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Factors Affecting Green Residential Building Development: Social Network Analysis

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Abstract: Green residential buildings (GRBs) are one of the effective practices of energy saving and emission reduction in the construction industry. However, many real estate developers in China are less willing to develop GRBs, because of the factors affecting green residential building development (GRBD). In order to promote the sustainable development of GRBs in China, this paper, based on the perspective of real estate developers, identifies the influential and critical factors affecting GRBD, using the method of social network analysis (SNA). Firstly, 14 factors affecting GRBD are determined from 64 preliminary factors of three main elements, and the framework is established. Secondly, the relationships between the 14 factors are analyzed by SNA. Finally, four critical factors for GRBD, which are on the local economy development level, development strategy and innovation orientation, developer's acknowledgement and positioning for GRBD, and experience and ability for GRBD, are identified by the social network centrality test. The findings illustrate the key issues that affect the development of GRBs, and provide references for policy making by the government and strategy formulation by real estate developers.

Keywords: green residential building; social network analysis; influential factors; critical factors; development strategy

1. Introduction

Resource shortage and environmental deterioration affect the development of the construction industry. It is estimated that, in China, the construction industry consumes 40–50% of raw materials and about 20% of energy [1]. Although many functions have been submitted to reduce energy consumption [2–4], there are great numbers of high-energy consuming buildings in China, many of which are currently under construction [1]. Green building (GB), as one of the best practices of sustainable development in the construction industry, has drawn much attention [5–8]. Many researches of GB have been analyzed from different aspects, for example: Technological innovation [9–11], energy saving [12–14], risk management [15–18], influential factors for development [19–21], policy incentives and regulations [22–24], and economical benefit [25–27] etc.

In particular, the energy consumption of residential buildings is far more than that of other types, accounting for about 70% of CO_2 emissions of the whole construction industry, and affecting residents' psychological and physical health [28,29]. In order to meet the national policy of China's sustainable development and the strategy of low carbon economy, and to promote the transformation and development of Chinese real estate enterprises, the Chinese housing market has transferred into "the era of green residential buildings (GRBs)" [30,31]. However, in China, green residential building development (GRBD) is still in its infancy [32,33]. Many barriers exist in the development process, such as high hurdle rates for new developers [34], and lack of experience and financial incentive [35,36].

GRBs are different from general GBs. The general public GBs are inclined to adopt environmentally friendly technology with the support and initiative of the government [37]. The development of commercial buildings for residential use is usually conservative on energy saving and environment protection because of the benefit segmentation between developers and users [38]. GRBD is a complex process with multiple organizations and social backgrounds, and the developers, as a core stakeholder, play an important role in the whole process [39]. The whole process of GRBD is restricted by the elements of the environment, resources, and technology. The determination of the relationships between the influencing GRBD factors and the critical factors affecting GRBD will help to improve the enthusiasm of developers in China. Thus far, limited studies have explored how to encourage developers on the GRBD.

The paper contributes to the body of knowledge from three aspects: Firstly, based on the whole life cycle of GRBD and the perspective of real estate developers, 14 factors affecting development are determined from 64 preliminary factors of three main elements, and the framework is established. Secondly, the incidence matrix and adjacency matrix of 14 factors according to the method of questionnaire survey and social network analysis (SNA). The sociogram is helpful for analyzing the relationships and the impact between different factors. Finally, the critical factors are determined through the centrality of influential factors. The results of critical factors are conducive to promoting policy recommendations and development strategies for developers.

2. Literature Review

2.1. Factors Influencing GRBD

Since the concept of GBs was clearly defined in the United Nations Conference on Environment and Development in 1992, more and more researches on GBs have been carried out. Early researches focused on the concept, influence factors, and evaluation [40–42]. However, scholars have found that there are some differences in factors and evaluation systems in different types of GBs, and the researches on GRBs are particularly prominent [32,43].

GRB, which is one of the best practices of sustainable development in the architectural field, is an important branch of GB [40]. Many countries have done a lot of research into the construction of GRBs, for example: Singapore [44,45], UK [46], USA [40], China [47–49], and India [50]. There are many stakeholders in the process of GRBD, and the relationships between influential factors are extremely complex. The government actively promoting GRBD, the residents having some knowledge on GRB, and the maturing technology of GRB all affect GRBD uptake, however obstacles to its widespread adoption still exist [47,51]. In order to solve the obstacles, