in systematic research, including organizational or institutional reports and files, programme proposals, application forms, summaries and radio and television programme scripts. According to Yin (2017), document analysis is an intensive method that enriches the descriptions of a phenomenon, event, organization or a programme and is particularly applicable to qualitative case studies.

Document analysis was adopted in this study to extract useful information about the SPD of the projects investigated in the three case studies and to facilitate the analysis. The documents to be analyzed mainly included the official records of these projects. Document analysis was also performed to investigate the variables and constraints in the SPD of these projects and to investigate the critical factors in the proposed framework.

4.5 SUMMARY

The research methodology is elaborated in this chapter, process and design. This study mainly relied on triangulation, i.e. quantitative and qualitative research methods. Specific data collection (i.e. literature reviews, questionnaire surveys, face-to-face interviews and case studies) and analysis methods (i.e. descriptive statistics, non-parametric test, exploratory factor analysis, content analysis and document analysis) were also described and selected to facilitate the fulfilment of the research aim and objectives.

CHAPTER 5 A THEORETICAL FRAMEWORK FOR SPD IN GREEN BUILDINGS

5.1 INTRODUCTION

This chapter elaborates the development of the theoretical framework, which provides a foundation to develop the framework for effective SPD in green residential buildings. Firstly, the process of developing the theoretical framework was presented. Secondly, the literature was reviewed to guide the development of the theoretical framework. Thirdly, the 13 variables that were abstracted from 5 major GBRTs were summarized and included in the theoretical framework. Lastly, a theoretical framework for SPD in green buildings was proposed and explained in detail.

5.2 DEVELOPMENT OF THE THEORETICAL FRAMEWORK

According to Abend (2008), "theory is formulated to explain, predict and understand phenomena and, in many cases, to challenge and expand existing knowledge within the limits of critical boundary assumptions". A theoretical framework means collecting interrelated concepts and theories that describe the causes of research problems.

A theoretical framework can strengthen the research study in the following ways:

- a theoretical framework links the researcher with the existing knowledge and provides a basis for the hypotheses development and for selecting appropriate research methods;
- clarifying the theoretical assumptions of the research forces the researchers to address why and how. It allows researchers to shift intellectually from simply describing a phenomenon that can be observed to including all aspects of the

phenomenon; and

- a theoretical framework specifies those key variables that affect the phenomenon of interest and emphasizes the need to examine how these key variables may differ and under what circumstances.

In order to develop a theoretical framework for SPD in green buildings, it is necessary to identify the variables involved in the SPD process beforehand. Five mainstream GBRTs, including BREEAM, LEED, BEAM Plus, GM and ASGB, were selected for this research study considering their popularity and influence degree. Among the selected GBRTs, BREEAM, LEED and GM are implemented in developed countries, ESGB/ASGB is designed for a developing country, and BEAM Plus is applied in a developed region. As the first established green building rating system, BREEAM was considered in this research study because it is now a leading and influential evaluation tool around the world. LEED, as the other widely used and influential third-party verified rating system especially in China, is of significance to be selected in this research. BEAM, which has been updated as BEAM Plus now, was implemented in very early years and relatively mature system in Hong Kong. GM is designed considering the typical climate and regions, i.e. the tropical climate and high-density regions, which providing a meaningful differentiation of buildings in the real estate market. Furthermore, China owns the largest construction market, as the research study is conducted in the context of China, it is important to involve ASGB, the most influential GBRT in China, in this study. These GBRTs were comprehensively evaluated to identify as many variables as possible. In the first round, a list of 15 variables was developed by looking through and summarizing the detailed SPD-related requirements in the selected GBRTs, including “land use”, “site assessment”, “passive building design”, “open space”, “neighborhood amenities”, “local transport”, “green vehicle parking”, “reduced parking footprint”, “ecological value and protection”, “cultural heritage”, “landscaping and irrigation”, “microclimate around buildings”, “neighborhood daylight access”, “storm water management” and “environmental management plan”. In the second round, a discussion with 3 experienced researchers in sustainable and green buildings including one professor (whose research interests include sustainable site planning and sustainable development), one associate professor (whose research interests include project management of green buildings), and one assistant professor (who studies on green building design and urban planning and development) was conducted to confirm whether these variables are significant from a theoretical perspective. The variables “neighborhood amenities” and “local transport” were eventually excluded from the research study because as the pre-existing conditions, they were already on or around the construction sites and preceded the implementation of SPD. “Neighborhood amenities”, which include the basic services and recreational facilities available in the neighborhood, encourage the development of buildings, whilst “local transport” discourages the use of private vehicles and taxis, encourages the development of a sustainable transport system and provides alternative transport modes. Nevertheless, these two variables are relevant to site location when included in BEAM Plus. Therefore, except for these two variables, a list of 13 variables was eventually obtained as shown in Table 5.1. The involvement of these variables and their effect on

SPD are discussed thoroughly in Section 5.3.

Table 5.1 Major variables in SPD of green residential buildings

NO.	Variable	Description	Source
1	Land use	Economic and intensive use of land, reasonable green space setting and rational utilization of underground space.	ASGB
2	Site assessment	Complete and document field investigation or assessment including information on topography, hydrology, climate, vegetation, soils, human use, and human health impacts.	BEAM Plus, ASGB
3	Open space	Provide open space for promoting residential recreation, forming attractive surroundings and facilitating sense of community.	LEED
4	Passive building design	Promote passive building design according to the local climate and reduce dependency on active maintenance to improve human comfort	BEAM Plus, LEED
5	Green vehicles parking	Reduce air pollution by promoting green vehicles and providing parking space and facilities for green vehicles	LEED
6	Landscaping and irrigation	Encourage landscaping irrigation with non-potable water, choose appropriate plants on site to mitigate ecological damage	BEAM Plus, GM, LEED, BREEAM
7	Storm water management	Encourage storm water runoff before discharge to public drains.	ASGB
8	Neighborhood daylight access	Ensure the daylight access of buildings and surrounding sensitive buildings to the required level.	BEAM Plus, ASGB
9	Cultural heritage	Encourage developers to protect sites or buildings of cultural heritage and ensure that the new development will not affect the	BEAM Plus, LEED

		surrounding cultural heritage negatively.	
10	Microclimate around buildings	Consider microclimate around the buildings including wind amplification, elevated temperatures and air ventilation assessment.	BEAM Plus, BREEAM
11	Reduced parking footprint	Reduce environmental harms by limited parking space	LEED, GM, BEAM Plus
12	Ecological value and protection	Locate on low ecological value land or implement appropriate design measures to promote the ecological value of the land, and protect the ecological features within the site boundary	BREEAM
13	Environmental management plan	Encourage an Environmental Management Plan to reduce noise, dust and air emissions, water pollution and ensure human health issues on site.	BEAM Plus, ASGB

5.3 MAJOR VARIABLES IN SPD OF GREEN RESIDENTIAL BUILDINGS

The following sections describe the 13 variables mentioned above in SPD of green buildings.

5.3.1 Land Use

5.3.1.1 Land and Land Use

Given its essential role in supporting human life, land is considered the most important natural resource and means for social production. Land use has become an important policy issue because of its effects on the interdependencies amongst individuals and communities and its major influence on economic development and social welfare (Bergstrom et al., 2013). The relationship between land use and sustainable development is also plagued by several issues such as natural resource availability, ecosystem and biodiversity conservation, and different climate systems (Häkkinen et al., 2013). Accordingly, ecological land use complementation has emerged as a useful urban planning method for conserving biodiversity in urban areas and for encouraging urban residents to involve themselves further in biodiversity management (Colding, 2007). Building a conservation-oriented society is the common interests of sustainable development around the world. An economical and intensive land use can effectively promote the harmonious development of human beings and nature. Therefore, economic land use (i.e. utilizing the least amount of land area possible) must be considered in the planning and design of building projects (Deng et al., 2006). To implement an economical and intensive land use system, Guangxing (2012) established a new mechanism that considered four aspects, namely, strengthening constraints, establishing incentives, improving the market and establishing common accountability. In recent decades, urban land use has been related to a huge increase in energy, water and fertiliser consumption, which in turn weaken the capacity of ecosystems in food production, freshwater and forest resource sustainment, climate and air quality regulation, and infectious diseases amelioration. Although current land use can increase the material goods supply in a short period, these practices may disrupt many long-term ecosystem services at the regional and global levels. To minimize such adverse effects, land management strategies considering environmental, social and economic benefits should be formulated. For instance, increasing the amount of green spaces in urban areas can reduce surface runoff and heat island effects (Foley et al., 2005).

5.3.1.2 Green Space

The land of green spaces is covered with grass, shrubs, trees or other vegetation partly or completely. When implementing environmental transition initiatives, the green spaces in cities should be maintained as much as possible and must be transformed into a landscape structure that can be effectively adapted and integrated into compact urban areas (Jim, 2004). Expanding urban green spaces may ease the adverse impacts of urbanisation in a sustainable way, enhance the attractiveness of cities to their citizens, reverse urban sprawl and reduce traffic demand (De Ridder et al., 2004). Green spaces are relatively cheap and widely used for leisure and recreation purposes and can positively affect the health and wellbeing of city residents (Schipperijn et al., 2010).

5.3.1.3 Underground Space

Underground spaces are situated below the ground level (i.e. natural elevation of the ground surface that may be artificially raised or lowered). The effective use of underground spaces promotes the development of highly compact communities without damaging the quality of the environment. Under sustainable development principle, underground construction can reduce environmental hazards, reduce energy consumption, and reduce local traffic needs (Rönkä et al., 1998). Underground spaces also allow the construction of facilities in locations with limited space or in communities that strongly oppose the construction of such facilities. Underground areas are also isolated from the effects of various climate and severe weather (Godard, 2004).

5.3.2 Site Assessment

In green SPD, designers must consider various climate and site-related factors (e.g. orientation, position and layout of buildings and topography of the construction site), take advantage of the natural conditions in and around the construction site and ensure the appropriate and rational usage of the topography, vegetation and natural water in the site.

Site assessment aims to evaluate the conditions of a site prior the commencement of building construction to guide the sustainable programmes development and decision making in relevant site design. This step plays a crucial role in SPD process, which evaluates the existing or potential sites related to project development and determines the limits and opportunities for the environment, programme and development. A well-executed site assessment also lays the foundation for the proposing a sustainable project development way which is cost-effective, environmentally friendly, and reasonable. Taking notes and recording information in a narrative or graphical format are necessary in guaranteeing an effective assessment. Reports needs also be submitted to describe in detail how the design team strives to integrate the project with its surroundings and to highlight its negative, neutral or positive impacts. Accordingly, the following key information must be included in site assessment documents:

- *Soil.* Information on soil and topography can help to identify those areas with a high erosion potential. Soil information can also be useful in selecting, sizing, designing and implementing storm water management measures.

- *Topography.* In site planning, design and site layout, it is crucial to be clear of the information on site topography. Topographic maps provide useful site-related information which can be used by site planners and designers in determining the site layout, including the drainage patterns, slope and length, and location of ecologically sensitive features.
- *Hydrology.* Hydrologic information is crucial in identifying, delineating and recording the depression areas (i.e. lakes, ponds and streams) on the project site, the available opportunities for collecting and reusing rainwater and a centralized flow area on or around the project site. Hydrologic information helps planners and designers create drainage patterns, assess the drainage features and devise storm water management measures for protecting ecologically sensitive areas.
- *Climate.* When constructing a green building, designers must consider the climate in the construction site because such factor can influence the building design. Designers must also formulate passive design strategies based on the climate in the site.
- *Vegetation.* Information on the amount of green spaces, the availability of unique habitats and the species, sizes and types of vegetation in the construction site must also be collected to help planners and designers understand the stability and vulnerability of the site.
- *Human use.* Facilitating human use is one of the most important purposes of SPD. When conducting survey works for a project, the status of the construction site and the extent to which it can satisfy human use must be evaluated. Several

elements, including landscape views, surrounding transportation infrastructures, adjacent properties, and high potential recycled or reused construction materials, must also be taken into account.

- *Human health effects.* The effects of the construction site on human health must also be determined. Related factors include the proximity of vulnerable populations to the construction site, the opportunities for physical activities within the vicinity and the proximity of the site to major sources of air pollution. Air pollution has acute and chronic adverse impacts on human health issues. Short- and long-term exposure to this type of pollution has also associated with premature death and shortened life expectancy (Kampa and Castanas, 2008).

5.3.3 Open Space

5.3.3.1 Open Space Definition

An open space refers to any piece of land which is accessible to the public with no buildings or other built structures on it. These open spaces, which include green spaces, schoolyards, playgrounds, public rest areas, plazas and vacant lots, encourage residents to interact with their environment or neighbours and engage in passive entertainment or physical activities. Maintaining a large open space can also help to promote biodiversity. To maximize the open space in a construction site and meet the open space requirements in local areas, the development footprint of construction projects must be reduced, and a vegetated open space should be developed within the construction site.

5.3.3.2 Open Space Benefits

Open spaces offer many benefits to citizens that can be summarized in four basic aspects, including recreational, ecological, aesthetic and social values.

- *Recreational value.* Open spaces provide recreational opportunities for citizens and residents, which is often appreciated. Recreation in urban space includes active recreation and passive recreation. Active recreations include organized sports and individual exercises. Passive recreations mean people may simply be exposed to open space.
- *Ecological value.* The natural protection and conservation of urban environments can directly influence people. Open spaces promote biodiversity and provide spaces for natural species in urban areas.
- *Aesthetic value.* Open spaces have obvious aesthetic values. Attractive neighborhoods are conductive to positive attitudes towards life and social norms. Proximity to recreational facilities increases the likelihood that people will convert walking intentions into practical actions.
- *Social value.* From the individual perspective, open spaces establish a direct relationship amongst space, personal health and human development. Meanwhile, from the community perspective, open spaces promote interactions amongst community members.

5.3.3.3 Open Space Strategy

Open space strategy is a useful approach for planning the current and future use of open spaces within a municipality. A comprehensive open space strategy also provides a foundation for the planning and implementation of these spaces (Design Council CABE team, UK, 2008). Developing such strategy requires designers to thoroughly review the effective management of existing open spaces, evaluate their assets and precast the future demands for additional open spaces actively. An open space strategy is important in the following aspects:

- outlines the existing open space resources and determines the future need for such spaces;
- provides a basis for making decisions regarding the provision and development of open spaces in the future;
- facilitates financial and resource planning and asset management;
- identifies those areas with an insufficient amount of open space and determines how to obtain or dispose land to be transformed into open spaces;
- facilitate the coordination in open space planning; and
- clarify the expectations of communities and local governments regarding the provision and development of open spaces.

An open space strategy is formulated in six steps, which are illustrated in Figure 5.1 and summarized as follows:

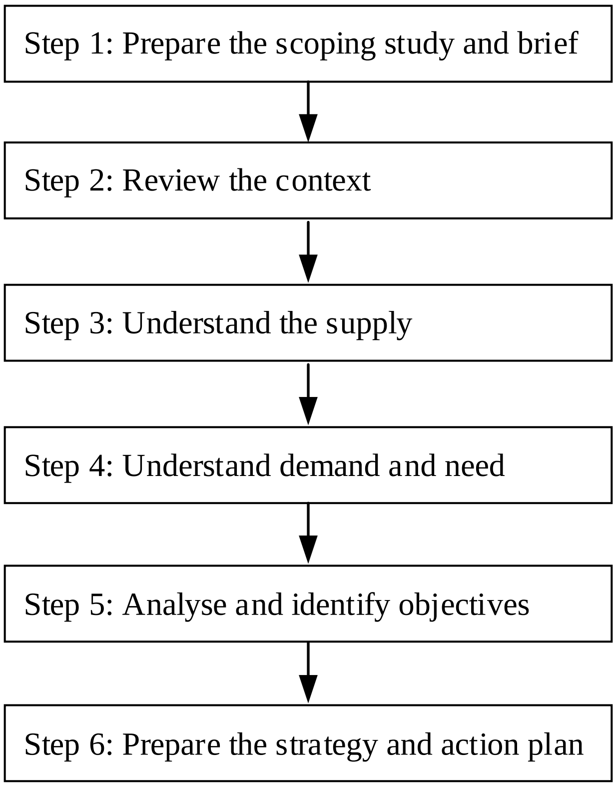

Figure 5.1 The process of preparing an open space strategy

(Source: Design Council CABE team, UK, 2008)

- formulate the aims of the open space strategy and to identify the key stakeholders, team members and manager of the project;
- summarize the open space context and identify its key characteristics after collecting all necessary data;
- evaluate the existing open spaces and construct a database that contains the key information of these spaces;
- define the current and future demand for open spaces through consultations;
- analyze the supply and demand of open spaces and outline the preliminary directions, future policies and key issues involved in the construction of these spaces; and

- prepare a draft open space strategy, an implementation plan and a final open space strategy that combines the results of the public consultations and the draft strategy.

According to Design Council CABE team, UK (2008), an open space strategy that is implemented at the site level must be related to both site and landscape management.

5.3.4 Passive Building Design

Su (2008) defined passive design as a unique method that take use of natural elements such as the sunlight to heat, cool or light a building. This approach is also the most cost-effective and widely used strategy for reducing the heat load in residential buildings. Utilizing passive solutions can eliminate or reduce the usage of mechanical systems, the consumption of energy and the emission of CO_2 into the atmosphere.

The construction of passive buildings requires careful planning and must be guided from five basic aspects, namely, orientation, insulation, overhangs and shadings, double or triple glazing and thermal mass. Passive design considers the building structure, the building orientation, the windows location of windows and installation of skylight, and insulation and building materials. Installing operable windows that can be manually opened or closed allows occupants to control the amount of air entering their rooms. Placing operable windows on opposite walls can also guide the flow of breeze into a building and promote a natural ventilation. Effective passive design strategies, such as solar heating, natural ventilation and evaporative cooling, have also been explored in previous research. A passive solar or thermal design utilizes solar energy to maximize heating or cooling. Passive-designed systems require minimal maintenance and greatly reduce the energy use of buildings by minimizing or eliminating the use of mechanical systems for regulating indoor temperature and lighting.

Passive design has several important components, which are summarized as follows:

- *Design for climate.* A good passive design ensures that the occupants get thermal comfort with minimal auxiliary heating or cooling. Designers from different regions must consider various design strategies to cope with local changes in the climate.
- *Orientation.* In passive buildings, the first consideration of orientation is in which hemisphere the building is located, as in the northern hemisphere the southern facade often faces the quarter, whilst in the southern hemisphere the northern facade normally faces the north. It is because to facilitate the building surface to obtain he maximum solar radiation in the longer dimension, the longer axis of the building should be in the east or west upward direction.
- *Overhangs and shading.* As an important part in passive building design, overhangs and shadings can reduce summer temperatures in buildings, improve the comfort of building occupants and conserve energy. Buildings with aptly sized overhangs or shading can also prevent overheating during the summer.
- *Solar heating and cooling.* Solar heating and cooling systems use the sun as an energy source. As a renewable resource, solar energy can provide families with

enough power to meet their daily energy requirements. Solar energy is collected by using solar collectors that convert sunlight into usable energy.

- *Insulation.* By acting as a barrier to heat flow, insulation keeps a building warm during the winter and cool during the summer. Insulation products have been categorized into bulk and reflective insulation products, which are sometimes combined to form composite materials. Bulk insulation is good for keeping heat inside the building, whilst reflective insulation is good for keeping heat outside the building.
- *Lighting and daylighting design.* Using daylight in buildings is a key strategy in passive design that can improve the visual and thermal comfort of the building occupants. The efficient use and control of daylight and artificial lights can also reduce the energy demands of occupants and enhance their productivity.

5.3.5 Green Vehicles Parking

5.3.5.1 Green Vehicles

A green vehicle is a road motor vehicle that produces minimal impacts on the environment by using alternative fuels. Therefore, promoting the use of green vehicles over conventional fuel automobiles can help to reduce environmental pollution.

To promote green vehicle use, studies and innovations on road transportation should address the following challenges:

- efficient utilization of energy;

- utilization of non-conventional energy sources, such as electricity, renewable energy and tailored fuels; and
- utilization of advanced power-train technologies, new vehicle architectures and interfaces between the vehicle and the charging infrastructure.

Electric vehicle charging

A certain percentage of the parking spaces on the construction site should be dedicated to the installation of charging stations for plug-in electric vehicles.

Liquid, gas or battery facilities

Facilities that can refill multiple green vehicles simultaneously such as liquid or gas fuel refuelling facilities or charging stations should also be installed within the construction site.

5.3.5.2 Benefits of Green Vehicle Use

Environmental benefits

Vehicle emissions can increase the concentration of pollutants in the atmosphere and subsequently lead to climate change. These gases mainly include carbon dioxide, methane and nitrous oxide. The transportation sector is also amongst the fastest-growing sources of greenhouse gases. Using green vehicles can increase the application of clean energy and subsequently reduce greenhouse gas emissions.

Health benefits

Vehicle pollutants can negatively affect human health, such as by increasing their exposure to respiratory and cardiopulmonary diseases and lung cancer. Therefore, by limiting the amount of pollution, green vehicles can greatly benefit human health.

Monetary benefits

Hybrid and plug-in electric vehicles have lower fuel costs compared with conventional vehicles. Although green vehicles may be significantly more expensive than conventional vehicles, their prices tend to decrease along with their increasing production volume. Moreover, the initial costs of these vehicles can be offset by the related fuel cost savings, federal tax credits and government incentives.

5.3.6 Landscaping and Irrigation

5.3.6.1 Landscaping

Landscaping is the activity of changing the visible characteristics of land in a region as well as the following main elements:

- living elements, such as animals and plants;
- natural elements, such as terrains, topographies, elevations and waterbodies; and
- abstract elements, such as weather and lighting conditions.

5.3.6.2 Landscape Irrigation

Landscape irrigation is a watering system for creating and maintaining lawns, gardens and artificial landscapes. The main function of a landscape irrigation system is to ensure that water can be evenly distributed in any landscape.

When choosing an irrigation system, several factors must be considered, including the size of lawns or gardens, geographical location, underground facilities and environmental regulations of the area. The types of vegetation (e.g. flowers, trees, vegetables and grass) in the area must also be taken into account. An irrigation system can be classified into drip irrigation systems, mobile systems, overhead systems and underground lawn irrigation systems.

- Drip irrigation systems are often used in flower and vegetable gardens and are often regarded as more cost effective and environmentally friendly than sprinkler systems, which tend to use more than twice the amount of water to maintain the landscape.
- Mobile systems are generally preferred for irrigating lawns and flower and vegetable gardens. These systems use standard garden hoses and sprinklers and consume much time as they need to be regularly moved and rebuilt.
- Overhead systems are ideal for irrigating flower and vegetable gardens yet are unsuitable for irrigating lawns. These systems are placed on a timber with tubes and pipes installed overhead. As one of its most important benefits, this system does not affect the appearance of the landscape.
- Underground lawn irrigation systems are very popular landscape irrigation systems that comprise pop-up sprinkler heads and automatic timers and are highly suitable for irrigating big/small lawns and flower and vegetable gardens. These systems can

positively influence the environment by applying minor adjustments. For instance, applying water near the roots of plants can reduce the amount of unnecessary water evaporation.

Some rainwater or recycled water-based systems can also be used to irrigate the landscape. Those drought-tolerant plants can also be planted on the construction site to reduce drinking water consumption. In addition, the following elements should also be taken into account:

- using rainwater and other non-potable water for landscape irrigation;
- using rain sensors and automatic water-saving irrigation systems; and
- planting drought-tolerant plants that can reduce the amount of irrigation.

5.3.7 Storm Water Management

5.3.7.1 Storm Water

Storm water is produced during precipitation events and during the melting of snow and ice. Storm water can seep through soil, be absorbed and evaporated on the surface or flow into nearby streams, rivers or other waterbodies. The water balance or natural hydrology in forest areas can only be changed through the growth of plants and the infiltration, evaporation and transpiration of rainfall. Meanwhile, the natural hydrology in urban areas has been gradely modified after their land has been cleared of vegetation and covered by hard or impervious surfaces. The changes in the water balance and flow timing in urban areas, such as sudden increases in their water volume and velocity, can also influence the nearby bays and waterways. The other potential impacts of these changes include

- changing the structure and suitability of aquatic habitats;
- disturbing the animals and plants in waterways and affecting animal breeding habits;
- eroding stream banks;
- increasing water turbidity and pollution and subsequently reducing water quality; and
- increasing litter and oil volumes.

These changes have reduced the usage of waterways and have significantly threatened the animals living in these waterbodies. When planning a new development, infrastructure and development control strategies should be formulated in advance to manage storm water and prevent flooding.

5.3.7.2 Storm Water Management

The goal of storm water management is to manage surface runoff which plays a key role in preventing the farmland loss and flooding in inhabited urban or rural areas. Several approaches can be applied to manage storm water, including detaining, retaining or providing reusable rainwater discharge points and facilitating the infiltration of rainwater to groundwater levels. Within the capacity of existing infrastructure, it should be best to preserve or simulate natural hydrologic cycle in storm water management. Storm water is generally stored in the following facilities:

- *Detention ponds.* Detention ponds are usually dry except in rainy seasons or during the melting of snow. These ponds have a decelerated water flow and provide a temporary storage for managing the quality and quantity of storm water.
- *Retention ponds.* Retention ponds or wet ponds are primarily designed to improve the quality of water from storm water flows.
- *Onsite storm water detention.* Onsite storm water detention is a temporary water storage facility that is formed by creating a depression in a paved or landscaped area, an underground tank or a combination of both.
- *Rainwater harvesting.* Rainwater harvesting has been increasingly employed in urban areas because of its benefits in the conservation of potable water and the reduction of storm water runoff.
- *Green roofs.* Green roofs are also known as living roofs or roof gardens, contain a thin layer of vegetation and growth medium and are installed on traditional flat or sloping roofs.
- *Constructed wetlands.* Constructed wetlands use natural processes, such as wetland vegetation, soils and related microbial combinations, to improve water quality.

Storm water is infiltrated by using the following facilities:

- *Infiltration trenches.* Infiltration trenches are especially designed for managing storm water quality. Rainwater falls on impervious surfaces and accumulates contaminants as it flows down the surface.

- *Grass filter stripes.* Grass filter stripes, also known as filter stripes or grassed filters, are strategically planted between fields and surface waters, such as rivers, streams, lakes and gutters, to preserve water quality.
- *Grassed swales.* Grassed swales are stable and open grassed channels that decelerate and partially infiltrate storm water runoff to improve water quality.
- *Pervious pavements.* Pervious pavements are permeable surfaces with a stone reservoir built underneath that allows rainwater and snowmelt to seep through the surface and into the ground.
- *Infiltration basins.* Infiltration basins or infiltration ponds are storm water management systems that use highly permeable soils to temporarily store storm water runoff.

5.3.8 Neighborhood Daylight Access

5.3.8.1 Light-Sensitive Buildings

The construction of tall buildings greatly influences the neighbouring developments and amenities as well as the direct and indirect exposure of the surrounding buildings to sunlight. Meanwhile, the architectural appearance and layout of adjacent buildings can influence the surrounding views and the development of natural ventilation corridors. When developing new buildings, if sensitive buildings are involved in the surrounding areas where daylight is considered a valuable resource, the impact of the new building construction on the existing or planned adjacent sensitive buildings should be assessed. Sensitive buildings may refer to

1) Residential buildings;
2) Non-residential buildings premise that require daylight to

- create a well-lighted environment that is facilitating to work or study in (e.g. schools and offices);
- conserve energy and create a good environment for transient occupancy (e.g. circulation areas in shopping malls and rooms for indoor gaming); and
- meet the daily needs for neighborhood view (e.g. hotels and hospitals).

5.3.8.2 Daylight Access

Human beings are naturally drawn by windows and natural light. Such attraction has been ascribed to several reasons. For instance, by looking outside their windows, people can instantly obtain information about the time and weather. Daylight can also strongly affect the mood and energy level of people by influencing their chronobiologic system, which mainly drives their sleep and wake cycles.

Natural light brings the following psychological benefits to building occupants:

- access to daylight increases their comfort levels and reduces stress;
- these people often prefer to work near windows;
- natural light provides them with stimulation during daytime; and

- using natural light reduces energy consumption and costs.

5.3.8.3 Neighborhood Daylight Access

The light inside buildings generally come from the sun and from the light reflected in the spaces between and around buildings. A neighborhood of light configures the urban fabric by responding to the climates and provide daylight access for all buildings and the spaces between them. In green SPD, the extent to which the construction of a building will affect the daylight access of sensitive neighbouring buildings should be comprehensively analyzed. The changes in the daylight access of a building can be objectively assessed based on the changes of the vertical sunlight coefficient of sensitive receivers or based on the changes in their viewing angles, whichever is more appropriate.

As cities continue to grow at an unprecedented rate, the density of residential buildings must be expanded to meet the requirements of the increasing residents. Meanwhile, to build and maintain their competence, cities also should ensure that the quality of the built environment should be kept even the building density is increasing. To achieve sustainable development, buildings should be designed whilst the availability of daylight in the neighborhood should be taken into consideration. The access of building occupants to daylight, air and views should also be maintained.

5.3.9 Cultural Heritage

5.3.9.1 Definition of Cultural Heritage

Cultural heritage is a lifestyle developed by a community, which is handed down from one generation to another. Such heritage may include customs, places, objects, artistic expressions and values that provide tangible and intangible manifestations of the value systems, beliefs, traditions and lifestyles for certain groups of people. As an important cultural facet, cultural heritage can also be used as a visible and tangible element that links history with the present day.

Types of cultural heritage

Cultural heritage is an extensive concept that can refer to the following:

- built environments, urban landscapes and archaeological remains;
- natural environments, rural landscapes, coasts and coastlines and agricultural heritage; and
- relics, books and documents, articles and pictures.

Cultural heritage protection

Cultural heritage allows one to understand and explain the social and cultural changes and to form his/her understanding of the past. Developers around the world have gradually acknowledged the relationship between culture and development. Cultural heritage was formerly regarded only as a source of income but is currently recognized as a dynamic and transformative force. In urban development, the ability of cultural heritage to creatively integrate old and new developments enhances the aesthetic value of cities, preserves their historical integrity and allows their early development patterns to be experienced and appreciated by future generations. According to Williams (2001), "preservation of cultural heritage resources is essential to sustainable development. It recognizes the importance of cultural continuity and of human history in nourishing social cohesion, a sense of self, of belonging, and of place in a context within which to understand the past and to contemplate the future". To protect and preserve the local and regional cultural heritage on or within the construction sites, such as the archaeological and historic buildings, and monuments located near these areas must be conserved and protected. The available cultural heritage resources must also be protected by providing local residents with incentives and encouraging them to engage in community development.

5.3.9.2 Site of Cultural Heritage

According to the Environmental Impact Assessment Ordinance in Hong Kong, the definition of "site of cultural heritage" refers to monuments or historic places, buildings, sites, structures or relics. In other words, any place, building, site, structure or relic of paleontological significance as determined by the Antiquities and Monuments Office can be defined as site of cultural heritage.

Sites of cultural heritage generally include archaeological sites and buildings, historical buildings, ancient biological sites, and other cultural heritage characteristics such as ancient street furniture, lime kilns, graves and runways.

To maintain cultural sustainability, during SPD and the project implementation, rigorous measures should be conducted to ensure that the cultural heritage characteristics at and around the construction sites are properly preserved and protected.

5.3.10 Microclimate around Buildings

5.3.10.1 Microclimate

Rosenberg et al. (1983) defined microclimate as the climate near the ground where plants and animals live. The atmospheric conditions in these areas generally differ from those in surrounding areas; in other words, microclimate is specific to small areas, such as gardens, parks or valleys. In a microclimate, the weather variables such as temperature, rainfall, wind, or humidity may be slightly different from the overwhelming conditions in this area and the conditions that may be reasonably expected under certain atmospheric pressure or cloud cover types. Many slightly different local microclimate blends also constitute the entire microclimate of a town or a city.

5.3.10.2 Microclimate around Buildings

The microclimate around buildings includes the usual and often-entered areas, such as entrances and exits, walking routes, open spaces, streets, podium gardens, sidewalks, rest areas and recreation and play areas. When designing the microclimate conditions on the construction site, features such as wind, sunshine, temperature and air quality should all be considered and balanced.

Pedestrian-level wind

The microclimates around buildings may be have limited natural ventilation, which can lead to stagnation and an increase in temperature. Meanwhile, the topography around buildings can amplify the pedestrian-level wind and consequently bring discomfort and fatigue to pedestrians, damage the nearby vegetation and accumulate debris. Therefore, the comfort levels of pedestrians near buildings must be assessed early in SPD of green residential buildings by reviewing the wind climate, topography of the construction site and the mass and orientation of the surrounding buildings. In addition, the architectural feature of podiums can be involved in the building design in order to reduce the impact of wind on the ground.

Mitigation of elevated temperatures

The microclimates near waterbodies may slightly reduce the temperature in these areas, whilst the brick, concrete and asphalt in urban areas all absorb solar energy, thereby increasing the temperature, radiating heat to ambient air and generating an urban heat island effect. Using non-reflective external surfaces can also increase the localised temperature along with the level of solar heat and then radiate this heat back to the surrounding environment. However, the impact of such increase in temperature may be limited to pedestrian and recreation areas. The temperatures in local surroundings may also be slightly higher than those in open and highly ventilated areas. The resulting urban heat island then brings discomfort to the residents and adversely affects the surrounding vegetation and wildlife.

To relieve the elevated temperatures of exposed public areas, some strategies and design solutions must be proposed during the design, construction and remodelling of new buildings. These strategies may include providing shade in impervious walkways or parking spaces, building cool roofs by using highly reflective materials and installing green roofs that are covered with vegetation (Gagliano et al., 2015; Wang et al., 2016).

- Cool roofs. Dark coloured roofs can absorb a large amount of solar energy and subsequently increase the costs, carbon footprint and amount of energy consumed by buildings for cooling purposes. Meanwhile, installing a light coloured, high albedo roof can effectively reflect away energy and heat.
- Green roofs. Roofs absorb heat from the sun and become very hot especially during summer, thereby increasing the amount of energy consumed for cooling the building. Given the natural cooling ability of plants, installing a vegetated green roof can balance the temperature on the surface of the roof and consequently reduce the temperature inside the building.
- Green walls. Green walls refer to self-sufficient vertical gardens that are installed on buildings. A living wall system can provide buildings—especially those without room for large shadowing trees or traditional gardens—protection from the sun, thereby keeping their temperature at moderate levels.

- Cool pavements. Appropriate materials and construction techniques must be employed to reduce the solar heat absorption and emission of concrete pavements. Light coloured and relatively porous paving materials must be used near residential buildings to promote cooling and to enhance the comfort levels of nearby residents.
- Trees. The shade provided by trees not only protects homes and other structures from excessive solar heat but also effectively reduces their energy consumption and utility costs. Planting trees strategically to shade buildings and outdoor areas can also offer homes to wild animals and enhance the value and beauty of the surrounding buildings.
- Shading. Providing shade in outdoor living areas can maintain their temperature and make them attractive destinations during summer. The shading of concrete patios and walkways can reduce the amount of reflected solar heat and provide a comfortable living environment.

Natural air ventilation

Natural air ventilation, which refers to the potential airflow within buildings, is a popular green strategy for building designers and owners because of its ability to improve indoor air environment and reduce the related investment and operating costs. The potential airflow greatly depends on the topography of the construction site, the ground roughness, and the characteristics of nearby buildings. Some quantitative methods are employed for the numerical calculation and physical modelling of natural air ventilation.

- Natural air ventilation potential. The pressure field around buildings, which depends on the prevailing wind conditions, must be analyzed to evaluate the natural air ventilation potential of buildings.
- Optimizing indoor thermal comfort. The natural air ventilation on the construction site provides building designers with valuable references that can help them plan architectural forms and orientations, windows, openings and other aperture shapes and locations.
- Solar radiation fluxes on the walls of buildings. Assessing the solar gain on the glass surfaces, façades, roofs or envelopes of buildings provides designers with necessary input data to ensure a low energy consumption and passive building heat balance in ecological areas.

5.3.11 Reduced Parking Footprint

5.3.11.1 Minimizing Site Development Footprint

Minimizing the development footprint on construction sites is helpful in preserving or restoring the existing natural areas. Using site master plans to guide current and future developments also ensures that open spaces can be designated and protected as large, contiguous areas that provide a habitat for wildlife and maintain a stable ecological process (Hopper, 2012).

Site development footprint can be minimized in many ways, some of which include

- developing on sites which have already been developed before such as brownfields;

- developing clustered or multi-buildings that can simultaneously maximize the open spaces and minimize the structural footprints;
- considering the topography of the construction area during the implementation of the project can minimize soil grading and topsoil removal and retaining structures; and
- minimizing site disturbance by clustering underground utilities and grouping them with roads.

Reducing the area of impervious surfaces within the construction site can directly reduce the volume of storm water runoff and associated pollutants. Several approaches may be adopted to achieve this objective, such as reducing the length and width of roads, applying clustering methods to reduce building footprint, reducing the amount of mandated parking spaces, and reducing setbacks and frontages.

5.3.11.2 Reduced Parking Footprint

Reduced parking footprint means reducing the total area of paved roads and allowing rainwater and snowmelt to pass through the landscape to surface waters and filter to groundwater aquifers naturally. Reducing parking footprint can also minimize the environmental hazards associated with parking facilities, such as motor vehicle dependency, land consumption and storm water runoff. Reduced parking footprint is an effective technique for ensuring the long-term protection and reducing the cost of drinking water.

5.3.11.3 Ways to Reduce Parking Footprint

In practice, parking footprint can be reduced by limiting the land area dedicated to surface parking. An efficient parking eliminates the underutilized portions of parking pavements, which often use both sides of turning lanes as parking bays. Some parts of parking spaces can also be designated for compact cars and can be reduced in size. Parking spaces can be shared between the occupants in buildings and the non-residential users who have different parking time. To minimize the parking surface area as much as possible, multilevel parking decks can be installed wherever feasible. Limiting the paved areas can also reduce runoff, construction cost and land consumption. Parking footprint can also be reduced in several other ways, such as

- establishing regulations for the development of shared parking for adjacent uses at different times of the day; and
- encouraging shared footprint or multi-level parking design during the site planning.

“Unbundled parking”, which separates the parking costs from the leases or purchase price of apartments, can also effectively reduce parking footprint. In this way, there are several choices for the building occupants:

- sell or lease parking spaces separately;
- provide discounts to those residents who do not use their allocated parking spaces; and
- sign lease agreements with those residents who share or negotiate parking fees with

other building tenants.

These efforts to reduce parking footprint are commercially viable if the land prices are high or if the development density and other transportation modes (e.g. walking, cycling and taking public transport) do not affect the choices of occupants.

5.3.12 Ecological Value Protection

5.3.12.1 Ecological Value of Construction Sites

Green buildings are encouraged to be developed on land with limited value to wildlife in order to avoid physical damage to the existing ecological features during the implementation of a project. A land can be regarded as a low ecological value one when the following conditions are met:

- The construction site is located far away from well-defined geographical spaces and is managed through legal or other effective ways to conserve its natural environment and associated ecosystem services in the long term.
- No habitats with ecological value, such as woodlands, wetlands, grasslands, dwarf shrub habitats and arid and semi-arid deserts, are located on or within 100 m of the construction site.
- No mature or semi-mature vegetation are planted on the boundary of the construction site or in nearby occupied or derelict buildings that may provide shelter for wildlife.

5.3.12.2 Enhancing Site Ecology

Biodiversity enhancement is an expected consequence of green SPD. Several measures can be used to enhance biodiversity, and each of these measures greatly depend on the scale, location, characteristics, local biodiversity priorities and relationship of the construction site with the adjacent habitats. These measures include

- providing bats and birds with a habitat in new buildings;
- incorporating green roofs and green walls into the building development planning;
- adopting native species and integrating ecological measures into the landscape and green space of the construction site;
- planting trees in hard landscapes;
- incorporating hedgerows, meadows and wetlands into the creation and restoration of habitats;
- incorporating wetlands, such as ponds, ditches and reed beds, into sustainable drainage schemes; and
- incorporating appropriate vegetation into the boundary treatment.

5.3.12.3 Biodiversity Conservation

Habitat protection is an effective way for minimizing the impact of a new building project on the natural environment. On construction sites, green buildings encourage the preservation of native species habitats in order to maintain or increase the local diversity. Green SPD tries to minimize the long-term impact of construction projects on the biodiversity of their surrounding environments. Willis and Birks (2006) argued that paleo ecological records can provide planners with a long-term perspective when addressing biodiversity conservation issues relating to biological invasion, wildfire, climate change and natural variability. Chatterjee (2009) emphasized the need to adopt and appreciate building ecology. To train young engineers and professionals in "building ecology", five types of knowledge need to be considered, namely, interdependency knowledge, preservation and efficiency knowledge, surviving designs knowledge, natural systems knowledge and knowledge of change. In proactive SPD practices, biodiversity conservation is included as an essential programme objective (Connery, 2009).

5.3.13 Environmental Management Plan

5.3.13.1 Environmental Management Plan on the Construction Site

The construction and demolition of buildings not only significantly affect the surrounding environment such as ecology, air, noise and water quality, but also generate waste within and outside construction sites. Recruiting contractors with a fair level of environmental awareness and the ability to implement good environmental practices on construction sites can significantly contribute to the reduction of environmental pollution and waste. The construction projects are completed mainly on construction sites. When these sites are poorly managed, they may become a source of environmental nuisances and pollution that not only affect the on-site staff but also the neighbouring residents and the public. Therefore, contractors should implement appropriate strategies on these sites to minimize the adverse impacts of the construction activities and the demolitions on the surrounding environment. An effective environmental management plan aims to minimize adverse impacts on or within the construction sites such as the noise, air and water pollution generated by building projects, thereby improving the personal health on or within the construction site.

5.3.13.2 Controlling Environmental Nuisances on Construction Sites

The following environmental nuisances are often observed on construction sites:

- *Noise.* Noise on construction sites refers to the loud noise generated by using powered mechanical equipment, the installation or removal of formwork or scaffolding, the handling of rubble and the rebar handling and hammering operations. To reduce these disturbances, contractors should be engaged in proper planning, implementing noise abatement measures, improving their operation and maintenance procedures, performing their noise-generating activities within a specified schedule and teaching their colleagues to be noise conscientious.
- *Air.* The air pollution on construction sites includes the black smoke or fumes emitted by construction equipment, the dust generated by demolition activities, vehicle operations, handling of materials and usage of conveyor systems and concrete ingredients or the various particles emitted from the burning of construction wastes. To address these nuisances, building designers contractors should engage in proper planning, cover their dust-generating equipment, use

hard paving and spray their main transportation roads with water, control their usage of vehicles on the construction site and install their concrete batching tools in appropriate locations.

- *Water.* Water nuisance on construction sites includes the blockage of sewers or drains by silt, cement, mortar or concrete, waste water discharge, flooding, and health problems due to wastewater accumulation. Such nuisances can be addressed by engaging in proper planning, conducting site maintenance and conserving or reusing water.
- *Health.* Health nuisance on sites includes the breeding of mosquitoes or flies, infestation of rodents and accumulation of debris. To address these problems, contractors should plan properly to store and dispose their food and water and carefully manage their construction waste.

5.4 A THEORETICAL FRAMEWORK FOR SPD IN GREEN BUILDINGS

SPD is a key issue in the development of a sustainable building construction site. Site planners and designers are required to engage in SPD to minimize the disturbances generated by the construction processes. Two versions of the theoretical framework for the SPD of green buildings are shown in Figures 5.2 and 5.3.

As shown in Figure 5.2, the 13 variables for the SPD of green buildings are categorized into four groups, namely, major issues, efficient resource use, surrounding conditions and natural environment.

Land use is one of the most important matter in SPD as it involves the interdependencies amongst individuals and communities which significantly affect economic and social wellbeing. A reasonable land use presents a useful approach in urban planning given its ability to promote biodiversity and enhance the available services in an ecosystem.

Site assessment evaluates the conditions of the construction site prior to the designing of buildings in order to develop sustainable programme and to help designers make informed decisions related to site design. Taking full advantage of the site conditions and characteristics (e.g. soil, topography, hydrology, climate, vegetation and structural factors) can also provide an important basis for establishing a sustainable way for the project development which is cost-effective, environmentally friendly, and reasonable.

To implement an environmental management plan is helpful in minimizing the noise pollution, air pollution, water consumption and waste generated by construction projects and subsequently improve the health of people on or within construction sites.

When designing the construction site and building layout, the conditions of the surrounding areas should be considered, including the neighborhood daylight access, cultural heritage and microclimate around buildings. The effective utilization of resources must also be considered along with the usage of other sustainable tools, such as open spaces, passive building designs, green vehicles, landscaping and irrigation and storm water management. Some design principles, including reducing parking footprint and protecting ecological value, can also be utilized in the SPD process.

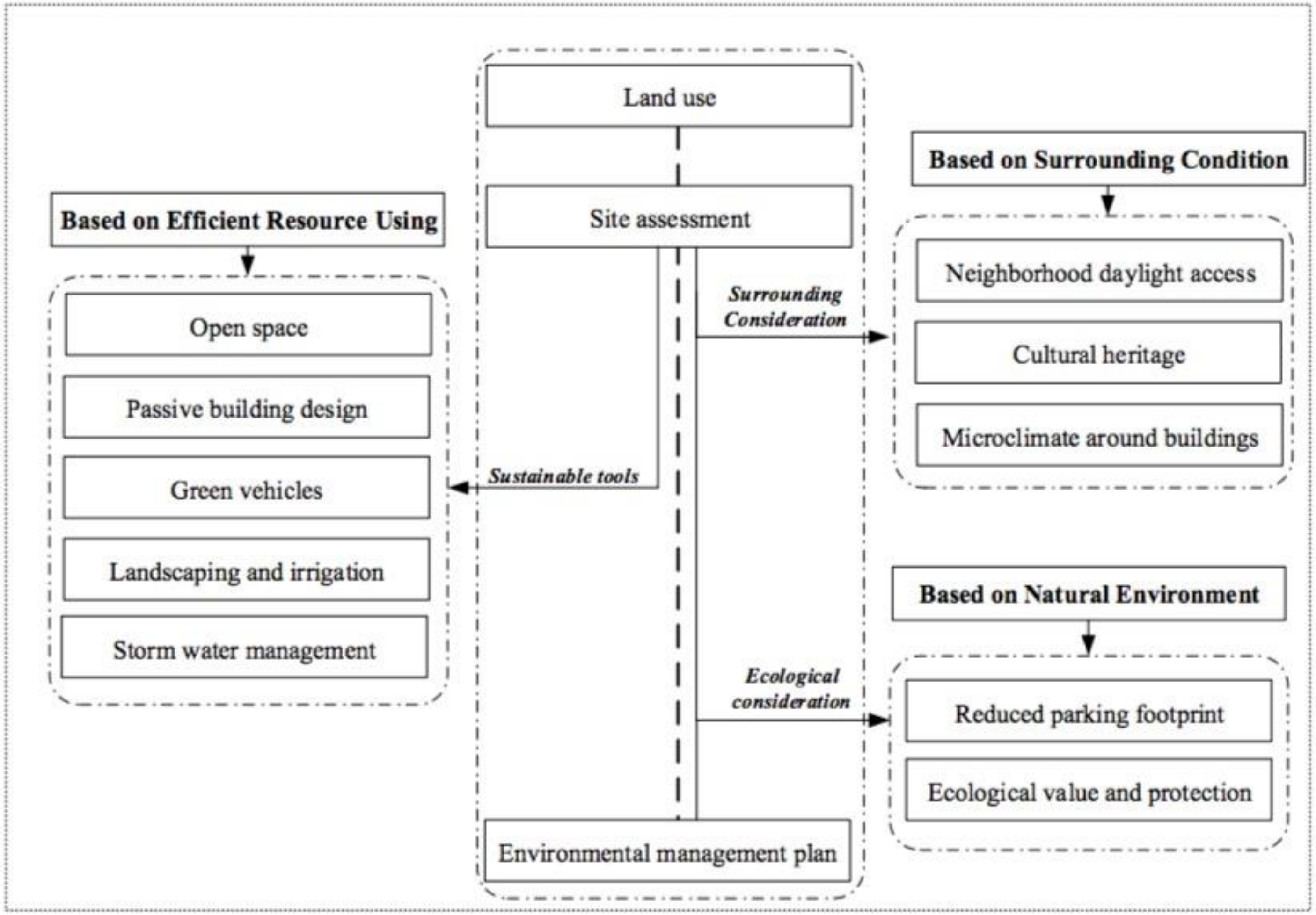

Figure 5.2 A theoretical framework for SPD in green buildings (Preliminary version)

The SPD process of green buildings was considered whilst revising the theoretical framework. Based on the SPD process proposed by LaGro (2011) (Figure 3.1), the SPD process of green buildings (Figure 5.3) contains the site planning, site design, green evaluation, and construction documentation stages. In the site planning stage, the briefing/programming and site selection is the first step, then the construction site must be evaluated to provide designers with valuable references that can inform their decisions related to site design. In the site design stage, conceptual and detailed designs that focus on the key elements and spatial organization of construction sites are formulated under the guidance of sustainable principles. In the green evaluation stage, the SPD plan is evaluated based on its economic feasibility, the local policies in the construction site, and the development level of local green buildings. At the construction documentation stage, the site design is transferred into a technical language which is convenient for contractors to implement the project.

The SPD variables were regrouped into three categories based on three sustainable principles, namely, efficient resource use, surrounding conditions, and natural environment. The sustainable resources use can improve resource use efficiency and reduce the consumption of energy and other resources. Six variables were classified under this principle, including land use, passive building design, green vehicle parking, reduced parking footprint, landscaping and irrigation and storm water management. As for the other variables, open space and neighborhood daylight access were classified under the principle of surrounding conditions, whilst microclimate around buildings, cultural heritage, ecological value protection and environmental management plan were classified under the natural environment principle.

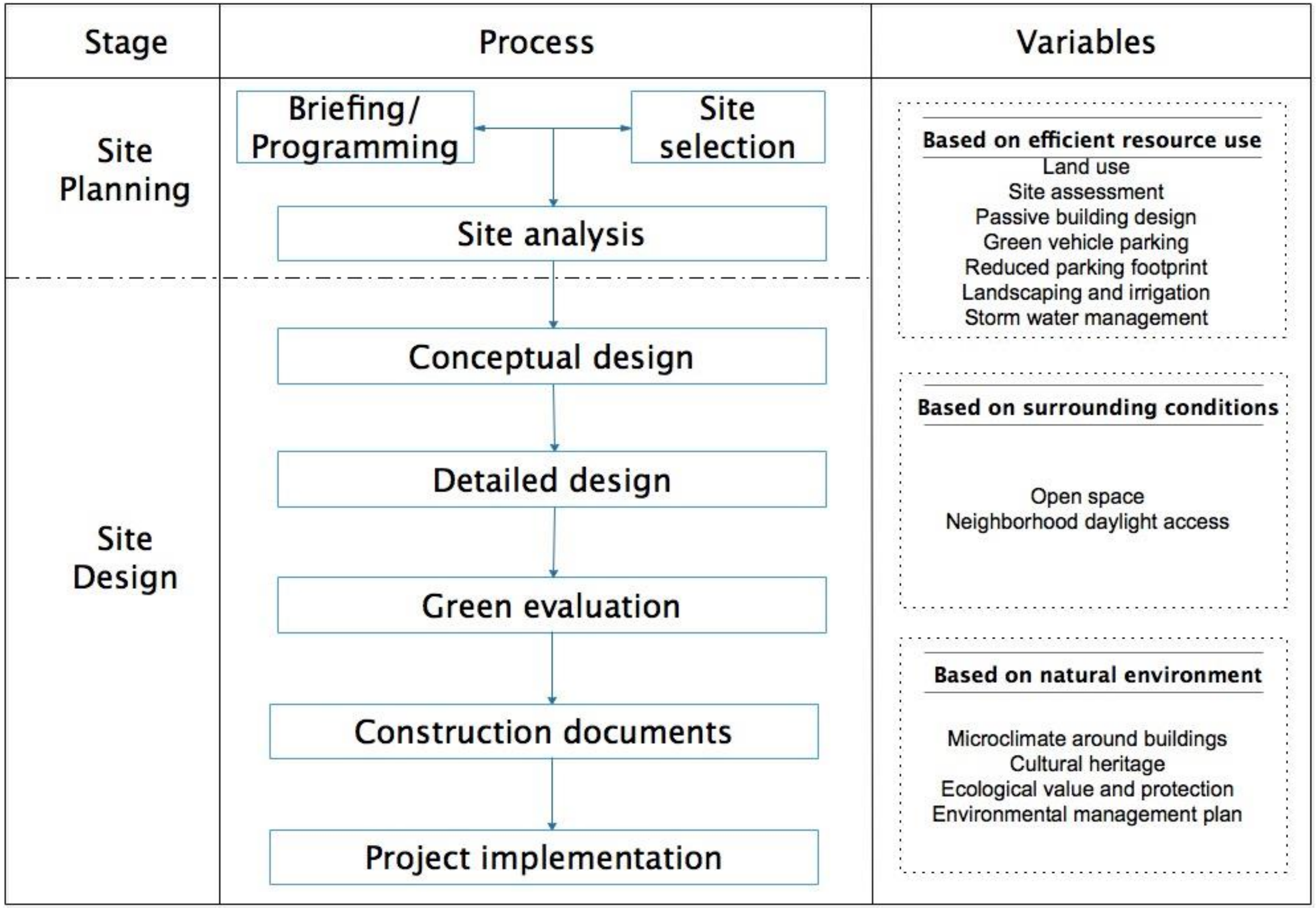

Figure 5.3 A theoretical framework for SPD in green buildings (Revised version)

5.5 SUMMARY

This chapter described the development of a theoretical framework for SPD in green buildings. Firstly, the definition and application of the theoretical framework were described before outlining the steps in developing the framework. Secondly, 13 variables that influence the SPD of green buildings were summarized. These variables include “land use”, “site assessment”, “passive building design”, “open space”, “green vehicle parking”, “reduced parking footprint”, “ecological value and protection”, “cultural heritage”, “landscaping and irrigation”, “microclimate around buildings”, “neighborhood daylight access”, “storm water management” and “environmental management plan”. The proposed theoretical framework can lay a foundation for the development of a framework for effective SPD in green residential buildings.

CHAPTER 6 A PRELIMINARY FRAMEWORK FOR SPD OF GREEN BUILDINGS

6.1 INTRODUCTION

This chapter establishes a preliminary framework for effective SPD in green residential buildings. By adopting a questionnaire survey, the perceptions of green construction industry practitioners are investigated towards the importance of and difficulty to realize SPD items in green residential buildings. The survey results are analyzed afterwards, the perceptions of respondents in Hong Kong and Mainland China are compared and exploratory factor analysis is conducted to identify critical factors of SPD in green residential buildings. To ensure an effective SPD in green buildings, several other components are identified by conducting face-to-face interviews with green building practitioners. A preliminary framework for effective SPD in green residential buildings is eventually established.

6.2 CONCEPTUAL FRAMEWORK

In order to conduct effective SPD in green residential buildings, the variables, the process, stakeholders, sustainable principles, and effective planning and design approaches in SPD are important concerns. Sev (2009) suggested a framework for stakeholders in the construction industry which includes principles, strategies and methods. Figure 6.1 shows the conceptual framework for effective SPD in green residential buildings.

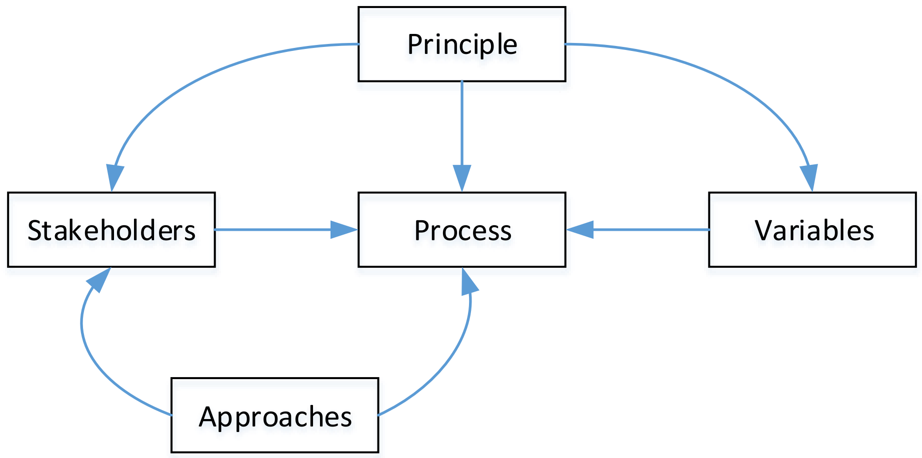

Figure 6.1 A conceptual framework for effective SPD in green residential buildings

6.3 QUESTIONNAIRE SURVEY

According to the 13 variables involved in the theoretical framework, relevant items within these variables are identified based on looking through the detailed requirements and descriptions about site aspect in the five selected GBRTs and reviewing relevant site aspect requirements in previous literatures, which was listed in Table 6.1, i.e. 13 variables and corresponding 38 items.

Table 6.1 Variables and items in SPD of green residential buildings

(Source: Huo et al., 2018)

Variable	Item in SPD	Source
V1.Land Use	IT1. Economical and intensive land use should be the first and foremost concern in SPD of green buildings	ASGB, Häkkinen et al. (2013)
	IT2. The construction project should be recommended to be developed on brownfield	ASGB, BEAM Plus, LEED, Loures and Vaz (2016)
	IT3. Sufficient green space should be considered in SPD of green buildings	ASGB, Schipperijn et al. (2010)
	IT4. Rational underground space utilization should be involved in SPD of green buildings	ASGB, Rönkä et al. (1998)
V2.Site Assessment	IT5. SPD in green buildings should be designed according to the natural conditions on site	ASGB, LEED
	IT6. Culturally and architecturally significant features should be incorporated in SPD	BEAM Plus
	IT7. Air ventilation issues at the site level should be considered properly	ASGB, BEAM Plus, Kampa and Castanas (2008)
V3.Open Space	IT8. Sufficient open space should be designed for attractive surroundings	LEED, Hughey et al. (2016)
	IT9. A comprehensive open-space strategy should be formed to lay a foundation for open-space planning and action	LEED, Design Council CABE team, UK (2008)
V4.Passive Building Design	IT10. Passive building design should be used in accordance with the natural elements in SPD of green buildings	BEAM Plus
	IT11. Summer temperatures should be reduced by providing overhangs and shadings	BEAM Plus, Chen et al. (2015)
	IT12. Solar heating and cooling systems should be designed to reduce energy use	GM
	IT13. Bulk insulation and reflective insulation should be used to improve living comfort	BEAM Plus, LEED, Chen et al. (2015)
V5.Green-Vehicle Parking	IT14. A certain percentage of parking spaces for green vehicles should be provided	LEED
	IT15. Electric vehicle charging or fueling facilities for green vehicles should be designed in SPD of green buildings	LEED
V6.Landscaping and Irrigation	IT16. Non-potable water should be used for landscape irrigation	GM
	IT17. Pre-existing materials should be used for hard-landscaped areas	BEAM Plus, LEED, GM, BREEAM

	IT18. Appropriate plantings should be provided on construction site	BEAM Plus, GM
V7.Storm Water Management	IT19. Proper storm water management measures should be taken to manage surface runoff	ASGB
	IT20. Storm water storage devices should be installed rationally	ASGB
	IT21. Storm water infiltration devices should be installed rationally	ASGB
V8.Neighborhood Daylight Access	IT22. Reasonable building density and layout should be ensured on construction sites	ASGB
	IT23. Access to daylight for neighboring sensitive buildings should be maintained	BEAM Plus
	IT24. Daylight and light trespass requirements should be met	BEAM Plus, LEED, Chen et al. (2015)
V9.Cultural Heritage	IT25. Proper measures should be taken to protect and preserve cultural heritage on site	BEAM Plus, Williams (2001)
	IT26. New buildings should be compatible with the heritage features	LEED, BEAM Plus
V10.Microclimate around Buildings	IT27. Wind velocities in pedestrian areas should be reduced to ensure pedestrian comfort	BEAM Plus
	IT28. Proper measures should be taken to mitigate elevated temperatures	BEAM Plus
	IT29. Natural ventilation should be encouraged for higher indoor air quality	BREEAM
V11.Reduced Parking Footprint	IT30. The amount of land area dedicated to surface parking should be limited	BEAM Plus
	IT31. Covered or sheltered parking spaces should be designed to reduce parking footprint	LEED, BEAM Plus
V12.Ecological Value and Protection	IT32. Developing green buildings on land of low ecological value should be encouraged	BREEAM
	IT33. Appropriate design measures should be implemented contributing to the ecological value	BREEAM, Connery (2009)
V13.Environmental Management Plan	IT34. An environmental management document should be implemented on site	BEAM Plus
	IT35. Adequate mitigation measures for construction noise should be provided on site	BEAM Plus, ASGB
	IT36. Adequate mitigation measures for dust and air emissions should be applied on site	BEAM Plus, ASGB
	IT37. Adequate measures to reduce water pollution should be undertaken on site	BEAM Plus, ASGB
	IT38. Adequate measures for human health issues should be implemented on site	BEAM Plus

6.3.1 Questionnaire Design

To identify factors affecting SPD of green buildings, a questionnaire survey was designed and conducted in Mainland China and in Hong Kong respectively. Through the questionnaire survey, the importance of and difficulty to realize the SPD related items in green buildings rated by the construction professionals can be measured, the critical factors were then identified by statistical analysis.

The questionnaire contains three sections. Firstly, the background information of the research study was briefly introduced, and the respondents were confirmed that the collected information would be only for academic use and the data were collected anonymously. In the main body of the questionnaire, Section A collects the background information of the respondents, including the organization type, working experience, working type, number of projects participated in, staff number in current project. Section B is about the investigation of the importance of the variables and items in practice. The perception of practitioners on the 38 SPD related items in green buildings was measured using a Likert scale. The importance of variables was measured by a scale of 1-5, in which 1= extremely unimportant, 2 = unimportant, 3 = neutral, 4 = important and 5 = extremely important. Similarly, the difficulty to realize the variables was measured as 1 = extremely easy, 2 = easy, 3 = neutral, 4 = difficult and 5 = extremely difficult. In addition, the respondents were asked that whether there were other issues that should be considered during SPD in green buildings based on their understanding. Finally, a closure statement was presented, which not only informed the respondents that the questionnaire survey is completed, but also showed the gratitude of the investigators to the respondents.

6.3.2 Questionnaire Distribution and Collection

A pilot study is needed before distributing the formal questionnaire to test whether the questionnaire was feasible, clear, and easy to understand. Six participants who have experience in green building development were involved, including two professors, one associate professor, two assistant professors, and a postgraduate researcher (Huo et al., 2018). The finalized questionnaire is presented in Appendix A.

The questionnaire survey was conducted in both Mainland China and in Hong Kong. In Mainland China, practitioners who have participated in green building projects and had management positions were selected as potential respondents considering their working experience and knowledge in green building development. The name list of the potential respondents was provided by green building projects, or from the professional chat groups in which there are practitioners that work in construction industry in various regions in China. The questionnaire was conducted based on a software called *Sojump* and the link of the questionnaire was sent to the potential participants. The potential participants were contacted in advance to make sure that they would like to be involved in the survey. If possible, they were also invited to send the questionnaire to the one they know who works in green building area. After one month, 188 valid responses were collected from various regions in Mainland China such as Chongqing, Beijing, Shanghai, Sichuan, Guangdong, Jiangsu, etc. As the strategy of “snowball sample” was applied in questionnaire distribution, the exact response rate was difficult to be calculated.

To get a comprehensive understanding of SPD in green buildings in the context of China, the questionnaire was also distributed in Hong Kong, as the green building development status in Hong Kong and in Mainland China has some differences. Firstly, the questionnaire was emailed to 221 practitioners experienced in green building development. The list of initially identified practitioners was drawn randomly from the Building Department, the Housing Department, and the Hong Kong Green Building Council (HKGBC). This included qualified architects, surveyors, landscape architects, and clerk of works. After a 2-week waiting period, a reminder letter was sent to the practitioners who had not responded. And after a period of two months, only 24 valid responses were received from the 221 questionnaires distributed, which is reasonable considering practitioners in the construction industry of Hong Kong may be reluctant to participate in questionnaire surveys due to their busy schedules. In order to increase the response in Hong Kong, the questionnaire was sent to other 153 potential respondents by post who were randomly picked up from the Hong Kong Institute of Architects Directory and the Builders Directory in Hong Kong. By using random sampling, each sample has the same probability to be selected, which provides an unbiased representation of the total population. All the potential respondents were guaranteed that the collected questionnaire would be anonymous and confidential, and the collected information would only be used for academic use. After one month, 46 valid responses were received. The total amount of the valid responses was 70, and the response rate in Hong Kong was around 19%.

Considering the regions of the total 258 respondents in the context of China, around 70% of them were from Mainland China, and the remaining 30% were from Hong Kong. Major background information of the respondents is stated in Table 6.2. For the organization type, respondents from the design institute/architecture firm accounted for around one third of the total sample, which was followed by those from construction organization and real estate development organization. Regarding the working experience in green building area, around 40% of the respondents had 2 to 5 years' working experience, and 22% of them had worked in the green building area for 6 to 10 years. When it related to their working type, a multiple-choice option was provided, as the respondents may have different working experience and the multiple choices give them the flexibility to make proper choices. It can be seen that most of the respondents were working relating project management, green design, and construction management. The number of projects the respondents have participated in is at least one, and more than half of the respondents participated in 1 to 5 green projects, as the duration of construction project is relatively long, if the respondents fully participate in a green project, the total number of green projects they could have participated in was limited. When it concerns about the staff number in these current project, more than half of the projects had less than 50 staff on site.

Table 6.2 Background information of the respondents in the questionnaire survey

Category	**Respondents**	
	Number	**Percentage**
Organization type		
Government sector	27	10%
Real estate development organization	46	18%
Design institute/ Architecture firm	71	28%
Construction organization	56	22%
Supervision company	6	2%
Green consultation company	42	16%
Others	10	4%
Total	**258**	**100%**
Working experience		
1 to 2 years	40	16%
2 to 5 years	107	41%
6-10 years	56	22%
11-15 years	28	11%
More than 15 years	27	10%
Total	**258**	**100%**
Working type (multiple choice)		
Planning approval	23	N/A
Project management	96	N/A
Green design	64	N/A
Construction management	68	N/A
Surveying management	15	N/A
Green consultation	31	N/A
Others	33	N/A
Total		**N/A**
Number of green projects participated in		
1-5	149	58%
6-10	49	19%
11-20	21	8%

More than 20	39	15%
Total	**258**	**100%**
Staff number		
Less than 50	149	58%
51-100	44	17%
101-200	29	11%
More than 200	36	14%
Total	**258**	**100%**

6.3.3 Data Analysis

In order to analyze the collected data from the questionnaire survey, the Statistical Package for Social Science (SPSS 22.0) was applied.

6.3.3.1 Statistical analysis

The Cronbach's alpha coefficient for the 38 SPD items was 0.950, which is much higher than the acceptable threshold of 0.70, indicating high data reliability (Fellows and Liu, 2015). The significance of the items in the questionnaire was tested by t test. The null hypothesis (H_0) of $\mu \leq \mu_0$ was tested against the alternative hypothesis (H_1) of $\mu > \mu_0$, where μ denotes the mean value of the respondents and μ_0 denotes a threshold rating that, when exceeded, indicates that the item is significant. Similar to the questionnaire survey, the value of μ_0 is set to 3 and those items with ratings of above 3 are regarded by the respondents as "important" and "extremely important". The null hypothesis (H_0) is rejected when the observed t value exceeds the critical t value ($t_c = t_{(n-1,\alpha)}$, where n-1 denotes the degree of freedom and α denotes the 5% significance level). The results of the item analysis are presented in Table 6.3. The second column of the table shows the t test value, the third column indicates that the t test has 257 degrees of freedom and the fourth column presents the two-tailed significance value. By going through the critical t value table, with 257 degrees of freedom and $\alpha=0.05$, the one-tail critical t value is 1.645, which means that the null hypothesis is rejected for those items in which absolute t value is larger than the critical t value. All 38 SPD items have passed the t test and are considered significant. Therefore, the effectiveness of these items is tested afterwards.

Table 6.3 t-test results of the importance of SPD items in green residential buildings

Item	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
IT1	13.903	257	.000	.8992	.772	1.027
IT2	6.262	257	.000	.3837	.263	.504
IT3	20.536	257	.000	1.1202	1.013	1.228
IT4	13.233	257	.000	.8295	.706	.953
IT5	15.079	257	.000	.8876	.772	1.004
IT6	7.867	257	.000	.5116	.384	.640
IT7	14.359	257	.000	.8643	.746	.983
IT8	14.770	257	.000	.8256	.716	.936
IT9	13.615	257	.000	.7752	.663	.887
IT10	11.963	257	.000	.7016	.586	.817
IT11	10.111	257	.000	.6550	.527	.783
IT12	11.937	257	.000	.7674	.641	.894
IT13	13.551	257	.000	.8217	.702	.941
IT14	6.653	257	.000	.4302	.303	.558
IT15	8.021	257	.000	.5620	.424	.700
IT16	13.734	257	.000	.8837	.757	1.010
IT17	11.042	257	.000	.6357	.522	.749
IT18	11.039	257	.000	.7132	.586	.840
IT19	16.787	257	.000	.9380	.828	1.048
IT20	14.156	257	.000	.8605	.741	.980
IT21	14.885	257	.000	.8333	.723	.944
IT22	17.878	257	.000	1.0155	.904	1.127
IT23	14.976	257	.000	.8915	.774	1.009
IT24	17.047	257	.000	.9535	.843	1.064
IT25	11.990	257	.000	.8023	.671	.934
IT26	11.440	257	.000	.6589	.545	.772
IT27	5.211	257	.000	.3372	.210	.465
IT28	11.838	257	.000	.7209	.601	.841
IT29	17.823	257	.000	1.0194	.907	1.132
IT30	8.133	257	.000	.5039	.382	.626
IT31	4.812	257	.000	.3217	.190	.453
IT32	12.829	257	.000	.7442	.630	.858
IT33	17.336	257	.000	.9729	.862	1.083
IT34	16.155	257	.000	.9457	.830	1.061
IT35	19.913	257	.000	1.0930	.985	1.201

IT36	20.271	257	.000	1.1473	1.036	1.259
IT37	21.555	257	.000	1.2093	1.099	1.320
IT38	19.646	257	.000	1.1667	1.050	1.284

6.3.3.2 Mean Value Analysis

The mean values and importance/difficulty rankings of the SPD items in green residential buildings are listed in Table 6.4. The perceptions of the respondents towards the importance and difficulty of these items were summarized, and the top five important and difficult items identified by respondents from different backgrounds were compared.

Table 6.4 Mean values and rankings of the importance of and difficulty to realize the SPD items in green residential buildings

Items	Importance		Difficulty	
	Mean	Rank	Mean	Rank
IT1	3.90	12	3.42	5
IT2	3.38	36	3.30	14
IT3	4.12	4	3.11	25
IT4	3.83	18	3.59	1
IT5	3.89	13	2.91	31
IT6	3.51	33	3.16	24
IT7	3.86	16	3.24	20
IT8	3.83	18*	3.41	6
IT9	3.78	23	3.45	4
IT10	3.70	28	3.32	11
IT11	3.66	29	2.81	36
IT12	3.77	24	3.20	23
IT13	3.82	21	3.28	16
IT14	3.43	35	2.83	34
IT15	3.56	32	2.92	30
IT16	3.88	15	2.72	37
IT17	3.64	31	2.90	33
IT18	3.71	27	2.60	38
IT19	3.94	11	2.91	31*
IT20	3.86	16*	3.06	29
IT21	3.83	18*	3.07	27
IT22	4.02	6*	3.24	20*
IT23	3.89	13*	3.35	9
IT24	3.95	9	3.26	17*
IT25	3.80	22	3.41	6*
IT26	3.66	29*	3.47	3
IT27	3.34	37	3.31	12
IT28	3.72	26	3.36	8
IT29	4.02	6	3.29	15
IT30	3.50	34	3.07	27*
IT31	3.32	38	2.83	34*
IT32	3.74	25	3.25	19
IT33	3.97	8	3.57	2
IT34	3.95	9*	3.09	26
IT35	4.09	5	3.26	17
IT36	4.15	3	3.31	12*
IT37	4.21	1	3.24	20*

IT38	4.17	2	3.33	10

Note: * means an equal rank, the next rank is skipped.

Top five important items in SPD of green residential buildings

“IT37 Adequate measures to reduce water pollution should be undertaken on site” was ranked in the first place concerning the importance scores. As the urbanization expanded rapidly, the water resources and urban waterlog related problems was gradually increasing. Especially in the construction industry of urban areas, the application of impermeable materials accounts for a large proportion, rainwater pollution is a serious problem in water damage. Dietz (2007) stated that instead of traditional storm water management, LID is an alternative in which the sites are preserved in an undisturbed condition as many as possible. Based on the LID concept, the idea of sponge city was conducted in China from 2014 to absorb, storage, infiltrate and purify the rainwater in urban areas (Shao et al., 2016).

The second place was achieved by “IT38 Adequate measures for human health issues should be implemented on site”. The health of on-site workers will be affected by the construction activities directly or indirectly. As green buildings are people-centred, human health issues are considered importantly. On the one hand, by reducing the exposure to toxic substances such as safe material provision, minimization of long-term release of volatile products, and proper material store, the human health risks on the construction site can be minimized (Cole, 2000). On the other hand, it is necessary to conduct stricter work condition control and health management for construction workers, like strict working hours monitoring, and drinking water monitoring during working time (Morioka et al. 2006).

“IT36 Adequate mitigation measures for dust and air emissions should be applied on site” was regarded as the third most important item in this survey. Shen and Tam (2002) stated that the construction activities involve physical facilities construction, which results in air pollution, water pollution, traffic emission and the generation of construction waste. The environmental quality on site and the health of construction workers can be seriously affected by the dust and air emissions during construction process. In order to reduce environmental pollution and improve environmental quality, one important issue is to enhance indoor and outdoor air quality. At the project level, investigating the construction dust sources is essential in mitigating dust generation (Wu et al., 2016b). In addition, selecting less volatile materials is also effective in controlling air pollution on site when formulating construction management plan for improving indoor and outdoor air quality.

The fourth important concern was “IT3 Sufficient green space should be considered in SPD of green buildings”. Schipperijn et al. (2010) stated that green space is a relatively cheap and much used cultural and leisure space, which has a positive impact on the health and wellbeing of the occupants and residents. By providing urban green space, it is beneficial to local climate improvement, biodiversity protection, water conservation, and citizen welfare and recreation as the provision of ecosystem services (Lafortezza and Chen, 2016; Mattijssen et al. 2017). Meanwhile, the urban thermal environment has closed relationship with green space, and improving urban green space planning can control the deteriorating trend of thermal environment timely (Yang et al., 2017). De Ridder et al (2004) also claimed that if the green spaces in cities have been enhanced, there is a potential that the adverse effects of urbanization can be mitigated in a sustainable way, which makes the cities more attractive to live in, reverses urban sprawl, and reduces transport needs at the same time.

“IT35 Adequate mitigation measures for construction noise should be provided on site” took the fifth place. One of the inherent social and environmental factors in construction activities is the noise pollution caused by construction activities. To mitigate construction noise on site, there are several effective solutions such as arranging construction working time reasonably, implementing closed construction, using isolated protective equipment, and using low-noise and low-vibration construction machinery. Moreover, Hammad et al. (2015) claimed that the sound level received by the receivers near the construction site is greatly affected by the site layout plan, which is an essential part when conducting SPD in green buildings.

Top five difficult items in SPD of green residential buildings

“IT4 Rational underground space utilization should be involved in SPD of green buildings” ranked the first place that the respondents regarded it as the most difficult item to realize in SPD of green buildings. As underground space management is an issue that involving several departments, such as land resource department, urban planning department, and construction department, one difficult concern in this process is multi-sectoral management. The underground space use lacks the unified coordination and the specific development and the planning organization, the related domain legislation is also not perfect. There are often conflicts between underground space development, groundwater and geothermal energy development (Li et al., 2016). Additionally, as the increasing number of high-rise buildings with pile foundation, new obstacles for underground space use have been caused and the developing cost are increasing.

The respondents regarded “IT33 Appropriate design measures should be implemented contributing to the ecological value” as the second difficult item to realize in SPD of green buildings. As stated by Connery (2009), the protection and conservation of biodiversity on site is an important concern in SPD practices, in green building development the indigenous species habitat provision and conservation on site is encouraged. To enhance site ecology, green walls and green roofs can be applied, along with the native species encouragement and habitat links and corridors provision. However, as the limited environmental protection awareness of the public, the construction practitioners remain in the stage that merely avoid damaging the environment, and they have not sought ways to enhance the ecological value and to develop a harmonious relationship between buildings and the environment.

The third difficult item concerned cultural heritage, i.e., “IT26 New buildings should be compatible with the heritage features”. In traditional Chinese buildings, such as Taiwanese traditional architecture, cave dwellings, and stilted buildings, green buildings should be realized combining with regional natural conditions, and “greenness” should be realized in a way with lower cost and easier technologies. However, the significance of traditional cultural heritage in urban areas is not fully awarded, conversely, it seems that Western trends are more attractive in the development of green buildings. Green buildings that respect and integrate regional cultural features should be encouraged in future urban planning.

“IT9 A comprehensive open-space strategy should be formed to lay a foundation for open-space planning and action” was considered as the fourth place. Closed communities are commonly used in the context of China, which led to excessive road spacing and reduced road density. Therefore, the development of an open space strategy is of significance as it considers the management of current open space effectively, which also provides an opportunity to consider the existing assets and actively forecast future needs for additional open space. While at present in China, the open space development in urban areas still needs to be improved, and a mature open space strategic theoretical system has yet to be formed. Normally open spaces are either used either overload or fall into disuse, and there is lack of planning and design from the perspective of the public.

The respondents regarded “IT1 Economical and intensive land use should be the first and foremost concern in SPD of green buildings” as the fifth difficult consideration. In urban area, the expanded development of a city leads to longer commute time, higher dependence degree on motor vehicles, which results in traffic congestion and air pollution. Therefore, it is essential to apply economic and intensive land use in order to protect the ecosystems, biodiversity and climates (Häkkinen et al., 2013). In the current rapid urbanization process in China, the hasty development in compact built-up areas have led to unreasonable building densities. In urban areas, a large amount of land is either excessively developed or inefficiently used. The potential for more economical and intensive land use is therefore great.

6.3.3.3 Comparisons of Respondents from Different Backgrounds

Kendall's Coefficient of Concordance (Kendall's W)

As a non-parametric technique, Kendall's coefficient of concordance (Kendall's W) can be applied to test the agreement among sets of rankings (Field, 2009). As the respondents came from different organizations in construction industry, Kendall's W was applicable to test whether different respondents in different groups agreed with the rankings of importance of and difficulty to realize the SPD items in green residential buildings. The value range of W is 0 to 1, which indicates ranging from no agreement to complete agreement. The null hypothesis (H_0) is "there is no agreement among the rankings of the SPD items given by the respondents". The null hypothesis (H_0) will be rejected if the significance level is below the significance threshold, i.e. $p \leqslant 0.001$, which indicates that the respondents have a certain degree of consistency in the rankings of SPD items. As shown in Table 6.5 and Table 6.6, the value of the Kendall's W test in the importance of SPD items is 0.074, and the chi-square value is 706.347 at df=37, with the significance level of 0.000; the value of the Kendall's W test in the difficulty of SPD items is 0.071, and the chi-square value is 673.994 at df=37, with the significance level of 0.000. The conclusion of the respondents has agreement on the SPD items rankings can be drawn.

Table 6.5 Kendall's W test results of the importance of SPD items

N	258
Kendall's W[a]	.074
Chi-Square	706.347
df	37
Asymp. Sig.	.000
a. Kendall's Coefficient of Concordance	

Table 6.6 Kendall's W test results of the difficulty of SPD items

N	258
Kendall's W[a]	.071
Chi-Square	673.994
df	37
Asymp. Sig.	.000
a. Kendall's Coefficient of Concordance	

Top five most important items ranked by respondents from various backgrounds

The top five most important items as identified by the respondents with different working organizations, working experience (years), number of participated green projects, and number of project staff members were compared in this section.

The views of respondents from real estate development organizations, design institutes/architecture firms and construction companies were compared in this research whilst those of respondents from other groups were ignored given their relatively small sample size. The respondents from real estate development organizations ranked sufficient green space consideration (IT3, rank 1), water pollution reduction (IT37, rank

1), human health issues protection (IT38), rational underground space utilization (IT4) and construction noise mitigation (IT35) as the five most important items, which indicated that these respondents were mostly concerned about the reduction of environmental footprint on construction sites and the efficient utilization of spaces. Those respondents from design institutes or architecture firms regarded dust and air emission mitigation (IT36), water pollution reduction (IT37), human health issues protection (IT38), construction noise mitigation (IT35) and reasonable building density and layout (IT22) as the most important items, which indicated that they were mostly concerned about reducing the environmental footprint on construction sites. Similarly, the respondents from construction companies regarded water pollution reduction (IT37), human health issues protection (IT38), dust and air emission mitigation (IT36), sufficient green space consideration (IT3) and construction noise mitigation (IT35) as the most important items.

The views of respondents with different years of work experience were then compared. Those respondents with no more than two years' working experience regarded water pollution reduction (IT37), construction noise mitigation (IT35, rank 2), dust and air emission mitigation (IT36, rank 2), human health issues protection (IT38, rank 2) and storm water storage devices provision (IT20) as the most important items, which indicated that these respondents were mostly concerned about reducing environmental footprint and collecting storm water. Those respondents with two to five years of work experience regarded water pollution reduction (IT37), human health issues protection (IT38), dust and air emission mitigation (IT36), sufficient green space consideration

(IT3) and construction noise mitigation (IT35) as the most important items, which reflected their major concerns on reducing environmental disturbances and allocating green spaces on construction sites. Those respondents with 6 to 10 years of experience ranked sufficient green space consideration (IT3, rank 1), reasonable building density and layout (IT22, rank 1), human health issues protection (IT38), water pollution reduction (IT37) and natural ventilation (IT29) as the most important items, which indicated that these respondents were mostly concerned about intensive land use and planning and reducing environmental disturbances.

The views of those respondents who have participated in different numbers of green projects were then compared. Those respondents who participated in less than five projects regarded water pollution reduction (IT37), human health issues protection (IT38, rank 2), dust and air emission mitigation (IT36, rank 2), sufficient green space consideration (IT3, rank 3) and construction noise mitigation (IT35, rank 3) as the most important items, which reflected their major concerns on reducing environmental disturbances and considering green spaces. Those respondents who participated in 6 to 10 projects ranked human health issues protection (IT38), economical and intensive land use (IT1, rank 2), sufficient green space consideration (IT3, rank 2), dust and air emission mitigation (IT36, rank 2) and proper storm water management measures (IT19) as the most important items, whilst those who participated in 11 to 20 projects ranked sufficient green space consideration (IT3), human health issues protection (IT38), dust and air emission mitigation (IT36, rank 3), water pollution reduction (IT37, rank 3) and open space strategy (IT9) as the most important. These rankings indicated that these two groups were mostly concerned about reducing environmental disturbances and planning open spaces.

The views of respondents from construction projects with different numbers of staff members were then compared. Those respondents who were involved in a green project with less than 50 staff members ranked water pollution reduction (IT37, rank 1), dust and air emission mitigation (IT36, rank 2), human health issues protection (IT38, rank 3), construction noise mitigation (IT35, rank 4) and sufficient green space consideration (IT3, rank 5) as the five most important items, those who were involved in a project with 51 to 100 staff members identified construction noise mitigation (IT35, rank 1), water pollution reduction (IT37, rank 2), human health issues protection (IT38, rank 3), dust and air emission mitigation (IT36, rank 4) and sufficient green space consideration (IT3, rank 5) as the most important and those who were involved in a project with more than 200 staff members ranked sufficient green space considerations (IT3, rank 1), human health issues protection (IT38, rank 1), wind environment issues consideration (IT7, rank 3), dust and air emission mitigation (IT36, rank 3) and comprehensive open space strategy (IT9, rank 5) as the most important items.

Top five most difficult items as ranked by respondents from different backgrounds

The top five most difficult items as ranked by the aforementioned respondents were also compared.

The respondents from design institutes/architecture firms regarded economical and intensive land use (IT1, rank1), rational underground space utilization (IT4, rank 1), neighborhood sensitive buildings daylight access maintenance (IT23, rank 3), daylight trespass requirements (IT24, rank 3), elevated temperature reduction (IT28, rank 5) and ecological value-added design (IT33, rank 5) as the most difficult items, those from construction companies regarded comprehensive open space strategy (IT9, rank1), ecological value-added design (IT33, rank 2), rational underground space utilization (IT4, rank 3), cultural heritage protection and preservation (IT25, rank 3) and sufficient open space design (IT8, rank 5) as the most difficult items and those from real estate development organizations considered ecological value-added design (IT33, rank 1), rational underground space utilization (IT4, rank 2), comprehensive open space strategy (IT9, rank 2), compatibility with surrounding cultural heritage (IT26, rank 4) and human health issues protection (IT38, rank 5) as the most difficult items to realize.

In terms of experience, those respondents with working experiences of less than 2 years regarded rational underground space utilization (IT4, rank 1), elevated temperature reduction (IT28, rank 2), water pollution reduction (IT37, rank 3), human health issues protection (IT38, rank 4) and cultural heritage protection and preservation (IT25, rank 5) as the most difficult items, those with two to five years of work experience regarded ecological value-added design (IT33, rank 1), rational underground space utilization (IT4, rank 2), comprehensive open space strategy (IT9, rank 3), sufficient open space design (IT8, rank 4) and compatibility with surrounding cultural heritage (IT26, rank 5) as the most difficult items and those with 6 to 10 years of work experience considered ecological value-added design (IT33, rank 1), rational underground space utilization

(IT4, rank 2), compatibility with surrounding cultural heritage (IT26, rank 3), development on brownfield (IT2, rank 4) and cultural heritage protection and preservation (IT25, rank 5) as the five most difficult items to realize.

In terms of number of green projects, those respondents who have participated in less than five green projects ranked ecological value-added design (IT33, rank 1), rational underground space utilization (IT4, rank 2), open space strategy (IT9, rank 3), compatibility with surrounding cultural heritage (IT26, rank 4) and cultural heritage protection and preservation (IT25, rank 5) as the most difficult items, those who participated in 6 to 10 green projects regarded rational underground space utilization (IT4, rank 1), sufficient open space design (IT8, rank 2), economical and intensive land use (IT1, rank 3), water pollution reduction (IT37, rank 4) and wind environment issues consideration (IT7, rank 5) as the most difficult items and those who participated in more than 20 green projects considered economical and intensive land use (IT1, rank 1), compatibility with surrounding cultural heritage (IT26, rank 1), natural ventilation encouragement (IT29, rank 1), ecological value-added design (IT33, rank 4), cultural heritage protection and preservation (IT25, rank 5) and elevated temperature reduction (IT28, rank 5) as the most difficult items to realize.

In terms of number of staff members, those respondents who have participated in green projects with less than 50 staff members regarded rational underground space utilization (IT4, rank 1) ecological value-added design (IT33, rank 2), open space strategy (IT9, rank 3), economical and intensive land use (IT1, rank 4) and compatibility with surrounding cultural heritage (IT26, rank 4) as the most difficult items, those who were involved in green projects with 51 to 100 staff members considered ecological value-added design (IT33, rank 1), rational underground space utilization (IT4, rank 2), open space strategy (IT9, rank 3), cultural heritage protection and preservation (IT25, rank 4) and human health issues protection (IT38, rank 4) as the most difficult items and those who were involved in projects with more than 200 staff members ranked cultural heritage protection and preservation (IT25, rank 1), rational underground space utilization (IT4, rank 2), compatibility with surrounding cultural heritage (IT26, rank 2), economical and intensive land use (IT1, rank 4) and ecological value-added design (IT33, rank 4) as the most difficult items to realize.

6.3.3.4 Comparisons Between Respondents in Hong Kong and Mainland China

When comparing the perceptions of respondents from the Mainland China and Hong Kong, the mean values in Table 6.7 show that there were slight differences in the ranks of the top five most important items. According to the responses from respondents in Hong Kong, the ranks of the top five items were almost consistent with the ranks within the total sample, like human health issues protection (IT38), dust and air emission mitigation (IT36), sufficient green space consideration (IT3), and water pollution reduction (IT37), which shows respondents in Hong Kong regarded environmental protection on site as important concerns. Additionally, they also regarded wind environment issue on site (IT7) as an important consideration. Within the Mainland group, the top five most important items were water pollution reduction (IT37), human health issues protection (IT38), dust and air emission mitigation (IT36), sufficient green space consideration (IT3), and construction noise mitigation (IT35), which has the same ranking when comparing with the total sample. It is because most of the respondents were from Mainland China and it implied that respondents had similar opinions on the top 5 most important SPD items in green residential buildings.

Table 6.7 Mean values and rankings of the importance of SPD items from respondents in Hong Kong and Mainland China

Items	Hong Kong		Mainland China	
	Mean	Ranking	Mean	Ranking
IT1	3.51	35	4.04	7
IT2	3.01	38	3.52	32
IT3	4.14	2	4.11	4
IT4	3.46	36	3.97	11
IT5	4.09	6	3.81	19
IT6	3.74	25	3.43	35
IT7	4.14	2*	3.76	23
IT8	4.03	9	3.75	24
IT9	4.09	6*	3.66	28
IT10	3.84	19	3.65	29
IT11	3.99	12	3.53	31
IT12	3.67	28	3.80	21
IT13	3.84	19*	3.81	19*
IT14	3.59	30	3.37	36
IT15	3.87	18	3.45	34
IT16	3.89	17	3.88	18
IT17	3.54	34	3.67	26
IT18	3.19	37	3.91	14
IT19	3.84	19*	3.97	11*
IT20	3.74	25*	3.90	16
IT21	3.69	27	3.89	17
IT22	3.91	15	4.05	6
IT23	3.83	22	3.91	14*
IT24	3.81	23	4.01	9
IT25	3.81	23*	3.80	21*
IT26	3.56	33	3.70	25
IT27	3.57	31	3.25	37
IT28	3.90	16	3.65	29*
IT29	4.01	10	4.02	8
IT30	3.57	31*	3.48	33
IT31	3.61	29	3.21	38
IT32	3.94	13	3.67	26*
IT33	3.93	14	3.99	10
IT34	4.01	10*	3.92	13
IT35	4.09	6*	4.10	5
IT36	4.14	2*	4.15	3

IT37	4.13	5	4.24	1
IT38	4.19	1	4.16	2

The mean values in Table 6.8 indicate that the respondents from Hong Kong and Mainland China have significantly divergent opinions with regard to the difficulty to realize the SPD items. Specifically, the respondents from Hong Kong regarded ecological value-added design (IT33), development on brownfield (IT2), cultural heritage protection and preservation (IT25), compatibility with surrounding cultural heritage (IT26) and economical and intensive land use (IT1) as the most difficult items, which highlighted their major concerns on ecological value protection, economic land use and cultural heritage protection. Meanwhile, the respondents from Mainland China regarded rational underground space utilization (IT4), ecological value-added design (IT33), comprehensive open space strategy (IT9), enough open space design (IT8) and human health issue protection (IT38) as the five most difficult items, which concerns about economic land use, open space design, ecological value protection and environmental management plan.

Table 6.8 Mean values and rankings of the difficulty of SPD items from respondents in Hong Kong and Mainland China

Items	Hong Kong		Mainland China	
	Mean	Ranking	Mean	Ranking
IT1	3.51	5	3.39	7
IT2	3.61	2	3.19	22
IT3	3.26	18	3.05	29
IT4	3.50	6	3.62	1
IT5	3.31	13	2.76	34
IT6	3.11	22	3.18	23
IT7	3.31	13*	3.21	20
IT8	3.31	13*	3.45	4
IT9	3.34	11	3.49	3
IT10	3.33	12	3.32	14
IT11	3.03	26	2.73	36
IT12	3.11	22*	3.23	18
IT13	2.99	30	3.39	7*
IT14	2.67	37	2.89	32
IT15	2.51	38	3.07	28
IT16	2.81	35	2.68	37
IT17	3.03	26*	2.85	33
IT18	2.89	34	2.49	38
IT19	2.79	36	2.96	31
IT20	2.99	30	3.09	26
IT21	3.13	20	3.05	29*
IT22	3.30	16	3.22	19
IT23	3.41	10	3.32	14*
IT24	3.46	8	3.18	23*
IT25	3.60	3	3.35	11
IT26	3.57	4	3.43	6
IT27	3.20	19	3.36	10
IT28	3.43	9	3.33	13
IT29	3.49	7	3.21	20*
IT30	2.99	30	3.11	25
IT31	3.01	28	2.76	34*
IT32	3.29	17	3.24	17
IT33	3.64	1	3.55	2
IT34	3.09	25	3.09	26*
IT35	3.13	20*	3.31	16
IT36	3.11	22*	3.38	9

IT37	2.94	33	3.35	11*
IT38	3.01	28*	3.45	4*

As a supplement to the overall perception of respondents in Hong Kong and Mainland China, a Mann-Whitney U test was applied to analyze the overall rankings in the importance and difficulty of SPD items between respondents in Hong Kong and Mainland China. Before applying this non-parametric test, a Shapiro-Wilk test was conducted to test the data normality, which has been widely used in previous studies (Ferretti et al., 2017; Darko and Chan, 2018). In the Shapiro-Wilk test, the null hypothesis H_0 is "The data were normally distributed". If the p-value in the tests of normality is less than 0.05 (the common alpha value), then H_0 should be rejected. As stated in Table 6.8, the p-value for each of the SPD item was 0.000, which indicated that the null hypothesis was rejected. The data was not normally distributed, and the non-parametric test Mann-Whitney U test was applicable.

Table 6.9 Results of the tests of Normality

Items	Importance			Difficulty		
	Statistic	df	Sig.	Statistic	df	Sig.
IT1	.841	258	.000	.882	258	.000
IT2	.896	258	.000	.894	258	.000
IT3	.811	258	.000	.897	258	.000
IT4	.868	258	.000	.889	258	.000
IT5	.862	258	.000	.895	258	.000
IT6	.901	258	.000	.905	258	.000
IT7	.860	258	.000	.895	258	.000
IT8	.839	258	.000	.889	258	.000
IT9	.869	258	.000	.890	258	.000
IT10	.873	258	.000	.883	258	.000
IT11	.884	258	.000	.910	258	.000
IT12	.873	258	.000	.909	258	.000
IT13	.868	258	.000	.904	258	.000
IT14	.903	258	.000	.915	258	.000
IT15	.894	258	.000	.916	258	.000
IT16	.838	258	.000	.906	258	.000
IT17	.884	258	.000	.891	258	.000
IT18	.881	258	.000	.905	258	.000
IT19	.854	258	.000	.906	258	.000
IT20	.865	258	.000	.906	258	.000
IT21	.868	258	.000	.903	258	.000
IT22	.820	258	.000	.903	258	.000
IT23	.840	258	.000	.903	258	.000
IT24	.838	258	.000	.901	258	.000
IT25	.864	258	.000	.902	258	.000
IT26	.881	258	.000	.893	258	.000
IT27	.903	258	.000	.894	258	.000
IT28	.875	258	.000	.892	258	.000
IT29	.829	258	.000	.899	258	.000
IT30	.895	258	.000	.914	258	.000
IT31	.904	258	.000	.902	258	.000
IT32	.880	258	.000	.891	258	.000
IT33	.852	258	.000	.885	258	.000
IT34	.850	258	.000	.884	258	.000
IT35	.817	258	.000	.895	258	.000
IT36	.791	258	.000	.896	258	.000
IT37	.766	258	.000	.903	258	.000

IT38	.787	258	.000	.900	258	.000

The Mann-Whitney U test results in Table 6.10 stated the differences between the Mainland China and Hong Kong respondents when considering the importance of SPD items in green residential buildings. 15 items are considered to have significant differences when it concerns the importance of the items, including IT1, IT2, IT4, IT5, IT6, IT7, IT8, IT9, IT11, IT15, IT18, IT27, IT28, IT31, and IT32. The concerned variables are "land use", "site assessment", "open space", and "microclimate around buildings". When concerning land use, respondents in Mainland China opined that it was more important than those in Hong Kong (like IT1, IT2, and IT4). Generally, respondents in Mainland China regarded economic land use, and brownfield development as the first consideration before developing a green project. The use of underground space was also considered more important in Mainland China, which was regarded as a policy issue brought about by land use pressure and climatic consideration (Hunt et al., 2016). In landscaping and irrigation, choosing appropriate plantings on site (IT18) were also drawn more attention by respondents in Mainland China, as China has a vast territory in Mainland and the regional climates should be concerned. While considering site assessment at the beginning of SPD, and the open space planning issues, respondents in Hong Kong showed more priorities (as IT5, IT6, IT7, IT8, and IT9). In addition, respondents from Hong Kong were also more concerned with the future needs of the residents and the community, such as summer temperature reduction (IT11) and electric charging or fueling facilities (IT15). Furthermore, the Hong Kong respondents attached more importance to mitigating heat with overhangs or other proper measures

(IT27, IT28, IT31). Due to the high density of Hong Kong, the urban island effect is an important issue. In addition, the respondents from Hong Kong encourage green building development on low ecological value (IT32). The results of Mann-Whitney U test showed that the respondents from Mainland China and Hong Kong disagreed on the importance level of 15 no. of items and agreed on the remain 23 no. of items. One possible reason for such differences in views could be that the different ideas and green building development levels in construction industry, respondents in Hong Kong concern more in future use of the green buildings.

When it concerns the difficulty of realizing the SPD items in green residential buildings, as stated in Table 6.10, the respondents have different opinions in the difficulty of 12 SPD items (IT2, IT5, IT11, IT13, IT15, IT18, IT24, IT25, IT29, IT36, IT37 and IT38) which is indicated from the results of the Mann–Whitney U test. The respondents from Mainland China assigned a higher ranking to the application of bulk and reflective insulation given the difficulty of implementing such technology (IT13) and pointed towards the limited availability of electric vehicle charging or fuelling facilities in the country (IT15). With regard to environmental management plan, the respondents from Mainland China perceived difficulties in implementing adequate measures to reduce dust and air emissions (IT36), preventing of water pollution (IT37) and improving human health (IT38). Meanwhile, the respondents from Hong Kong classified development on brownfield (IT2) and developing the design based on the natural conditions on the construction site (IT5) as difficult items and assigned higher mean values to some green measures, such as providing shadings or overhangs (IT11), providing appropriate plantings (IT18), meeting the daylight access requirements (IT24), protecting and reserving cultural heritage (IT25) and encouraging natural ventilation (IT29). Nevertheless, these two groups of respondents showed an agreement regarding the difficulty of 26 other items.

Table 6.10 Mann-Whitney U test results between respondents in Hong Kong and Mainland China

Items	Importance		Difficulty	
	Mann-Whitney U	**p-value**	**Mann-Whitney U**	**p-value**
IT1	4844.500	.001	6023.500	
IT2	4672.500	.000	4959.000	.001
IT3	6217.000		5703.500	
IT4	4554.000	.000	6041.000	
IT5	5578.500	.048	4308.000	.000
IT6	5398.000	.021	6393.000	
IT7	4941.000	.001	6062.500	
IT8	5196.500	.005	6296.500	
IT9	4613.500	.000	6001.000	
IT10	5729.000		6491.000	
IT11	5002.500	.002	5546.000	.042
IT12	5806.000		6062.000	
IT13	6575.000		4964.500	.001
IT14	5885.000		5864.000	
IT15	5174.500	.006	4859.500	.001
IT16	6485.000		5933.500	
IT17	5949.000		5732.500	
IT18	4090.000	.000	5264.500	.010
IT19	6167.000		6105.500	
IT20	5781.000		6286.000	
IT21	5658.000		6317.000	
IT22	6076.000		6193.000	
IT23	6261.000		6076.500	
IT24	5875.000		5513.000	.035
IT25	6497.500		5576.500	.050
IT26	6220.500		5967.500	
IT27	5381.000	.019	6101.500	
IT28	5511.000	.034	6224.000	
IT29	6490.000		5413.500	.021
IT30	6274.000		6136.000	
IT31	5190.000	.007	5734.500	
IT32	5516.000	.036	6350.000	
IT33	6295.000		6243.500	
IT34	6126.000		6557.000	
IT35	6515.500		5760.500	
IT36	6461.500		5440.000	.023

IT37	6133.000		4946.500	.001
IT38	6539.000		4831.500	.001

Note: Only the significant results of the Mann-Whitney U-test are shown

6.3.3.5 Exploratory Factor Analysis Results

The survey results for the importance of SPD items were examined by conducting an exploratory factor analysis via SPSS to identify the common trends amongst these items and to determine a relatively small number of factor groups. Referring to the test results in SPSS, the KMO value was 0.905, indicating that the sample is suitable for factor analysis. The Bartlett's Test of Sphericity were 3105.278 and the significance level is 0.000, which also indicates that the correlation matrix could be used in factor analysis (Pallant, 2013). As shown in Table 6.11, the total variance explained by the extracted five factors is 61.289%, and the remain 23 components only explained 38.711% of the total variance, which indicates that more half of the variance can be explained with the extracted five factors and the model is acceptable to be used for representing the data (Li et al., 2011, Chan et al., 2016). Table 6.12 shows the corresponding rotated component matrix and the items in the extracted factors. After suppressing those small coefficients with absolute values of lower than 0.5, 24 items were retained in the 5 extracted factors, whilst 14 items, including IT3, IT10, IT11, IT12, IT13, IT18, IT22, IT23, IT24, IT25, IT29, IT30, IT32 and IT33, were deleted.

Table 6.11 Total variance explained by the extracted five factors

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	8.954	37.310	37.310	8.954	37.310	37.310	3.953	16.472	16.472
2	1.797	7.489	44.799	1.797	7.489	44.799	3.209	13.370	29.842
3	1.461	6.088	50.886	1.461	6.088	50.886	3.136	13.065	42.907
4	1.270	5.293	56.180	1.270	5.293	56.180	2.587	10.779	53.686
5	1.226	5.110	61.289	1.226	5.110	61.289	1.825	7.603	61.289
6	.958	3.992	65.281						
7	.841	3.503	68.784						
8	.797	3.322	72.106						
9	.727	3.028	75.133						
10	.691	2.880	78.013						
11	.645	2.689	80.703						
12	.603	2.511	83.213						
13	.527	2.195	85.409						
14	.487	2.027	87.436						
15	.427	1.778	89.214						
16	.412	1.716	90.931						
17	.394	1.640	92.571						
18	.369	1.536	94.107						
19	.343	1.430	95.537						
20	.323	1.346	96.883						
21	.247	1.029	97.912						
22	.198	.824	98.736						
23	.172	.715	99.451						
24	.132	.549	100.000						
Extraction Method: Principal Component Analysis.									

Table 6.12 Critical factors in SPD of green residential buildings in China

Component	Factor 1	2	3	4	5
Factor 1: Environmental protection consideration					
IT36. Adequate mitigation measures for dust and air emissions should be applied on site	.835				
IT37. Adequate measures to reduce water pollution should be undertaken on site	.804				
IT35. Adequate mitigation measures for construction noise should be provided on site	.755				
IT38. Adequate measures for human health issues should be implemented on site	.738				
IT34. An environmental management document should be implemented on site	.725				
Factor 2: Effective use of space					
IT7. Air ventilation issues at the site level should be considered properly		.739			
IT8. Sufficient open space should be designed for attractive surroundings		.688			
IT6. Culturally and architecturally significant features should be incorporated in SPD		.667			
IT9. A comprehensive open-space strategy should be formed to lay a foundation for open-space planning and action		.642			
IT5. SPD in green buildings should be designed according to the natural conditions on site		.557			
IT26. New buildings should be compatible with the heritage features		.530			
Factor 3: Use of natural and existing resource					
IT20. Storm water storage devices should be installed rationally			.845		
IT21. Storm water infiltration devices should be installed rationally			.816		
IT19. Proper storm water management measures should be taken to manage surface runoff			.700		
IT17. Pre-existing materials should be used for hard-landscaped areas			.551		
IT16. Non-potable water should be used for landscape irrigation			.504		
Factor 4: Green parking and thermal environment					
IT31. Covered or sheltered parking spaces should be designed to reduce parking footprint				.701	
IT14. A certain percentage of parking spaces for green vehicles should be provided				.653	
IT27. Wind velocities in pedestrian areas should be reduced to ensure pedestrian comfort				.652	
IT28. Proper measures should be taken to mitigate elevated temperatures				.555	
IT15. Electric vehicle charging or fuelling facilities for green vehicles should be designed in SPD of green buildings				.543	
Factor 5: Use of land resource					
IT2. The construction project should be recommended to be developed on brownfield					.754
IT1. Economical and intensive land use should be the first and foremost concern in SPD of green buildings					.657
IT4. Rational underground space utilization should be involved in SPD of green buildings					.599

Based on the cross-factor loadings in the rotated component matrix and the items in each factor, the five extracted factors were named as environmental protection consideration, effective space utilization, natural and existing resource use, green parking and pedestrian areas, and land resource utilization. The interpretation and discussion of the five factors are summarized as follows.

Factor 1: environmental protection consideration

Five items were loaded onto this factor, including adequate measures to reduce dust and air emissions, water pollution reduction measures, a comprehensive environmental management plan, adequate measures to protect human health, and construction noise control measures (IT36, IT37, IT35, IT38, and IT34). As stated by Shen and Tam (2002), construction activity is a major source of environmental pollution, which results in water pollution, dust and air emission, noise pollution, and construction waste generation. If a construction site was mismanagement, it may cause serious environmental nuisance and related pollutions and lead to adverse effects to on-site workers, neighbours around the sites, and the public health. Therefore, during the planning and design stage, an environmental management plan which contains environmental monitoring and environmental audit is suggested to be formulated in order to guarantee a better environmental management in the construction stage (IT34). To reduce dust and air emission caused by construction is a significant way in improving environmental quality and promoting sustainable development (Zhang et al., 2013), which is in line with the results in this research, that adequate measures should be considered before construction to mitigate dust and air emissions (IT36). As it is important to manage water quality on construction site properly in green construction

(Tam et al., 2004), to plan adequate measures to reduce water pollution and control pollution from the source is also an important issue (IT37). Noise pollution on site is also a pollution that cannot be ignored during construction due to its high complaint rate, and proper preventive measures should be formulated in advance (IT35). To avoid human health nuisance on construction site, proper waste management measures should be planned and conducted to reduce the source of pollution (IT38).

Factor 2: effective use of space

This underlying factor group consisted of six items: IT7, IT8, IT6, IT9, IT5 and IT26. To provide natural ventilation and improve living comfort level, air ventilation around the building should be evaluated in the early site design stage by reviewing wind climate, the building mass and orientation, site topography, and surrounding buildings (IT7). As open space provides occupants with recreational areas and improves environmental quality and beauty of the neighborhood, sufficient open space consideration and a comprehensive open space strategy should also be drawn attention to when designing an attractive living environment (IT8, IT9). To take advantage of site conditions and surrounding environment, architecturally and culturally significant features in regional development are also encouraged to be incorporated in SPD (IT6). Cultural heritage helps people know more, to interpret social and cultural changes and to enhance their understanding of the past. Creative integration of old and new developments makes cities interesting and preserves the historical integrity and early development pattern of the city for future generations to experience and appreciate.

Maintaining the local and regional cultural heritage requires developers to preserve and protect archaeological sites, historic buildings, and monuments. In green building development, cultural heritage resources should be integrated into community development by encouraging residents to protect the heritage, which can promote the cultural continuation (IT26). The developers should also ensure that the cultural heritage characteristics within the site boundary can be preserved and protected properly (IT25).

Factor 3: use of natural and existing resource

Five items were loaded onto this factor, including storm water storage devices provision, storm water infiltration devices provision, proper storm water management measures, non-potable water irrigation, and pre-existing materials use, which were relevant to natural and existing resources use (i.e. IT20, IT21, IT19, IT17, IT16). Rainwater, as a reusable natural resource, should be considered and collected in green buildings as a means of saving water resources. When planning a new green development, rainwater infiltration or storage facilities should be properly set up, and appropriate storm water management measures should be taken to manage surface runoff (IT20, IT21 and IT19). In hard-landscaped areas, construction materials can be used to improve the landscape by design, and the use of pervious materials like gravel and brick can promote rapid infiltration of storm water into the ground and supplement soil water and groundwater(IT17). For landscape irrigation, it is recommended to use systems equipped with rainwater or recycled water, and plants with less irrigation needs should be used to reduce the consumption of potable water. The irrigation system and landscaping in green buildings should consider using the following elements: using non-potable water such as rainwater for landscaping irrigation, and using an automatic water-saving irrigation system with rainwater sensor (IT16).

Factor 4: green parking and thermal environment

Five items were contained in factor 4 which were concerned about the green parking and comfortable thermal environment on site (IT31, IT14, IT27, IT28 and IT15). To effectively mitigate temperatures, applicable measures include providing shades for non-roof impervious surfaces by using light-coloured high-albedo materials, covering the roof with materials with a high solar reflectance index, or providing vegetation for more than half of the roof areas, which is also applicable for providing covered or sheltered parking space to reduce parking footprint (IT31). In the design of a site thermal environment, the wind, sunlight, temperature, and air quality should be carefully balanced. To ensure the pedestrian comfort on site and to ensure a comfortable on site, wind velocities should be reduced in pedestrian areas(IT27). When designing, constructing, or remodelling new buildings, strategies and design solutions should be proposed to effectively mitigate temperatures (IT28). As green vehicles are beneficial to environmental protection, air quality, human health, and energy use and cost, they are encouraged to be widely used for sustainable development. Therefore, in SPD of green residential buildings, the parking spaces for green vehicles should be considered properly. Electrical vehicle supply equipment should be installed for a certain percentage of all the parking spaces in green buildings. These spaces should be clearly reserved for the use of green vehicles. In addition, it is better to install liquid or gas alternative fuel refuelling facilities, or battery switching stations which can meet the use of a number of vehicles (IT14 and IT15).

Factor 5: use of land resource

Factor 5 consisted of three items that focusing on effective land resource use (IT2, IT1, and IT4). To realize harmonious development between human beings and nature, economic land use is recommended, for instance, development on brownfield or previously used land is encouraged to save land resource (IT1 and IT2). Effective use of underground space creates more compact communities without leading to adverse environment effect. Sometimes a facility can be built underground where it is not possible for a surface facility or is not acceptable to the community (IT4).

6.4 FACE-TO-FACE INTERVIEWS

The SPD process, the relationships amongst stakeholders, the principles of SPD, and the planning and design approaches in SPD are also important concerns to ensure an effective SPD in green residential buildings as described in Figure 6.1.

In order to identify the other components in SPD of green residential buildings, Interviews with practitioners in green building development were conducted. The target interviewees were contacted in advance by email to confirm whether they are willing to be interviewed. An interview guide that included an introduction to the research aim and the proposed research questions was also attached to the invitation emails as shown in Appendix B. These target interviewees were selected considering their work experience and knowledge in green building development. A total of 9 interviews were finally conducted with 12 practitioners in green building development or experienced researchers in green buildings in Mainland China and Hong Kong, respectively. Eight of these interviewees agreed to have their interviews audio recorded, whilst the other four interviewees refused to have their answers recorded on tape. Some notes were also taken during the interviews.

The face-to-face interviews were conducted as semi-structured to allow the interviewees to express their opinions freely instead of answering each question briefly. The duration of each interview was ranging from 30 minutes to 1 hour, which depends on the discussions with the interviewees and their understanding of the research questions. All interviewees were ensured that the information collected in the interviews would be only for academic use and that their personal information would be kept confidential.

6.4.1 Qualitative Analysis using NVivo

Computer Assisted Qualitative Data Analysis Software (CAQDAS) is a typical information processing tool that has been applied in numerous research areas. Amongst the available software in the market, NVivo is one of the most commonly used tools for qualitative analysis (Bazeley and Jackson, 2013). NVivo was also employed in this work to analyze the interview data because of its user-friendly interface, clear logic, flexible and accessible approach to qualitative data analysis and non-dependence on theory (Vincent and Blandford, 2017; Di Maddaloni and Davis, 2018). To analyze the interview data, the audio-recorded interviews were transcribed and imported into NVivo 11 (QSR International) along with the interview notes. After familiarising with the data, initial codes were generated to reflect the features of these data. The interview data were categorized into several groups throughout the coding process (Tuckett, 2005).

To some extent, the coding process depended on whether the themes were "data driven" or "theory driven". For the former one, the themes were depended on the data, while in the latter one, the data would be categorized based on an existing theory (Braun and Clarke, 2006). The theory-driven approach is suited when a conceptual organization of a theme should be analyzed in the answers. As the interviews were conducted to help to identify the components in the framework of SPD in green buildings, the codes were mapped to five sub-themes to keep in line with the objectives of the interview study, namely differences between conventional buildings and green buildings, the SPD process in green buildings, the relationships amongst stakeholders, the sustainable principles in SPD of green buildings and the approaches in SPD of green buildings. The coding process in NVivo is illustrated in Figure 6.2.

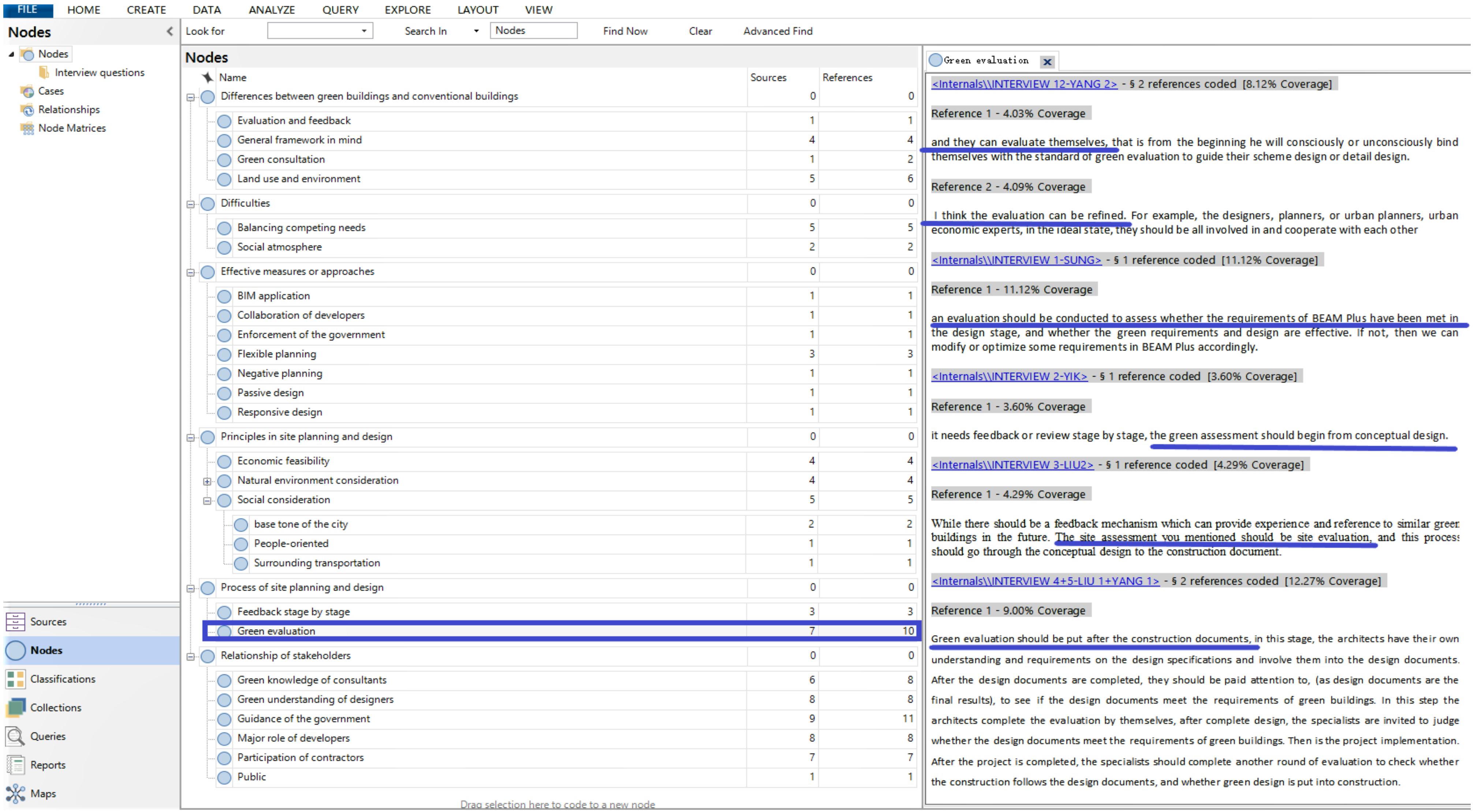

Figure 6.2 Coding process in NVivo

6.4.2 Differences between the SPD of Conventional and Green Buildings

The interviewees argued that the SPD of conventional buildings focused on maximizing land use whilst that of green buildings focused on balancing the relationship between land use and environment. One interviewee shared, "green building considers how to combine maximizing land use potential and minimizing impacts together." Before starting the SPD of green buildings, planners and designers should build a mental framework whilst taking into account the requirements of various GBRTs. The extent of including green components in the SPD process depends on the attitudes and skills of planners and designers because planning and design are regarded as creative processes. Continuous evaluation and feedback also play significant roles in the SPD of green buildings. As key stakeholders in green building development, green consultants must be involved as early as possible in the SPD process. According to one interviewee, "It is too late to involve a green consultant in the SPD after the planners and designers complete the design. At this stage, it is difficult to adjust the building type or orientation on a large scale. Moreover, the effects of green consultation are less than those of involving green consultants in the scheme design stage".

6.4.3 SPD Process in Green Buildings

When exploring the process of SPD in green buildings, the SPD process developed by LaGro (2011) was provided to the interviewees as a reference. Accordingly, this definition was employed in this research to examine the SPD process in green buildings.

However, the interviewees also shared that the term, “conceptual design”, in this definition should be replaced by “scheme design” to be in line with the terminologies being used in practice. As a significant characteristic of green buildings, green evaluation should be considered in each stage in the SPD process of green buildings, as shown in Figure 6.3.

In the SPD process, green issues are mainly considered by two groups, namely, designers and green specialists. The designers incorporate the green requirements of GBRTs into the scheme design and detail design based on their knowledge and understanding, that is, they perform the “green evaluation” by themselves. In the detail design, a technical document is composed that will be eventually used as the official document of the construction project. After completing the green design, several green specialists, including the members of green building councils, evaluate whether such design meets the requirements of a “green building label”. After implementing the project, green specialists evaluate whether the green requirements stipulated in the design stages have been successfully realized and whether the green design has been effectively executed. The feedback received after the implementation of a project can also be references for the future green building projects implementation. In sum, continuous evaluation and feedback play significant roles in ensuring an effective green SPD.

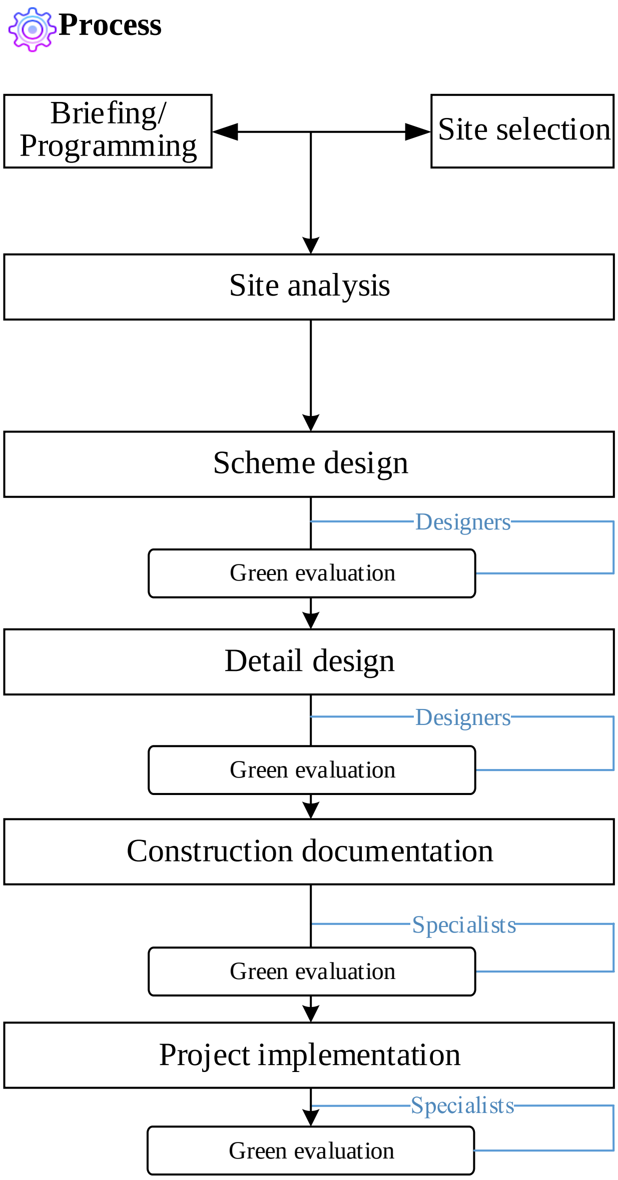

Figure 6.3 The process of SPD in green buildings
(Based on interviews)

6.4.4 Relationship amongst the Stakeholders in SPD of Green Buildings

According to Lockyer and Gordon (1996), a project is a unique process that contains "a set of coordinated activities with a start and a finish date, undertaken to achieve an objective conforming to specific requirements, including constraints on time, cost and resources". For green building development and further market transformation, many stakeholders are required to participate in this process (Yang and Zou, 2014). Generally, these stakeholders include the government, developers, designers, consultants, contractors and the public. The relationships amongst these stakeholders were constructed based on the interview data and are illustrated in Figure 6.4.

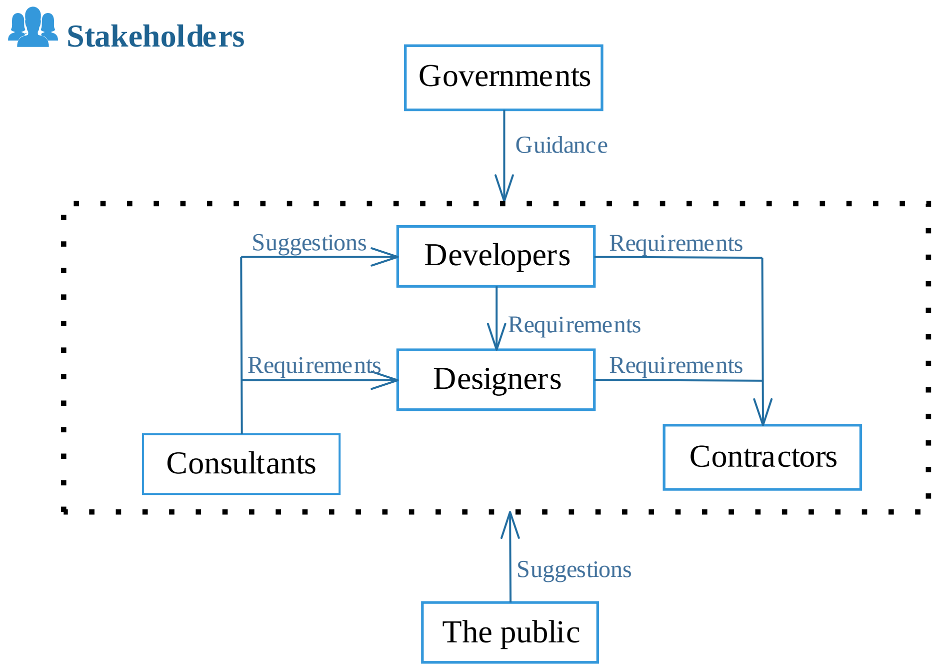

Figure 6.4 The relationship among stakeholders in SPD in green buildings
(Based on interviews)

As the decision makers of green building policies, the government implements constraints and provides policy guidance for the development of green buildings. Some basic parameters, including floor area ratio, greening rate and building density, are determined by the government before the commencement of a project. The government also provides several economic incentives for promoting the application of green buildings. For example, the Singapore government carried out “Green Mark Incentive Scheme for Construction Areas”, which rewards 2500$m^2$of construction area to those developers who construct a Gold Plus certificated green building in GM and

$5000m^2$construction area to those who construct GM Platinum level green buildings. Likewise, in Hong Kong, the government offers incentives on Gross Floor Area (GFA) concession and site coverage concessions to those private buildings with green features to promote the environmentally-friendly buildings construction in the private sector. The government may also guide the behaviors of other stakeholders during the SPD process of green buildings.

Developers play a leading role in green building development. Comparing with other stakeholders, developers expect to gain higher scores in green building evaluation and achieve a green building label at a lower cost. They have their own understanding and requirements for the project and make their decisions by referring to the professional information they receive from consultants and based on the reasonableness and economic feasibility of the project.

Designers or architects conduct SPD based on the requirements of the developers. Architects are unique-minded individuals that integrate green components into the SPD process to meet the requirements set by GBRTs and developers. One interviewee, who is an experienced architect, mentioned that although sometimes the word “green” was not mentioned during the planning and design stages, the designers were thinking about green concepts throughout the design process. Generally, in the development of green buildings, designers follow the requirements of the developers, whilst consultants sometimes also set their own requirements from a green perspective.

As the implementers of green projects, contractors need to meet the requirements of developers at each stage of the SPD process. As green construction is known for its heavy use of green technologies, construction organizations also need to take part in this process. The construction organizations are required to follow the green requirements set by developers and consultants, such as preserving old trees and utilizing the surface soil on the construction site.

The role of consultants in green building development depends on the developers and designers. In the case of Mainland China, consultants play minor roles in construction projects as their importance are not comprehensively realized by other stakeholders. Consultants provide developers with professional and technical information of green SPD. Developers will consider green investments, construction technologies, tax refunds and how to balance green requirements with construction costs. Before the SPD process, consultants thoroughly evaluate the construction site and set a target green building label level. In the interviews, a professor from Mainland China highlighted the importance of involving consultation firms in the early planning and design stages of green building development and integrating green consultation and design into the early stage of SPD. Therefore, in future construction projects, designers should show a high level of green consultation knowledge.

Another interviewee mentioned that consultants act as “bridges” in the SPD process, that is, they make green proposals in the SPD process, which would then be fulfilled by designers, encouraged by developers and supervised by the government. The major stakeholders or participants communicate with one another through emails, workshops and regular meetings.

As the occupants or end users of green residential buildings, the public should provide comments and suggestions to the other stakeholders during green building development. Their feedback is especially important during the occupancy stage to promote and improve the development of green buildings.

6.4.5 Principles of SPD in Green Buildings

The interview guideline delivered to the target interviewees contained information about the three basic principles of the SPD of green buildings, including efficient resource use, surrounding conditions and natural environment. The interviewees were also encouraged to propose other issues which they thought should be included amongst these principles based on their knowledge and experiences.

The interviewees generally agreed with the three aforementioned principles and proposed valuable comments and suggestions. For instance, they argued that the "surrounding conditions" principle should consider the culture, history and neighborhood of the construction area. One interviewee identified site safety as an important issue, especially in site slope and vertical greening design. The other interviewees also highlighted an overlap between the "efficient resource use" principle and the "based on surrounding conditions" principle. Therefore, careful wording and classification are crucial when determining the principles of sustainability. Moreover, when selecting which green technologies that should be involved in the SPD process, their operability on the construction site and acceptability amongst their end users is an important consideration.

Based on existing knowledge and the comments of the interviewees, the principles of SPD in green buildings were regrouped into three major aspects mentioned in sustainable development, i.e. from the environmental, economic, and social aspects.

- based on natural environment. Site security must be ensured when taking advantage of the natural conditions on and around the construction site. Before the SPD in green buildings, the degree of soil contamination such as the amount of radon in the soil must be detected. During site slope design and vertical greening, designers must have a clear idea of how to guarantee site security. The efficient utilization of natural resources, such as sunlight and natural ventilation, should also be considered when designing the building layout. Green SPD should also consider the local climate conditions, because each region has a unique natural environment. For instance, overhead layer is applicable in southern regions but not in northern regions because designers and planners focus on resisting cold winds in the northern region yet focus on air ventilation in the southern region.
- based on economic applicability. Before engaging in SPD, developers must consider the economic feasibility as an important issue of the construction project. Specifically, when identifying those technologies that should be applied to ensure an effective SPD in green buildings, developers need to choose those technologies that not only meet the requirements of GBRTs but also have economic feasibility

and operability on the construction site. High initial investments present an obvious obstacle for developers in green building development even though the overall costs of green buildings throughout their whole life cycle is lower than those in conventional buildings.

- based on social environment. The surrounding transportation and public facilities should be taken into consideration in SPD of green buildings as a social environment consideration to improve the comfort level of green building occupants. Incorporating the local architectural culture into the SPD process is an innovation in green building development as people-oriented is important characteristics of sustainable construction. The basic colours of the city should also be concerned. For instance, given that the urban areas in Chongqing have a base colour of earthy yellow, the new buildings in this area are suggested to be painted with earthy yellow, grey or similar colours.

6.4.6 Difficulties in SPD of Green Buildings

The application of SPD measures or technologies is not the only challenge in SPD of green buildings. According to one interviewee, “GBRTs have many good measures for SPD. If the investment in some green technologies or measures is too high, then the developers will not have any incentives to conduct SPD”. After green consultants propose their suggestions related to the application of SPD measures, the developers will consider if these suggestions can be implemented in their projects within a limited period they want to balance economic efficiency. The social atmosphere of green building development also needs to be improved. In coastal areas where green buildings have been well-developed, the major real estate development companies prefer to build two- or three-star green buildings to keep up with their continuously innovating competitors. Therefore, if major real estate development companies improve the quality of their projects and construct high-level green buildings, then the social atmosphere of green building development will be enhanced, thereby encouraging the government to promote such activity further.

6.4.7 Approaches in SPD of Green Buildings

The interviewees were asked to list some commonly used approaches in the SPD of green buildings. Some of them identified the skills, attitudes and knowledge of architects and designers as the important issues in SPD of green buildings, whilst others cited flexible planning, negative planning, passive design, responsive design, software simulation, government enforcement and collaboration amongst developers as effective approaches. In addition, a total of 11 approaches related to urban and building planning and design have also been proposed in the literature as shown in Table 6.13.

Table 6.13 Planning and design approaches in previous studies

NO.	Approaches	Characteristics	Sources
1	Iterative approach	Planning is an iterative approach. Many studies, assessments, alternative considerations and revisions need to be conducted before preparing a final plan.	Ku and Mills, (2010); Porwal and Hewage, (2013); Ahmad et al., 2017
2	Flexible approach	Flexibility means leaving rooms for future adjustments, modifications or revisions. In a flexible design, a plan is expected to meet immediate needs and consider future requirements.	Pinto-Varela et al., (2011); De Neufville, (2016); Fletcher et al., (2017)
3	Negative planning	Negative planning is a reverse spatial planning method towards urban development planning, where landscape is the primary concern as an infrastructure topic.	Yu et al., (2008); Li and Huang, (2016)
4	Integrated planning/design	An integrated planning/design encourages the stakeholders of green building development to collaborate in the establishment and achievement of project goals. This complex process also involves numerous disciplines and building systems.	Rekola et al., (2010); Van Hoof et al., (2010); Keeler and Vaidya, (2016); Mikaelsson and Larsson, (2017)
5	Biophilic design	Biophilic design is an innovative approach that incorporates natural materials, natural light, vegetation, nature view and other experiences of the natural world into the modern built environment. As a sustainable design strategy in architecture, biophilic design aims to reconnect people with the natural environment.	Kellert et al., (2011); Ryan et al., (2014); Gillis and Gatersleben, (2015)
6	Regenerative approach	Regenerative approach integrates the systemic view and the development continuity into the planning, which aims to establish a relationship of coevolution and cooperation between ecological and socio-cultural systems.	Lyle, (1996); Cole, (2012); Conte and Monno, (2016)
7	Environmentally responsive design	Environmentally responsive design means designing based on the site conditions, which increases site characteristics in the design process.	Hoffman and Henn (2008)
8	Holistic design	Holistic design focuses on the proper interactions and potential synergies	Okeil, (2010); Yin et al., (2013); Chen et al.,

		amongst various material processes. In sustainable buildings, holistic design refers to identifying and specifying various performance parameters, like architectural requirements and aesthetic appearance.	(2016)
9	Participatory planning	Participatory planning aims to understand the views and desires of various groups regarding the management of the planning area and try to take their opinions into account during the decision-making process.	Kangas and Store, (2003); Williams, (2007); Albert et al., (2014)
10	Value-based strategic planning	Value-based strategic planning is a systematic, participatory and transparent decision-making process, in which the priorities and choices should be determined and the scarce resources such as time, money and skills should be allocated. The aim is to achieve agreement based on local community values.	Habitat, U.N., (2011); Malekpour et al., (2015)
11	Universal design	Universal design aims to create an environment that allows people to live easy, healthy lives. This strategy can be accessed, understood and used by diverse groups.	Steinfeld and Maisel, (2012); Carpman and Grant, (2016)

Eight approaches in SPD of green buildings are developed by interpreting the results of the interviews and the literature review from the micro and mid- and macro-level perspectives.

From the mid or macro perspective, some interviewees and previous research stressed the importance of applying flexible planning, negative planning, biophilic design, and regenerative design in sustainable urban development. Flexible planning is especially applicable in urban development as this strategy leaves room for future adjustments, modifications or revisions. Negative planning is a reverse spatial planning method that prioritises the preservation and planning of non-urban development areas. Biophilic design is a sustainable architectural design which aims to reconnect people with the natural environment by integrating natural materials, light, vegetation, views and other experiences of the natural world into the modern built environment. Regenerative approach evaluates the continuity of the development process from a systemic view and aims to establish a partnership between the ecological systems and the socio-cultural systems (Conte and Monno, 2016). Instead of merely considering efficiency and applying engineering approaches in green building development, regenerative design establishes a future direction for green buildings by introducing heat, light, wind and water into these structures in an ecological way and setting the appropriate energy levels for transforming these resources (Gou and Xie, 2017).

From the micro perspective, integrated design, responsive design, iterative design and universal design can be taken into account in SPD of green buildings. For green buildings, the term "integrated design" not only refers to the collaborative efforts of team members from different areas but also to those teams working on the building design and the environmental impacts of their projects. Responsive design is also regarded as a proactive design where actively planners shape the future instead of merely trying to get ahead of events beyond their control. Iterative design adjusts the design parameters to examine their impacts on energy use, environment, comfort and cost. Combining BIM with this iterative process can help to define the characteristics of buildings in the early conceptual design stage (Ahmad et al., 2017). Accessibility is an important characteristic of universal design that can contribute to the development of green or sustainable design in terms of social equity.

6.5 A PRELIMINARY FRAMEWORK FOR SPD IN GREEN RESIDENTIAL BUILDINGS

A preliminary framework for SPD in green residential buildings was developed according to the results of the interview and the identified SPD variables. As shown in Figure 6.5, this framework elaborates the SPD process in green buildings and the green evaluation. The identified 13 variables should also be taken into consideration during the SPD process. Several approaches for facilitating effective SPD were also summarized from both the micro and macro perspectives. Three basic design principles were formulated based on the social, natural and economic aspects of sustainable development. The relationships amongst different stakeholders were also established.

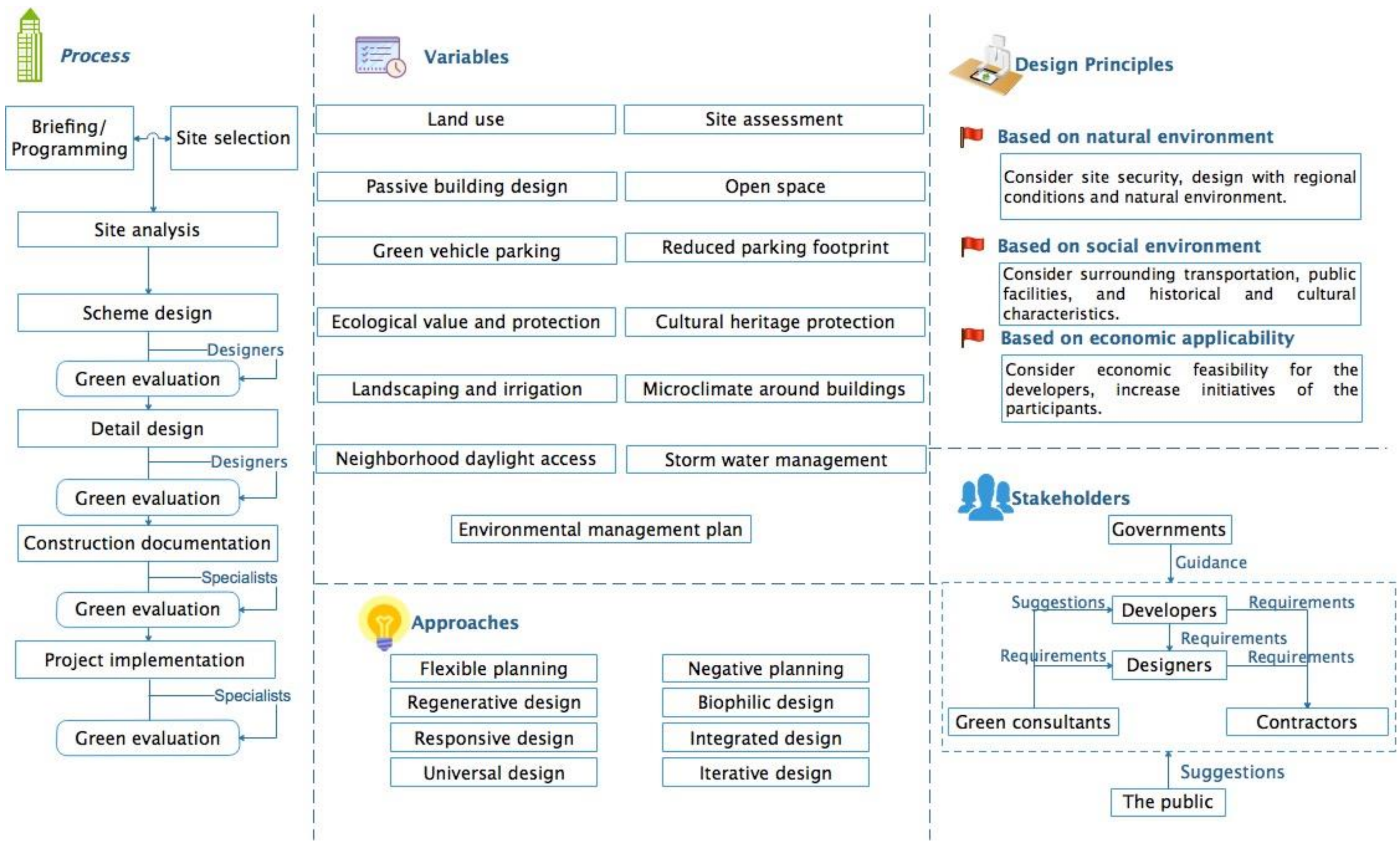

Figure 6.5 A preliminary framework for SPD of green residential buildings

6.6 SUMMARY

In this chapter, a preliminary framework for SPD in green residential buildings was developed. Firstly, a list of 38 SPD items in green buildings were identified according to the 13 variables in the theoretical framework. Secondly, a questionnaire survey was applied to investigate the perceptions of practitioners on the importance of and difficulty to realize SPD items and to identify critical factors of SPD in green residential buildings. Thirdly, the other components of the framework were identified by conducting face-to-face interviews with 12 practitioners in green building development and by analysing the interview data with NVivo. Fourthly, the preliminary framework was described. The next two chapters discuss the improvement and validation processes of the preliminary framework.

CHAPTER 7 IMPROVEMENT AND VALIDATION OF THE FRAMEWORK – CASE STUDIES

7.1 INTRODUCTION

This chapter improves and validates the preliminary framework for SPD in green residential buildings based on case studies. Three case studies were conducted including two in Mainland China and one Hong Kong. Two two-star certificated green building projects were selected in Mainland China. Generally, one-star and two-star certificated green buildings account for most of the certificated green buildings in Mainland China, therefore it is representative to select two two-star certified green buildings to conduct the case study. In addition, the selected green building project is the first public estate in that area. As the green building development in Hong Kong is much more mature than that in Mainland China, the case study conducted in Hong Kong was taken as a reference, which helps to make the contents of the framework more comprehensive and complete. Document analysis and interviews with practitioners in these projects were conducted in each case study. The project-related materials, such as the introduction of the project and the green evaluation report, were provided by the participants in these case studies. To provide additional information about these cases, those engineers or architects who were directly involved in the selected cases were interviewed face to face.

7.2 CASE STUDY 1: A RESIDENTIAL BUILDING PROJECT

7.2.1. Background Information

The selected case one is described in Figure 7.1. The project is located in Chongqing

New Northern Zone, Xiao Jia Gou Reservoir is at the north side of the site; Zhao Mu Mountain Botanical Garden is located at the south side of the site; Jia Ling River is at the western side; and Yangtze Golden Waterway is at the eastern side. Besides, the site is close to Chongqing Free Trade Port Area. The plot covers an area of 117811m^2, where the total construction area is 160095m^2 (the ground area is 113682m^2, and the underground area is 46412m^2), and the total investment is about 250 million yuan. This project is consisted of two plots, and the development period is from April 2014 to March 2018. Plot one includes 88 mid-rise residential buildings (excluding 88# building), accessory occupancy, and underground garage, with a total construction area of 103144 m^2 . Plot two includes residential buildings, commercial buildings, community accessory occupancy (community work room, property management room, community cultural activity room), and underground garage and equipment, with a total construction area of 56950m^2. An engineering manager who is in charge of this project was interviewed for about 40 minutes.

Figure 7.1 Studied area in project 1

7.2.2 Variables Involved in the SPD Process

- Land use: This project has a floor area ratio of 0.806, which meets the upper limit and the economic and intensive land use requirements, and a green space ratio of 32.50% is designed, which meets the green space requirements. Green roofs are installed on commercial buildings, whilst underground spaces are used as garages or entertainment rooms.
- Site assessment: One feature of green site design is to design based on site characteristics, which is also for cost control. Various types of residential buildings, including semi-detached villas, detached villas and townhouses, are involved in this project. The distribution of these buildings considers the landscape view and the height differences on the site to fully utilize its typography. Suitable air ventilation in this project is ensured by conducting wind environment simulation

including the wind speed and wind pressure on site.

- Open space: A diverse open space is reserved for this project. A leisure function area is provided to allow the residents to engage in fitness activities and sports. A golf park is also designed to attract the nearby residents and public. A mountain park is designed based on the topography of the site, in which runway and other fitness function facilities are design.
- Passive building design: In SPD, one requirement of passive building design is reflected on the permeability of the site, which is also considered in this project. Different types of permeable ground, including pervious concrete, water-permeable brick and grass-planting brick, are considered in this project. Each of these types serve different functions. Trees and other structures for shading are also installed in outdoor venues to reduce the intensity of the urban heat island effect.
- Green vehicle parking: To promote the utilization of green vehicles, 27 parking spaces for motorcycles and battery cars are provided in this project. To fully utilize these parking spaces, some of them are made accessible to the public by implementing a staggered parking plan and their operating hours are determined by the property management office.
- Landscaping and irrigation: This project has a landscape area of 68982m^2, which accounts for more than half of its land use. To conserve water, micro-irrigation and drip irrigation systems with soil moisture sensors are employed in the project. The recyclable materials on site include fixture, various steel and wood.
- Storm water management: A rainwater collection and utilization system is adopted

in this project for storm water management. After the rainwater from the roofs merges with that from the project site, the initial abandonment device is used and then the rainwater is sent to the water reservoir for detention, retention, flocculation and sediment removal. The rainwater is then lifted by the pump to the rainwater treatment equipment for purification. Afterwards, the purified rainwater is stored in a clean water basin and is distributed to landscape irrigation, car wash water and road watering networks through a constant pressure water supply system. Pervious bricks and asphalt are also used to build permeable pavements, which account for 50% of the entire project site.

- Neighborhood daylight access: Given that Chongqing has no strict daylight access requirements, the reasonable building interval was achieved based on the minimum requirements in the specifications to meet the daylight access.
- Cultural heritage: The project is located in an area where cultural heritage is not involved. Therefore, this variable is not considered in this project.
- Microclimate around buildings: To relieve the elevated temperature of exposed public areas, tall trees and green belts are designed along the sidewalks and crosswalks. Natural ventilation is promoted by installing ventilators on the exterior walls of buildings. These ventilators form a ventilating passage to realize natural ventilation.
- Reduced parking footprint: The project site has 40 ground parking spaces and 50 ground interior parking spaces, which together account for an area of $1138m^2$. The project site also has an underground parking area of $1044m^2$. Some semi-detached

villas and detached villas have their own ground parking spaces, whilst some townhouses have underground garages. Double-deck garages are also designed to reduce the earthwork and bring convenience to the occupants. Amongst all ground parking spaces in the area, 10% are designed for commercial buildings, whilst only 4% are designed for residential buildings.

- Ecological value and protection: The Xiao Jia Gou reservoir is located north of the project site. The green design pays special attention to the protection of this natural resource because of its important effect on the development of natural landscapes and in improving the living environment.
- Environmental management plan: Following the suggestions of a green consultation company, the construction organization plans certain environmental protection measures, such as an environmental protection plan, dust reduction plan, noise reduction plan and the OHSAS18000 Occupational Health and Safety System Document, before commencing the project.

7.2.3 Constraints on the Construction Site during SPD

- Some areas of the project site have low slopes, whilst rainwater convergence is observed in some hillsides. Therefore, the rainwater discharge in the project site is difficult to manage. Therefore, a rainwater collection and utilization system is adopted to solve this problem.
- The project site is located in low-lying areas, and the surrounding municipal roads are about 20 m higher than the site. Barricades or elevated structures are adopted

in the project site to reduce the amount of earthwork.

- Some areas of the project site show height differences and require extensive earthwork. To solve this problem, different types of residential buildings can be designed based on various heights.

7.3. CASE STUDY 2: A RESIDENTIAL HOUSE

7.3.1 Background Information

The study area of the second selected project is marked in Figure 7.2. The total land area is 248807 m^2, and the construction area is 708694 m^2 (including a ground area of 509210m^2 and an underground area of 199484m^2). The applied project includes four plots in phase 1, and three plots in phase 2. The engineering properties of the project are new residential buildings. The whole project includes five phases, the total investment is 2.4 billion yuan, and is developed from November 2012 to December 2017. The whole project is under construction when conducting the case study. An architect working in the corresponding consultation company was interviewed for around 30 minutes.

Figure 7.2 Studied area in project 2

7.3.2 Variables Involved in SPD Process

- Land use: The project site is originally an agricultural and forest land without any harmful radioactive sources found nearby. The residential land per capita of the project site is reduced below the standard limits to meet the economical and intensive land use requirements. The project site also has a green space ratio of 37.51% and public green space area of 39657m^2. The rational allocation of green spaces in this site provides its residents with opportunities to neighborhood communication and recreational activities. The project site also has an underground construction area of 199484 m^2, which ratio to the overall construction area is 263.4%. This underground construction area is mainly used for parking, storage and property management.

- Site assessment: The natural conditions of the project site are considered in the SPD of this project. Given the huge differences in the height of some areas, this project employs three SPD principles, namely, combining topography, meeting the overall layout requirements and avoiding extensive earthwork. The building design in this project is based on the natural conditions of the construction site, the shape, orientation and floor space of buildings and the ratio of windows to walls. The shape coefficient of all buildings within the project site satisfies the energy efficiency standards.
- Open space: Some activity and social areas for children and the elderly are set up on the project site. The resting spots in these areas are covered with trees and equipped with seats, thereby encouraging neighborhood communication and recreation activities.
- Passive building design: A self-insulating wall system is installed in the exterior envelopes of buildings, which are made out of energy-saving sintered shale hollow bricks. This system occupies a wall area of $127951m^2$. Insulation, which acts as a barrier to heat flow, is essential in keeping buildings warm during winter and cool during summer. Extruded polystyrene foam (XPS) is used as the insulation material for the roof and void floor slab, whilst polystyrene foam is used for insulating the exterior wall. The thickness of these insulation materials is calculated by using PKPM, a building energy saving design and analysis software, and by considering different building types.
- Green vehicle parking: Green vehicle parking space is not reserved in this project.

- Landscaping and irrigation: A circulating water supply system that uses treated storm water is adopted to ensure an excellent water quality, conserve the water resources and create a healthy outdoor space. The landscape irrigation methods employed in this project include combining the scattering nozzle with micro-spray irrigation. Steel, wood, aluminum alloy profiles, gypsum products, glass, etc. are reused in this project as recyclable materials. The plants in this project mainly include indigenous flora with high weatherability, high survival rates and strong resistance to diseases and pests. No less than 50 types of indigenous plants can be found in each plot. Arbour, shrubs and lawns are also added rationally to improve the utilization of green spaces and to increase the amount of plants. Therefore, despite its small size, the green space can generate a large amount of ecological and landscape benefits.

- Storm water management: The storm water on the project site is recycled and reused properly. The roofs of each building are equipped with a traditional gravity roof drainage system, the rainwater collection pipeline and lying depth are designed based on the community terrain, a rainwater reuse system is installed at the end of the storm water pipe network, and rain segregation wells are set up at the end of the system. After the initial flow, the rainwater successively moves to the grid wells and the water storage sedimentation tank before being pumped to the screw mixer and mixed with medicine. After filtering quartz sand or medicine, the filtered water is stored in the rainwater tank and is used for watering plants, roads and landscapes and for washing the rainwater treatment equipment used on the project site. Outdoor pervious ground, such as green areas and pervious bricks, are used to infiltrate storm water. Around 78% of the outdoor ground on the project site is pervious.

- Neighborhood daylight access: The project implements some relevant provisions to ensure that the buildings have appropriate spacing and good lighting. The layouts employed in the project consider the residential buildings insolation interval and ventilation requirements of the buildings. Exterior windows are installed in the bedrooms, living rooms and kitchens in each residential unit. The lighting design requirements of the main function rooms (e.g. bedroom, living room and kitchen) are satisfied by considering the ratio of glazing to the floor area. The ECOTECT software is adopted to predict the natural lighting in each residential unit. The daylight factor in the major functional rooms exceeds 2.4, thereby meeting the lighting requirements of residential buildings as shown in Figure 7.3.

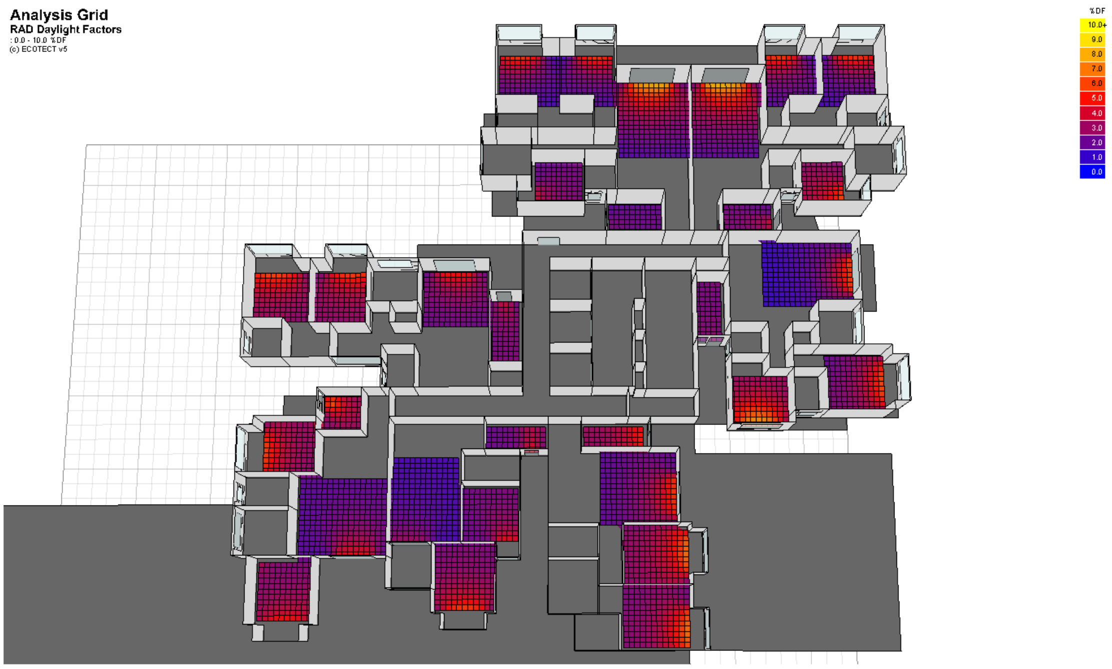

Figure 7.3 Distribution for daylight factor in major functional rooms

- Cultural heritage: The project does not have any cultural heritage issues.
- Microclimate around buildings: The PHOENICS software is applied to simulate and analyze the distribution of outdoor wind environment in the residential area. The results reveal the absence of any partially windless or vortex region that may affect the dissipation of outdoor heat and contaminants as shown in Figure 7.4, and the temperature distribution is in Figure 7.5. Natural ventilation is used to conserve energy, protect the environment, improve indoor air quality and ensure healthy living. Therefore, designers optimize the design of residential units and organize common drafts to improve the ventilation effect. Window ventilators are also installed to meet the natural ventilation requirements and improve the comfort levels of residents.

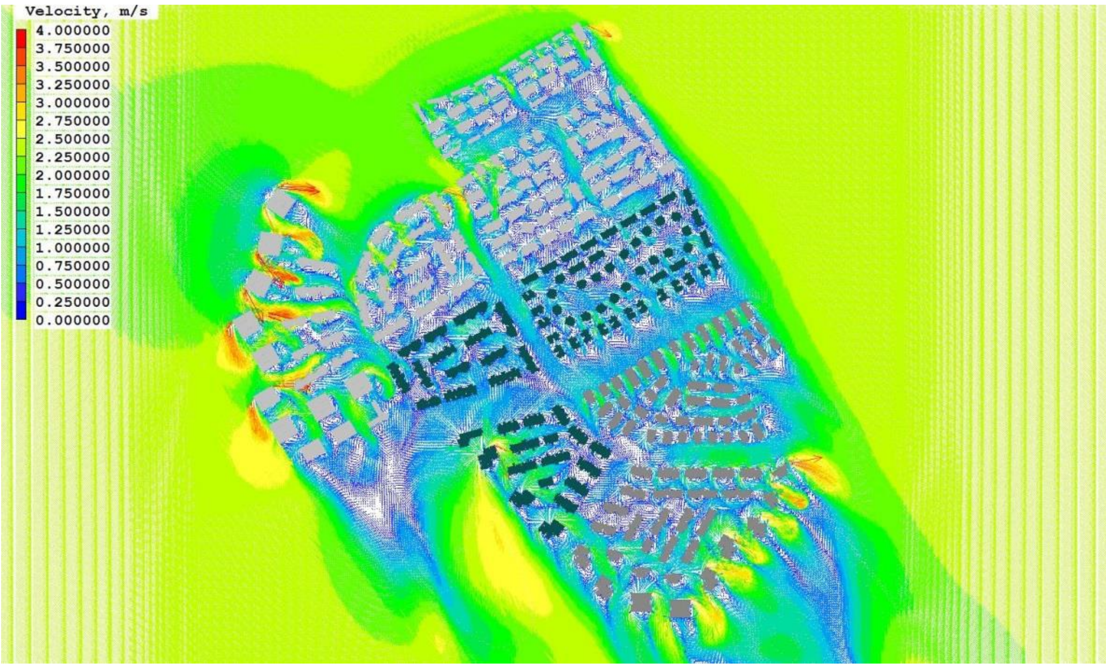

Figure 7.4 Velocity distribution vector graph for wind area (Height of 1.5m)

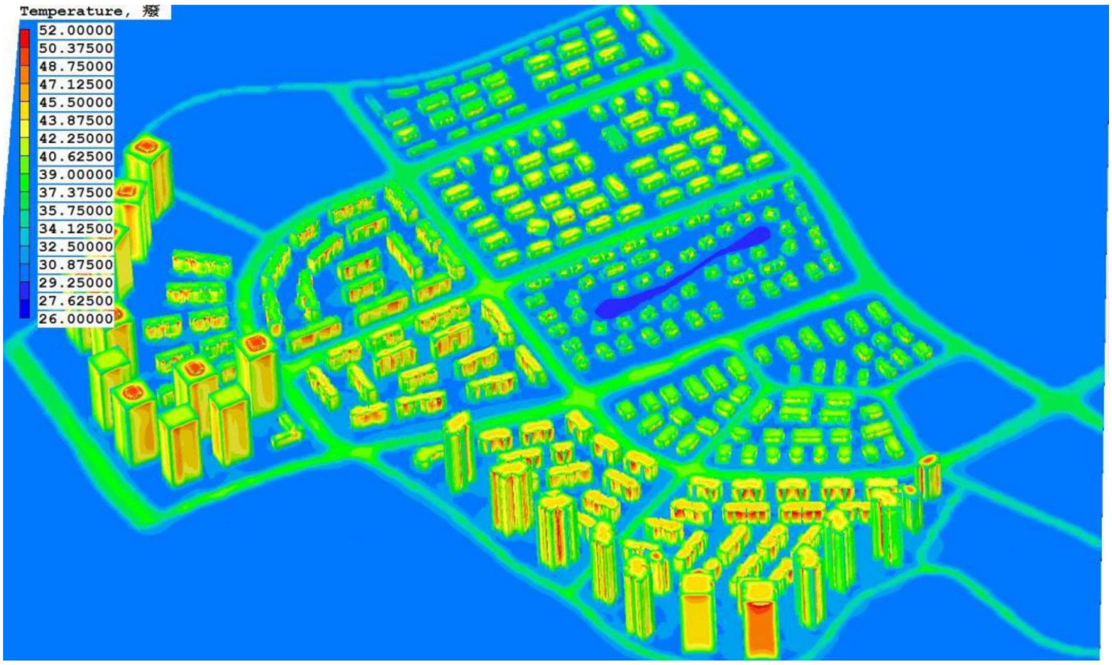

Figure 7.5 Temperature distribution on land surface

- Reduced parking footprint: To limit the surface parking space, only 34 surface parking spaces are designed in selected phases. These spaces only account for less than 2% of the total parking space and mainly serve as temporary parking spaces for the commercial use around residential buildings.
- Ecological value and protection: The project is conducted on land with low ecological value. The project site is surrounded by undeveloped land without any sensitive protection objects, such as natural reserves, scenic areas, ecological function protection zones, basic farmland protection areas, forest parks and geological parks. In addition, by designing green spaces and types of plants, the ecological value on site can be improved.
- Environmental management plan: this project contains an environmental management plan, which aims to mitigate noise, air and water pollution and protect

human health. While it is formulated by the construction company before starting the construction stage instead of during the SPD stage.

7.3.3 Constraints on the Construction Site during SPD

- Given that the west side of the project site is connected to urban roads, the residential buildings along this road are exposed to outdoor traffic noise. To solve this problem, tall trees are designed to be planted around the community to form a green sound barrier. Double glazing glass exterior windows with excellent sound insulation capabilities are also installed in buildings.
- Some areas of the project site have complex topography and show huge differences in their height. Therefore, hanging layers or landscape steps are designed in these areas to reduce too much earthwork. Based on the landscape views and typography of the project site, different types of residential buildings are arranged in different zones.

7.4 CASE STUDY 3: A PUBLIC RENTAL HOUSE

7.4.1 Background Information

The selected case 3 is a public housing estate which located in Hung Shui Kiu, Yuen Long District, New Territories, Hong Kong. According to Hong Kong Government (2013), public housing occupies 60% of the new housing production in Hong Kong. The study area of this case is shown in Figure 7.6. It comprises nine domestic blocks ranging from 16 to 24 stories with a total of 4,905 flats, and the total area is about 6.4

hectares. It was started from about 2008 and completed in 2015, which is the first public estate in Hung Shui Kiu. The Hong Kong Housing Authority project the won the Grand Award in the New Buildings category (Completed Projects - Residential Building) in 2016. The project has already been completed when the case study was conducted. Two architects are involved in this case study interview, one is a senior architect, the other one is a project architect. The interview lasts for about 70 minutes.

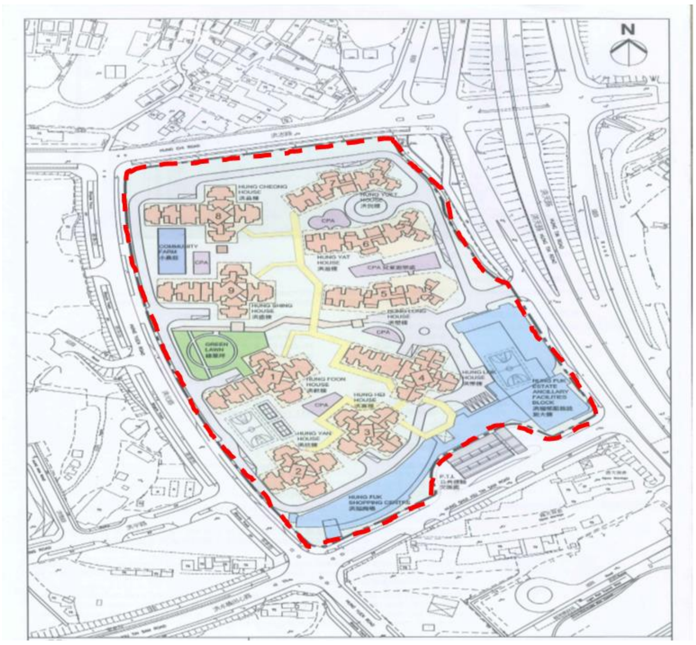

Figure 7.6 Studied area in project 3

7.4.2 Variables Involved in SPD Process

- Land use: When determining the maximum plot ratio of each zone, the constraints on development capacity such as environmental, topological or geotechnical conditions, planning principles and urban design considerations such as local characteristics and settings are considered. The construction site has a plot ratio of

3.5, which is set by the planning department for medium-density public housing. The project site is formerly a low-density neighborhood before the commencement of the project. To improve the environmental quality at the pedestrian level and mitigate the heat island effect, the green ratio of the project site is increased to almost 30% after the commencement of the project. A covered walkway with a tray planter system installed on its roof provides lush greenery that can be seen by residents from domestic blocks.

- Site assessment: Environmental consultants have conducted a series of technical studies before collecting data, exploring the available options and assessing how the possible impacts of the project can be addressed. These technical studies, which include air ventilation assessment, microclimate studies, project feasibility studies, architectural feasibility studies, site potential studies, land use studies, chimney emission impact assessment and ground assessment, are conducted on new housing sites. To avoid the traffic noise around the project, setback was reserved from the major road to the building. Car parks and ancillary blocks are also set along Hong Tin Road and Hung Shui Kiu Tin Sam Road as buffers to traffic noise. When considering the culturally significant features involvement, some Chinese cultural features are incorporated into the design of the estate.
- Open space: The project site has a sitting out area of over 1000 m^2 with various equipment and courts that can be used by residents of all ages. Each person is designated with a 1 m^2 open space, which meets the requirements of the Hong Kong planning guideline. A three-level hierarchy is employed whilst designing the

open space in this estate. A courtyard and plaza are designed at the entrance of the estate to provide its residents with an extensive view. The covered path leads to a butterfly bridge and leisure area. A green community lawn is designed in the central part of the estate for leisure purposes. Several play areas for children are also designed near each block. A mini-woodland and a natural walking path are constructed at the edge of the estate to provide a natural and quiet environment for residents.

- Passive building design: Six photovoltaic panels with poles are installed outdoors to protect the environment and to gather solar energy. The solar energy absorbed during daytime will be converted into electricity before storing, and the stored electricity will then be used to produce adjacent lighting at night. The width of common corridors and lobbies exceeds the statutory requirement, thereby allowing a natural ventilation and enhancing the living environment quality. In the design layout, the blocks are designed parallel to one another, whilst a breezeway spanning from east to west allows the breeze to pass freely through each block and create an exquisite landscape view. In this way, the estate saves energy from air conditioning.
- Green vehicle parking: A total of 139 and 331 parking spaces for cars and bicycles can be found in this estate. Indoor parking spaces with standard charging facilities are also provided for private cars. The other parking spaces are equipped with conduits and cable piles to facilitate the future installation of facilities for charging electric vehicles.
- Landscaping and irrigation: The landscape of the project site includes a natural

walking path, community farm and green lawn where residents can gather. Native plants are specifically used in this landscape because of their high survival rate. Pervious pavements account for 55% of the outdoor pavement area. Some water points are installed for irrigation, and an automatic irrigation system is installed as a supplement in those areas where artificial irrigation is inconvenient. A root zone irrigation system is also installed to mitigate water evaporation and to conserve water. The reuse of construction waste for landscape work has enhanced the environmental awareness of the public. After demolishing roadside planters to build bus stops, the debris (granite blocks) are reused for paving and constructing planters in the estate.

- Storm water management: A rainwater harvesting system is installed to collect rainwater from the rooftops of three domestic blocks. The collected rainwater is then sterilised and stored for irrigating planters.
- Neighborhood daylight access: The vertical daylight factor is calculated by a simulation software at the beginning of the site planning. The orientation and location of the blocks can be adjusted slightly to ensure an adequate distance amongst them and to provide each block with a sufficient access to daylight.
- Cultural heritage: The project site does not have any cultural history. Nevertheless, some Chinese cultural features are incorporated into the design of the estate. A heritage corner and a cultural activity area are also built to promote cultural heritage activities within the area.
- Microclimate around buildings: A building environmental consultant examines the

microclimate and sun shadowing on the project site during the design stage. A breezeway spanning from east to west is also installed to allow the breeze to pass freely through the blocks and to create an exquisite landscape.

- Reduced parking footprint: Most of the parking spaces for the residents are built on an underground space. Some lodge bays are also used for temporary parking.
- Ecological value and protection: The project is developed on a land with little ecological value before the commencement of the project. Based on our green site design, it can be a site with high ecological value because of the presence of community farms, mini-woodlands, green lawns and recycling gardens as well as the reuse of plants from the Long Bin plant nursery. Reusing construction waste for landscape work can also enhance the environmental awareness of the public.
- Environmental management plan: The construction company prepares and implements an environmental management plan in the construction stage. However, this plan is rarely brought up in the SPD stage.

7.4.3 Constraints on the Construction Site during SPD

- The project site is surrounded by four busy roads, including the Hung Chi Road, Hung Yuen Road, Hung Tin Road and Hung Shui Kiu Tin Sam Road. Traffic noise presents a major problem for this green project. Accordingly, domestic blocks are orientated and arranged properly to minimize the impact of traffic noise. The layout and building blocks are also configured to address the site constraints and to limit the traffic noise. A proper setback is designed for the residential buildings located close to Hung Chi Road and Hung Yuen Road, a covered public transport interchange is designed near Hung Tin Road and a shopping centre and ancillary facilities block are established near the roadside to serve as buffers to traffic noise. In addition, the noise barrier placed on top of the ancillary facilities block and the single-aspect corridors of domestic blocks are facing away from the roads to obstruct traffic noise. Noise barrier fins are also installed at several locations of the external wall of these domestic blocks.

- The project site is within the scheduled area no. 2 (Northwest New Territories), which is known for its complex geological conditions. A deeply weathered rock lies 95 m below the ground level in the southern part of the project site. A public transport interchange and some low-rise commercial buildings are constructed in this area to avoid this deep weathering zone.

7.5 FINDINGS FROM THE THREE CASE STUDIES

7.5.1 Analysis 1: Variables and Items in SPD of Green Residential Buildings

Two certified green residential building projects in Mainland China and one green award-winning project in Hong Kong were summarized to further understand the SPD in green residential buildings and the actual variables involved. The SPD of green buildings can be further improved by examining the differences and similarities between the consideration in the proposed framework and in practical projects.

Almost all of 13 variables in the preliminary framework for SPD of green buildings are involved in the three case projects to some extent, thereby underscoring the importance of these variables. However, given their unique characteristics, these projects show slight differences in their variables. Table 7.1 compares the considerations in these cases and summarizes the theoretical framework presented earlier in this research.

Table 7.1 Considerations in SPD in three green projects

NO.	Variable and item	Project 1	Project 2	Project 3
V1	**Land use**			
IT1	Economical and intensive land use	√	√	√
IT2	Development on brownfield	—	—	√
IT3	Sufficient green space consideration	√	√	√
IT4	Rational underground space utilization	√	√	—
V2	**Site condition assessment**			
IT5	Design according to the natural conditions	√	√	√
IT6	Culturally and architecturally significant features involvement	—	—	√
IT7	Air ventilation issues consideration	√	√	√
V3	**Open space**			
IT8	Sufficient open space design	√	√	√
IT9	A comprehensive open space strategy	—	—	—
V4	**Passive building design**			
IT10	Natural elements consideration	√	—	√
IT11	Overhangs and shadings provision	√	√	√
IT12	Solar heating and cooling systems design	—	—	√
IT13	Bulk insulation and reflective insulation use	—	√	—
V5	**Green vehicle parking**			
IT14	Green vehicle parking space provision	√	—	√
IT15	Electric vehicle charging or fueling facilities design	—	—	√
V6	**Landscaping and irrigation**			
IT16	Non-potable water irrigation	√	√	√
IT17	Pre-existing materials use	√	√	√
IT18	Appropriate plantings provision	—	√	√
V7	**Storm water management**			
IT19	Proper storm water management measures	√	√	√
1T20	Storm water storage devices provision	√	√	√
IT21	Storm water infiltration devices provision	√	√	√
V8	**Neighborhood daylight access**			
IT22	Reasonable building density and layout	√	√	√
IT23	Neighboring sensitive buildings daylight access maintenance	—	√	√
IT24	Daylight trespass requirements	√	√	√
V9	**Cultural heritage protection**			
IT25	Cultural heritage protection and preservation	—	—	√
IT26	Compatibility with surrounding cultural heritage	—	—	—

V10	**Microclimate around buildings**			
IT27	Wind velocities in pedestrian areas reduction	√	√	√
IT28	Elevated temperature reduction	√	—	√
IT29	Natural ventilation encouragement	√	√	√
V11	**Reduced parking footprint**			
IT30	Limited surface parking area	√	√	√
IT31	Covered or sheltered parking space design	—	—	—
V12	**Ecological value and protection**			
IT32	Low ecological value land development	√	√	√
IT33	Ecological value-added design	√	√	√
V13	**Environmental management plan**			
IT34	Environmental management documents	—	—	—
IT35	Construction noise mitigation	—	—	—
IT36	Dust and air emission mitigation	—	—	—
IT37	Water pollution reduction	—	—	—
IT38	Human health issues protection	—	—	—

The results of the case study reveal that except for “environmental management documents”, “water pollution reduction”, “human health issues protection”, “dust and air emission mitigation” and “construction noise mitigation”, which all belong to the variable “environment management plan”, the other top 10 most important SPD items identified by the participants are all involved in the three projects. It is worth noting that although interviewees indicated that an environmental management document was considered in their projects, it was prepared and implemented in the construction stage and was rarely brought up in the SPD stage. The interviewed architects regarded “environmental management plan” as a consideration of contractors instead of designers/planners. This finding points to the limited involvement of construction organizations in the SPD of green buildings and casts doubts with regard to the structural integrity of these buildings. The early involvement of contractors in the SPD process is helpful in improving green building development (Molenaar et al., 2009).

The increasingly popular green building delivery methods, such as design–build and integrated project delivery, should also be taken into consideration in the early stage, to elicit an efficient design through team integration (Mollaoglu-Korkmaz et al., 2013; Hwang et al., 2016; Chang et al., 2017).

The comparison among the selected cases shows that some SPD items such as brownfield development, cultural features involvement and cultural heritage protection and preservation, solar energy use, and electric vehicle charging or fuelling facilities design, are considered more comprehensively in Hong Kong than in Mainland China. Such differences can be ascribed to the high green perception in Hong Kong construction and the fact that the government offers more incentives to developers for public projects than for private ones. It is noticed that the cultural heritage protection (V9) and its relevant items are rarely taken into consideration in the three case projects. Only the third project involves some traditional Chinese cultural elements. Wang et al. (2014) stated that protecting and preserving the cultural and historical heritage is one of the greatest concerns in urban renewal initiatives because such projects usually take place in old urban areas. Therefore, cultural heritage is largely ignored in the development of green new buildings.

In addition, some of the identified SPD items have also been ignored in the three case projects, including comprehensive open space strategy, compatibility with surrounding cultural heritage and covered or sheltered parking space design. The exclusion of these items can be ascribed to several factors, including the gaps between theory and practice, the limited resources or time allocated for the project and the lack of consensus on green buildings during the SPD process.

7.5.2 Analysis 2: SPD Process of Green Buildings

When it concerns the process of SPD of green buildings, generally the interviewees agreed with the preliminary framework by the researchers. They also provided valuable suggestions for improvement.

In the first and second projects, the interviewees suggested detailed information regarding each stage of the SPD in green buildings should be contained, such as in briefing/programming, site selection, site analysis, scheme design, detail design and construction document design. Such detailed information further clarifies the SPD process of green buildings.

The application stage of the green building certification process was also further explained by the interviewees. After the construction document design, an application form for green evaluation need to be submitted. If the project successfully passes the green evaluation (which will be conducted by green specialists and green assessors), then a green building design label will be issued.

For the third project, the interviewees suggested that the designers should focus on green consideration and input rather than on green evaluation between the scheme design and detail design stages.

7.5.3 Analysis 3: Relationships amongst Stakeholders

The interviewees generally agreed with the proposed relationships amongst the stakeholders. For the third project, the interviewees suggested that the "green consultants" should be simply referred to as "consultants". They also highlighted the important role of the public in green building projects. Therefore, the requirements and demands of the public and residents should be taken into account in the green building design.

7.5.4 Analysis 4: Design Principles in SPD of Green Buildings

The three projects primarily focused on maximizing the functions of their project sites with a limited budget. Based on this value-oriented principle, the four principles of the preliminary framework were adjusted as follows:

- Based on economic feasibility. SPD is an economically feasible strategy for maximizing the development potential of a green project. The construction operability of these projects should also be considered to enhance the value of the SPD of green buildings.
- Based on natural environment. Site security is the most important consideration in SPD. The planning and design of the project site should consider its natural environment in order to ensure site security. To reduce the amount of earthwork, shorten the construction duration and reduce the related costs, the original typography of the site should be considered in the SPD process.

- Based on social consideration. To promote the sense of belongingness of the users and residents, the cultural and historical characteristics of the project site should be preserved and protected in the SPD of green buildings. The base tones of the city should also be considered in the building design.
- People-oriented consideration. Considering the surrounding transportation and other public facilities during the planning and designing of the site layout can help residents walk to these facilities with ease. A sufficient open space with appropriate design characteristics should also be considered to improve the daily lives of occupants and residents, especially the elderly and children.

7.5.5 Analysis 5: Planning and Design Approaches

Different types of planning and design approaches were adopted in the three projects, and the applicability of the previously proposed approaches was proven to some extent.

The first project adopted the iterative approach to analyze the economic value of different schemes for developing the project site. A proper development scheme was selected after several rounds of discussion and revision to effectively avoid risks.

The two projects in Mainland China adopted a responsive design to take into account the natural environment and conditions of their respective sites. Considering the original typologies of a construction site is especially important for those areas with complex typologies and large differences in their height.

The first and third case projects applied an integrated design, which involved an effective communication and discussion with different stakeholders. This approach helped to facilitate the effective implementation of the project and the realization of its objectives.

A universal design was also applied in the third case project to cater to the different needs of end users and to abide by the people-oriented principle of the project.

The ECOTECT and PHOENICS software were also applied in the first and second case projects to facilitate the SPD process.

ECOTECT is a BIM-based building design and environment analysis tool that contains extensive simulation and analysis functions and creates an easy working environment for designers (Autodesk, 2009). The main features of ECOTECT, such as solar analysis, lighting design, thermal analysis and ventilation, can be applied in SPD of green buildings to simulate and ensure a sufficient neighborhood daylight access and to improve the microclimate around buildings.

PHOENICS is a reliable and cost-effective CFD programme with a good track record in simulating fluid flow, heat transfer or mass transfer, chemical reactions and combustion in various applications. In the SPD of green residential buildings, the air ventilation at the site level was simulated by PHOENICS to ensure a comfortable wind environment in the residential area. This software was also applied to guarantee a favourable microclimate like wind velocities in pedestrian areas and to satisfy the natural ventilation requirements in the areas around buildings.

7.6 AN IMPROVED FRAMEWORK FOR SPD IN GREEN RESIDENTIAL BUILDINGS

An improved framework for SPD in green residential buildings was proposed based on the preliminary framework and the analysis of the case studies as shown in Figure 7.7.

The 13 variables and corresponding 38 items were elaborated in the framework to inform practitioners about the issues that they should consider in SPD of green residential buildings.

In the design principles, except for based on economic feasibility, based on social consideration, and based on natural environment that were stressed in sustainable development, a people-oriented design principle was highlighted because one important objective of green building development is to satisfy the needs of the building occupants. Utilizing the surrounding transportation and public facilities as much as possible can provide the occupants with a convenient living environment, whilst establishing a reasonable open space design can help them in their daily duties.

In the SPD process of green residential buildings, the major steps of SPD are also summarized in this framework to help the stakeholders clearly understand this process. Firstly, a briefing should be conducted by considering the market analysis, user demands and the preferences which is helpful in determining the future use of the site. In green residential projects, site selection should follow the urban and rural planning, and considering the surrounding amenities and local transportation. Then site analysis should be conducted which evaluates the region, climate, resource and topography on and around the construction site. During the scheme design, detail design, and construction documents design, designers should incorporate their green considerations and inputs. Through this process, the green project positioning, detailed green technologies, and scheme analysis and optimization should be confirmed. If the green design passes the green evaluation, the green building design label can be issued, and the project steps in the implementation stage. Green evaluation is applicable after the project completion to summarize the green experiences.

In the relationships of the stakeholders, the government guides and supervises the behaviors of the major participants including the developers, the designers, the consultants, and the contractors who should be cooperate with each other. The public can provide their suggestions of the whole process.

When it relating to the approaches during SPD, several approaches have been taken into account in the three cases studies, such as iterative approach, responsive design, integrated design, and universal design. The summarized nine approaches in this framework can be bear in mind and be combined with simulation software for future SPD, which helps to conduct the SPD effectively.

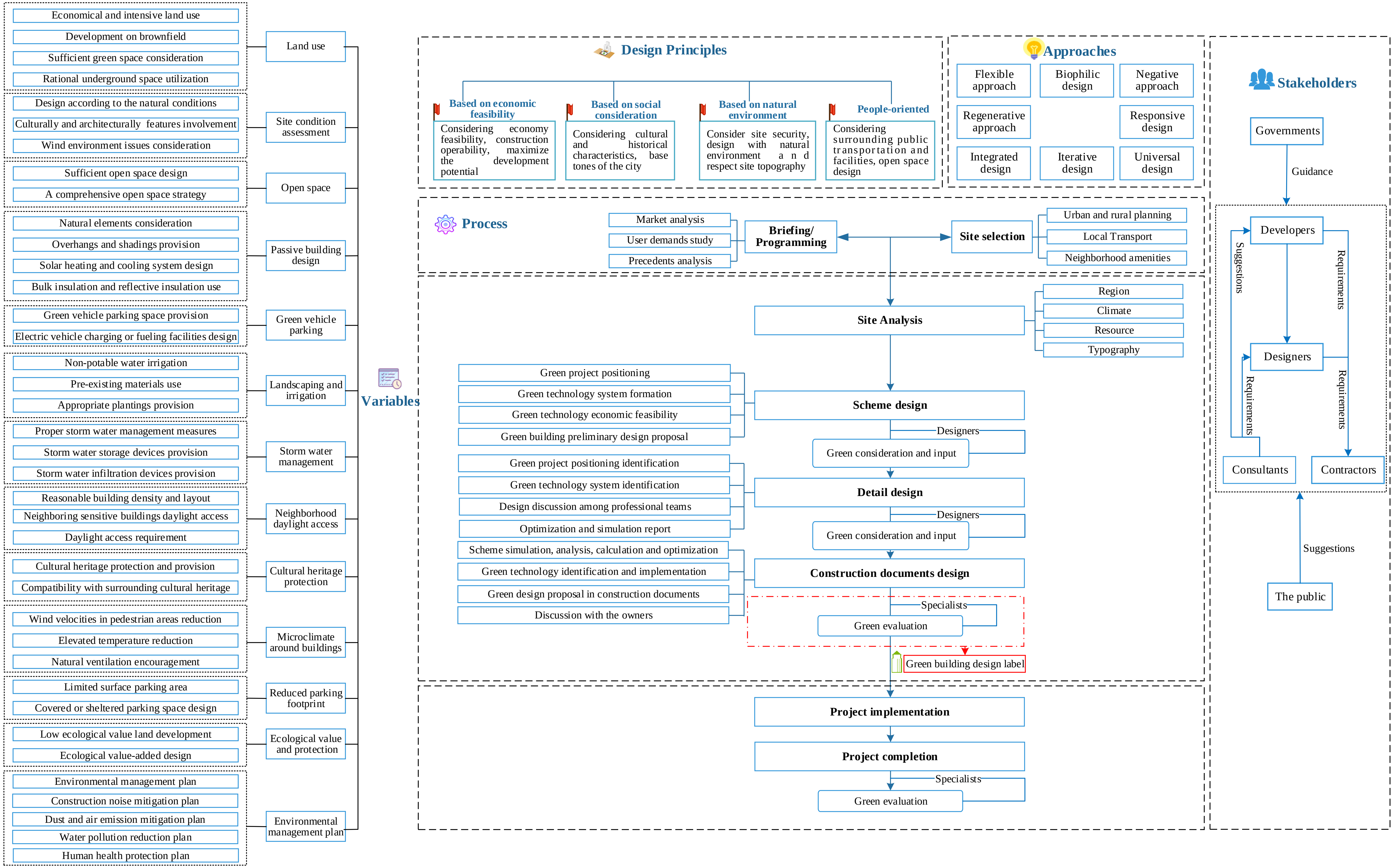

Figure 7.7 An improved framework for SPD in green residential buildings

7.7 SUMMARY

In this chapter, the preliminary framework for SPD in green buildings was improved and validated by conducting case studies. Three green residential projects, including two in Mainland China and one in Hong Kong, were examined to investigate the SPD issues encountered in practice. Document analysis and interviews with practitioners were also conducted. Most of the identified SPD variables were considered in these case projects, and the SPD process, the relationships amongst its stakeholders, the design principles and the planning and design approaches were all improved and validated. An improved framework for SPD in green residential buildings was established based on the preliminary framework and the suggestions and comments of the participants.

CHAPTER 8 IMPROVEMENT AND VALIDATION OF THE FRAMEWORK – FEEDBACK QUESTIONNAIRE

8.1 INTRODUCTION

8.2 PURPOSE OF THE FEEDBACK QUESTIONNAIRE

8.3 DISTRIBUTION AND COLLECTION OF FEEDBACK QUESTIONNAIRE

8.4 ANALYSIS OF THE SURVEY RESULTS

8.5 FINALIZED FRAMEWORK

8.6 SUMMARY

8.1 INTRODUCTION

This chapter discusses the improvement and validation of the improved framework via a feedback questionnaire survey. The agreement amongst the practitioners in the construction industry is tested in the survey. A framework for effective SPD in green residential buildings is then finalized after considering the suggestions and comments of the respondents.

8.2 PURPOSE OF THE FEEDBACK QUESTIONNAIRE

As a supplement to case studies, a feedback questionnaire can help to improve the rigor of the study. The overall perceptions of the practitioners to the proposed framework can be determined and the framework can be further improved and validated. The feedback questionnaire survey was performed in Mainland China and Hong Kong to test whether the proposed framework for SPD in green residential buildings can provide references for the construction industry practitioners to effectively conduct SPD (Appendix D).

8.3 DISTRIBUTION AND COLLECTION OF FEEDBACK QUESTIONNAIRES

In Mainland China, the feedback questionnaire was distributed amongst the participants of the first questionnaire survey and were willing to help to validate the proposed framework. A total of 27 valid responses were collected. Meanwhile, in Hong Kong, the feedback questionnaire was distributed amongst the postgraduate students of PolyU with working experience in the construction industry. To obtain highly reliable feedback, seven experienced architects in Hong Kong were also invited to participate in the survey. 22 valid responses were obtained in Hong Kong. These 49 responses were used to validate the proposed framework. When identifying the potential respondents, their position was considered to ensure that they have enough experience and knowledge. For example, the practitioners with senior management positions were preferred, such as project managers in real estate company and construction company, and senior architects.

8.4 ANALYSIS OF THE SURVEY RESULTS

The background information of the respondents is illustrated in Figures 8.1 and 8.2. Figure 8.1 shows that 41% of the respondents are architects, whilst Figure 8.2 shows that almost 60% of them have worked in the industry for more than 6 years, thereby ensuring that they are knowledgeable enough to provide feedback.

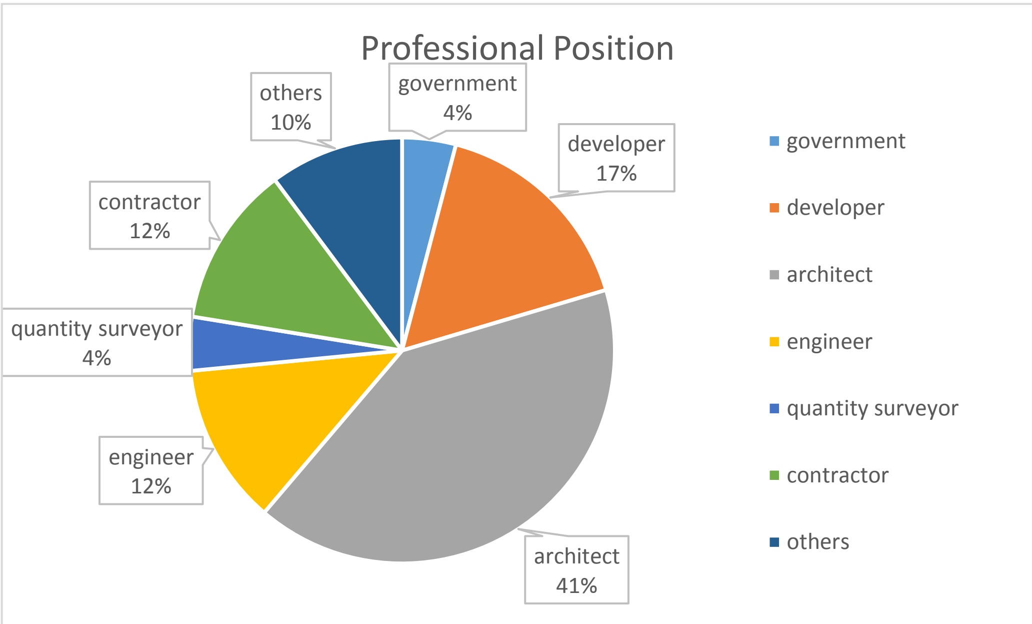

Figure 8.1 Professional post of respondents in the feedback questionnaire survey

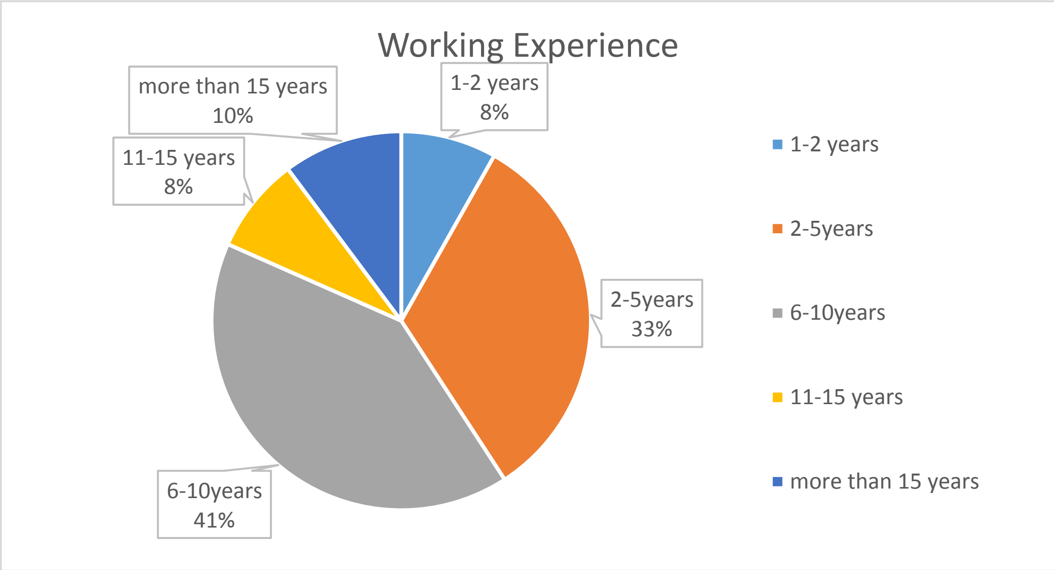

Figure 8.2 Working years of respondents in construction industry

In the feedback questionnaire, the agreement of the respondents with the nine major aspects of the proposed framework was tested. A five-point Likert-type scale was applied to test their agreement, in which 1 indicating “strongly disagree” and 5 indicating “strongly agree”. The feedback questionnaire survey results are summarized in Table 8.1. Each item in the scale received a mean score of above 3, thereby indicating that the respondents are generally satisfied with the proposed framework.

However, when comparing the mean value of the respondence in Hong Kong and Mainland China, it was found that the respondents in Hong Kong were less satisfied than those in Mainland China. To explain this finding, different green building development levels are considered. The green building development in Hong Kong has become relatively rapid and mature since the early establishment of BEAM in 1996. Meanwhile, although the development of green buildings in Mainland China started from 1992, the first GBRT was only established in 2006. Overall, the proposed framework for the SPD of green buildings can be used as reference to effectively conduct SPD, especially for practitioners in Mainland China.

Table 8.1 Feedback questionnaire survey results

Descriptions	**Mean**	**Mean 1**	**Mean 2**	**Std. Deviation**
a) The structure of the framework is well-organized.	4.08	3.86	4.26	.6469
b) The contents of the framework are appropriate.	4.00	3.86	4.11	.5835
c) The variables and items in the framework are complete.	3.96	3.81	4.07	.7133
d) The SPD process is clear and appropriate.	4.06	3.86	4.22	.6967
e) The design principles in the framework are comprehensive.	3.94	3.90	3.96	.6654
f) The approaches include adequate design and planning methods in practice.	4.00	3.71	4.22	.6842
g) The relationship of stakeholders is clear and appropriate.	3.90	3.62	4.11	.7506
h) The framework provides me useful information in SPD of a green building.	4.04	3.81	4.22	.6510
i) The framework will be used as a reference for effective SPD of green buildings.	4.13	3.76	4.41	.6724

Note: Mean is from all respondents, Mean 1 is from respondents in Hong Kong, Mean 2 is from respondents in Mainland China.

8.5 FINALIZED FRAMEWORK

When the respondents were asked to describe things they like most in the framework, most of the respondents agreed that the proposed framework provided comprehensive and detailed information about SPD of green residential buildings and that the variables were clearly distributed and defined. They also commented that the improved framework incorporated different aspects and had a clear, broad classification. Some thought that the proposed principles were sufficiently comprehensive, and they regarded economic feasibility as an important concern in the implementation of green building projects. The respondents also agreed that the roles of stakeholders in the SPD process were clearly stated.

The respondents were also asked about things they recognized as difficult in the framework. Most of them mentioned that the approaches mentioned in this framework were not elaborated and were difficult to understand based on their names alone. Given that the applicable approaches in SPD are elaborated in Chapter 6, explaining these approaches again in the framework would be redundant. Therefore, all the remaining approaches in the finalized framework are assigned with simple names. Some respondents also mentioned that the framework was quite complex to read because it incorporates plenty of information.

The respondents also provided some valuable suggestions after they were asked about how this framework can be improved. Firstly, they suggested that the statutory requirements of governments should be included as a precondition in the SPD of green buildings. Secondly, they suggested that the development of the framework should be clarified. The forms should be arranged in a logical manner so that the readers can trace the whole SPD process in a sequential way. Thirdly, they pointed out that the framework contained too much information about the variables and items, thereby increasing its potential to confuse the readers. Instead, these variables and items should be regrouped into broad categories. After incorporating these suggestions, the finalized framework for the SPD of green buildings was revised as shown in Figure 8.3. As in green building development, the developers play a proactive role and have contract relationships with other stakeholders, it will be better if the developer can lead the framework development and cooperate with the designers, consultants, and contractors.

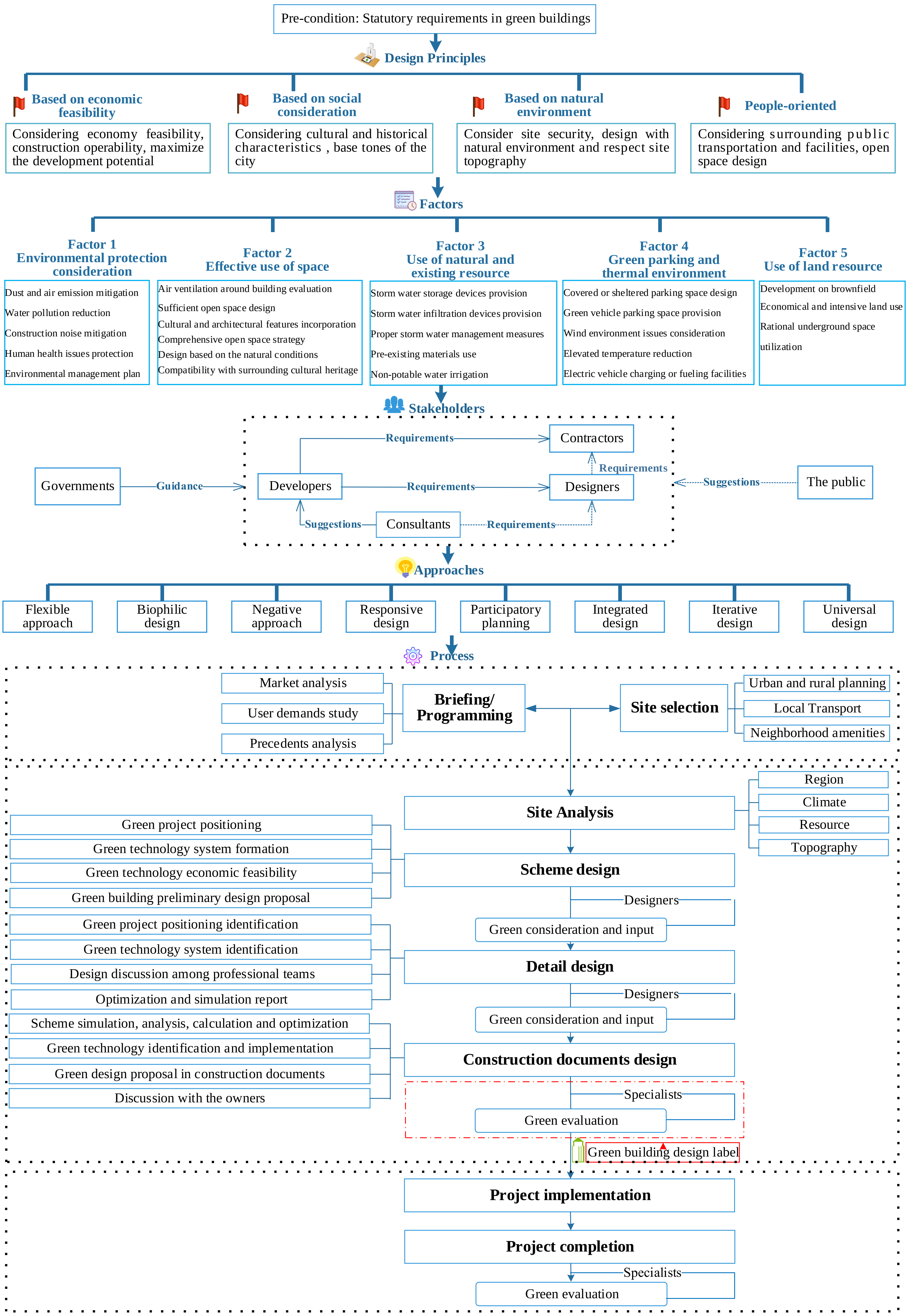

Figure 8.3 A framework for effective SPD of green residential buildings

8.6 SUMMARY

In this chapter, the proposed framework was improved and validated by conducting a feedback questionnaire survey in Mainland China and Hong Kong. The respondents generally agreed that the framework was comprehensive and could be used as reference for the participants in the SPD of green buildings. These respondents also provided valuable comments and suggestions that were considered in the finalized framework.

CHAPTER 9 CONCLUSIONS

9.1 INTRODUCTION

In this chapter the whole process of the research study is concluded. Firstly, the research aim and objectives are reviewed, and a summary of the major research findings is presented. Secondly, the significance and contribution of this research are presented. Thirdly, the limitations of this research are referred to and some recommendations for future research work are provided.

9.2 REVIEW OF THE RESEARCH OBJECTIVES

Green buildings have received much attention in recent years as a sustainable development practice. An effective SPD presents a key issue in the development of a sustainable site and ensures that the construction site is functionally efficient, aesthetically pleasing and environment friendly. Although previous studies have raised many issues related to SPD, a comprehensive framework for the SPD of green buildings is yet to be developed. The GBRTs being used around the world have also identified some variables and items related to SPD. However, the perceptions of construction industry practitioners towards these items have not been investigated. In addition, only few studies have explored how to implement an effective SPD of green buildings. Accordingly, this research study aims to develop a framework for effective SPD in green residential buildings.

To achieve the research aim, the following objectives are laid out for this research:

1) to establish a theoretical framework for SPD in green residential buildings;

2) to generate a list of variables that can affect SPD in green residential buildings and to identify critical factors during this process;

3) to develop a preliminary framework for effective SPD in green residential buildings;

4) to improve and validate the effectiveness of this framework in supporting SPD in green residential buildings.

The first objective was achieved through a thorough literature review and by interviewing experienced researchers. As shown in Section 5.3, five major GBRTs being used worldwide were examined to identify the variables related to SPD of green residential buildings. The variables in the theoretical framework were finalized by conducting interviews with 3 experienced researchers in green buildings.

The second objective was achieved by conducting a literature review and a questionnaire survey. Section 6.2 determines the items related to the SPD of green buildings based on the identified variables. A questionnaire survey was also designed and conducted to investigate the importance of and difficulty to realize the items in practice and to identify the critical factors in SPD of green buildings. Statistical analysis was also performed to explore the critical factors in SPD as reflected in the data.

The third objective was achieved according to the critical factors identified in the questionnaire survey and the results of face-to-face interviews. A qualitative analysis was conducted via NVivo to analyze the interview data. The components of the framework were eventually summarized.

The fourth objective was achieved by performing case studies and a feedback questionnaire survey. Firstly, document analysis and interviews with green building practitioners were conducted in case studies to investigate the SPD in practice and its differences from the proposed framework. Secondly, a feedback questionnaire survey was used to further improve and validate the proposed framework, and the comments and suggestions provided by the respondents were applied to improve the framework.

9.3 MAJOR RESEARCH FINDINGS

To facilitate the SPD in green buildings, this research study proposed a framework that included the factors, process, stakeholders, principles and approaches in SPD of green residential buildings.

By reviewing 5 major GBRTs and interviewing 3 experienced researchers, 13 SPD-related variables were identified, including “land use”, “site assessment”, “passive building design”, “open space”, “green vehicle parking”, “reduced parking footprint”, “ecological value and protection”, “cultural heritage”, “landscaping and irrigation”, “microclimate around buildings”, “neighborhood daylight access”, “storm water management” and “environmental management plan”. The theoretical framework was then established to identify how the variables affect the SPD of green buildings.

According to the theoretical framework, 38 items related to the SPD of green buildings were identified to provide the foundation for a questionnaire survey. The questionnaire was then designed to investigate the perceptions of green building practitioners towards these items. Statistical analysis was applied afterwards based on the collected data to evaluate the importance and difficulty of these SPD items in green buildings. Exploratory factor analysis was then used to investigate critical factors of SPD in green buildings.

By conducting face-to-face semi-structured interviews with 12 experienced practitioners and researchers in the area of green building development, a preliminary framework for effective SPD in green residential buildings was developed. The SPD process in green buildings was then developed based on the existing SPD processes. Three sustainable principles were generated from the natural, social and economic aspects. The relationships amongst the SPD stakeholders, such as the government, developers, designers, consultants, contractors and the public, were established, and several approaches that could facilitate an effective SPD in green residential buildings were identified, including flexible planning, negative planning, biophilic design, regenerative design from the mid or macro perspectives, integrated design, responsive design, iterative design and universal design from the micro perspective.

The proposed framework was improved and validated by conducting three case studies and a feedback questionnaire survey. The case studies on two green projects in Mainland China and one in Hong Kong identified several issues related to the SPD of green buildings in practice. Document analysis and interviews with one or two practitioners in these projects were also conducted to compare the proposed framework with the practical concerns. A feedback questionnaire survey was conducted to check whether this framework can provide a reference for the effective SPD in green residential buildings. The proposed framework for effective SPD in green residential buildings was then validated and finalized based on the comments and suggestions of the participants.

9.4 SIGNIFICANCE AND CONTRIBUTION OF THE RESEARCH

This research study proposes and tests a framework for effective SPD in green residential buildings in China. Based on the research findings, the critical factors in SPD of green residential buildings were identified whilst the process, stakeholders, principles and approaches of SPD in green residential buildings were investigated. These research findings are deemed significant because despite being a well-developed concept, SPD has been rarely examined comprehensively in the context of green residential buildings. Developing a framework specifically for SPD in green residential buildings not only helps to improve the present understanding of this process but also provides a valuable reference for conducting this process effectively.

The research findings offer several contributions to research and practice. For researchers, the proposed theoretical framework provides a basis for understanding the SPD in green residential buildings. These research findings also offer some implications to the construction industry. The identified variables, items and critical factors in SPD of green buildings can help researchers and practitioners develop a comprehensive understanding of the key issues within this process. Meanwhile, the identified sustainable principles can assist stakeholders in conducting SPD in green residential buildings effectively. The application of certain design and planning approaches also enhances the effectiveness of this process. Therefore, the components of the proposed framework for SPD in green residential buildings provide valuable references for both academics and industry practitioners.

9.5 LIMITATIONS AND FUTURE RESEARCH RECOMMENDATIONS

Two major limitations are included in this research. Firstly, due to the limited time and resources, this research was only conducted in Mainland China and Hong Kong. The questionnaire survey in Hong Kong yielded a relatively low response rate of 19%. The limited sample size in Hong Kong may comprise the comparison of the importance of SPD in green residential buildings between respondents in Mainland China and Hong Kong. Secondly, this research was only conducted in the context of China and primarily focused on new residential buildings. The SPD of green buildings may involve different considerations across different countries and building types.

Therefore, as this research study provides reference for conducting effective SPD in new residential green buildings, possible future research recommendations are as follows:

Firstly, the sample size can be enlarged by including other regions. Given that this research investigates the perceptions of practitioners towards the importance of and difficulty to realize these SPD items in green residential buildings based on a questionnaire survey and that different considerations may be involved across each region or climate, using a larger sample size can enhance the soundness of the analysis results.

Secondly, given that the proposed framework for SPD in green residential buildings has been validated by conducting three case studies and a feedback questionnaire survey, more types of real-life green building projects could be involved from the early planning and design stage to further develop a how-to guide based on the proposed framework.

APPENDIXES

APPENDIX A: QUESTIONNAIRE ON SITE PLANNING AND DESIGN (SPD) IN GREEN BUILDINGS

Site Planning and Design (SPD) is an early stage in green building development, and site planners must consider how to minimize the disturbance on construction site. Site planning is the art of arranging structures on the land and shaping the spaces between architecture, engineering, landscape architecture and city planning. To apply SPD strategy in green buildings can lay an important foundation for sustainable development.

Section A: Background Information

Q1. Please indicate the type of your organization

□Government sector □Real estate development organization □Design institute □Construction organization □Architecture firm □Supervision company □Consultation company □Others

Q2. Please indicate how long you have been participated in work relating to green building

□Less than 2 years □2-5 years □6-10 years □11-15 years □More than 15 years

Q3. Please indicate the work type that you are involved in

□Planning approval □Project management □Green design □Construction management □Surveying management □Green consultation □Others

Q4. The number of projects you have been involved in

□Less than 5 □6-10 □11-20 □More than 20

Q5. The number of on-site construction workers in the project you are involved in

□Less than 50 □51-100 □101-200 □More than 200

Section B: Items of SPD in Green Buildings

Q6. Items of SPD in green buildings

Previous studies of green SPD have made the following statements. Please indicate your level of agreement or disagreement with each statement. Please indicate your agreement according to your own understanding of SPD in green buildings. For the importance of each item, 1 = extremely unimportant, 2 = unimportant, 3 = neutral, 4 = important, and 5 = extremely important. Please mark in the corresponding box.

Variables and items of SPD in green buildings											
1)	**Land Use**	**Importance**					**Difficulty**				
a)	Economic and intensive land use should be the first and foremost concern in SPD of green buildings	1	2	3	4	5	1	2	3	4	5
b)	The construction project should be recommended to be developed on brownfield	1	2	3	4	5	1	2	3	4	5
c)	Enough green space should be considered in SPD of green buildings	1	2	3	4	5	1	2	3	4	5
d)	Rational underground space utilization should be involved in SPD of green buildings	1	2	3	4	5	1	2	3	4	5
2)	**Site Assessment**	**Importance**					**Difficulty**				
a)	SPD in green buildings should be designed according to the natural conditions on site	1	2	3	4	5	1	2	3	4	5
b)	Culturally and architecturally significant features should be incorporated in SPD	1	2	3	4	5	1	2	3	4	5
c)	Air ventilation issues on site level should be considered properly	1	2	3	4	5	1	2	3	4	5
3)	**Open Space**	**Importance**					**Difficulty**				
a)	Enough open space should be designed for attractive surroundings	1	2	3	4	5	1	2	3	4	5
b)	A comprehensive open space strategy should be formed to lay a foundation to open space planning and action	1	2	3	4	5	1	2	3	4	5
4)	**Passive Building Design**	**Importance**					**Difficulty**				
a)	Passive building design should be used in accordance with the natural elements in SPD of green buildings	1	2	3	4	5	1	2	3	4	5
b)	Summer temperatures should be reduced by providing overhangs and shadings	1	2	3	4	5	1	2	3	4	5
c)	Solar heating and cooling systems should be designed to reduce energy use	1	2	3	4	5	1	2	3	4	5
d)	Bulk insulation and reflective insulation should be used to improve living comfort	1	2	3	4	5	1	2	3	4	5

5)	Green Vehicles Parking	Importance					Difficulty				
a)	Certain percentage of parking spaces for green vehicles should be provided	1	2	3	4	5	1	2	3	4	5
b)	Electric vehicle charging or fueling facilities for green vehicles should be designed in SPD of green buildings	1	2	3	4	5	1	2	3	4	5
6)	**Landscaping and Irrigation**	**Importance**					**Difficulty**				
a)	Non-potable water using should be designed for landscape irrigation	1	2	3	4	5	1	2	3	4	5
b)	Pre-existing materials should be used for hard landscaped areas	1	2	3	4	5	1	2	3	4	5
c)	Appropriate plantings should be provided on construction site	1	2	3	4	5	1	2	3	4	5
7)	**Storm water Management**	**Importance**					**Difficulty**				
a)	Proper storm water management measures should be taken to manage surface runoff	1	2	3	4	5	1	2	3	4	5
b)	Storm water storage type devices should be set rationally	1	2	3	4	5	1	2	3	4	5
c)	Storm water infiltration type devices should be set rationally	1	2	3	4	5	1	2	3	4	5
8)	**Neighborhood Daylight Access**	**Importance**					**Difficulty**				
a)	Reasonable building density should be ensured on construction sites	1	2	3	4	5	1	2	3	4	5
b)	Access to daylight of neighboring sensitive buildings should be maintained	1	2	3	4	5	1	2	3	4	5
c)	Daylight and light trespass requirements should be met	1	2	3	4	5	1	2	3	4	5
9)	**Cultural Heritage**	**Importance**					**Difficulty**				
a)	Proper measures should be taken to protect and reserve cultural heritage on site	1	2	3	4	5	1	2	3	4	5
b)	New buildings should be compatible with the heritage features	1	2	3	4	5	1	2	3	4	5
10)	**Microclimate around Buildings**	**Importance**					**Difficulty**				
a)	Wind velocities on pedestrian area should be reduced to ensure pedestrian comfort	1	2	3	4	5	1	2	3	4	5
b)	Proper measures should be taken to mitigate elevated temperatures	1	2	3	4	5	1	2	3	4	5
c)	Natural ventilation should be encouraged for higher indoor air quality	1	2	3	4	5	1	2	3	4	5
11)	**Reduced Parking Footprint**	**Importance**					**Difficulty**				
a)	The amount of land area dedicated to surface parking should be limited	1	2	3	4	5	1	2	3	4	5
b)	Covered or sheltered parking space should be	1	2	3	4	5	1	2	3	4	5

	designed to reduce parking footprint									
12)	**Ecological Value and Protection**	**Importance**					**Difficulty**			
a)	Developing green building on low ecological value land should be encouraged	1	2	3	4	5	1	2	3	4	5
b)	Appropriate design measures should be implemented contributing to the ecological value	1	2	3	4	5	1	2	3	4	5
13)	**Environmental Management Plan**	**Importance**					**Difficulty**			
a)	An environmental management plan should be implemented on site	1	2	3	4	5	1	2	3	4	5
b)	Adequate mitigation measures for construction noise should be provided on site	1	2	3	4	5	1	2	3	4	5
c)	Adequate mitigation measures for dust and air emissions should be applied on site	1	2	3	4	5	1	2	3	4	5
d)	Adequate measures to reduce water pollution should be undertaken on site	1	2	3	4	5	1	2	3	4	5
e)	Adequate measures for human health issues should be implemented on site	1	2	3	4	5	1	2	3	4	5

Q7. Are there any other considerations should be involved in SPD in green buildings?

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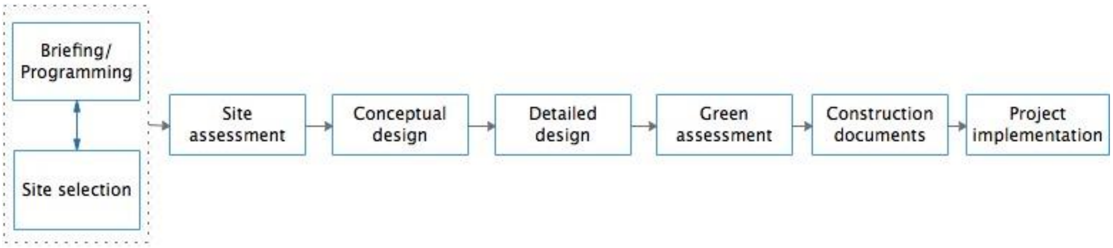
-The end-

Thanks for your participation

APPENDIX B: INTERVIEW GUIDE

1. According to your own experience in site planning and design (SPD) in green buildings, what are the major differences when comparing with conventional buildings?
2. Based on the SPD process developed by LaGro Jr (2011), the researchers revised the process in green building context, do you think the process is clear and complete?



3. In the site planning and site design in green buildings, how to involve stakeholders in the process?
4. Based on the literature review, three sustainable principles in site planning and site design in green buildings were identified:
   - Based on efficient resource use
   - Based on surrounding conditions
   - Based on natural environments

Do you think that there are any other principles should be followed in this process?

5. What do you think are the major obstacles and reasons in site planning and site design in green buildings?
6. What s approaches or suggestions do you think can be applied effectively in site planning and site design in green buildings?

APPENDIX C: INTERVIEW QUESTIONS IN CASE STUDIES

A preliminary framework for site planning and design(SPD) in green buildings was established by the researchers, including the process, major factors, stakeholder relationships, sustainable principles, and planning approaches. To explore in more details on specific issues and further develop the framework, the following interview questions are proposed. Please give your comments to these questions according to your working experience as far as you can.

Case study as illustration	**Please provide details**
Part 1: Basic information Please provide the following basic information of the project.	
Project location	
Project type	
Project size	
Contract sum	
Project duration	
Stage of the project	
Your position in the project	

<u>Part 2: Factors in site planning and site design of green buildings</u> Please identify that in the following factors, which are involved and how they are involved in site planning and site design in your project?	
Land use (Economic land use, green space consideration, underground space utilization)	
Site condition assessment (Design based on site conditions, culturally and architecturally significant features involvement, air ventilation issues consideration)	
Open space (Enough open space design, open space strategy consideration)	
Passive building design (Natural elements consideration, overhangs and shadings provision, solar energy use, insulation use)	
Green vehicle parking (Green vehicle parking space provision, electric vehicle charging or fueling facilities design)	
Landscaping and irrigation (Non-potable water irrigation, pre-existing plantings use, appropriate plantings provision)	
Storm water management (Storm water storage and infiltration devices provision, proper storm water management measures)	

Neighborhood daylight access (Reasonable building density, daylight access to neighboring sensitive buildings maintenance)	
Cultural heritage protection (Cultural heritage protection and preservation, compatibility with surrounding cultural heritage)	
Microclimate around buildings (Wind velocities reduction in pedestrian area, Elevated temperature reduction, natural ventilation encouragement)	
Reduced parking footprint (Limited surface parking area, covered or sheltered parking space design)	
Ecological value and protection (Low ecological value land development, ecological value protection)	
Environmental management protection (Environmental management plan, construction noise mitigation, dust and air emission mitigation, water pollution reduction, human health protection)	

Part 3: Open-ended questions Please provide your opinions on the following questions according to your experience in this project.	
What technologies are applied for effective site planning and design?	
What effective approaches are involved in this process?	
What are the constraints on site during this process? How these constraints are solved?	
Do you have any other suggestions to further develop this framework?	

APPENDIX D: FEEDBACK QUESTIONNAIRE

Instruction: Please tick (√) in an appropriate box in Section A and input text into the space provided in Section B. (The developed framework is attached as a PDF file.)

Section A

1. Please indicate your professional post.

□Government □Developer □Architect □Engineer □Quantity Surveyor □Contractor □Others______________

2. Please indicate your working experience.

□Less than 2 years □2-5 years □6-10 years □11-15 years □More than 15years

3. To what extent do you agree with the following statements?

(SA: Strongly Agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree)

	SA	A	N	D	SD
a) The structure of the framework is well-organized.	5	4	3	2	1
b) The contents of the framework are appropriate.	5	4	3	2	1
c) The variables and items in the framework are complete.	5	4	3	2	1
d) The site planning and design process is clear and appropriate.	5	4	3	2	1
e) The design principles in the framework are comprehensive.	5	4	3	2	1
f) The approaches include adequate design and planning methods in practice.	5	4	3	2	1
g) The relationship of stakeholders is clear and appropriate.	5	4	3	2	1
h) The framework provides me useful information in site planning and site design of a green building.	5	4	3	2	1
i) The framework will be used as a reference for future site planning and site design of green buildings.	5	4	3	2	1

Section B

4. What are the things you like MOST in this framework?

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

5. What are the things you found DIFFICULT in this framework?

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

6. What are the things you want to BE IMPROVED in this framework?

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

Thank you very much for completing this questionnaire!

-THE END-

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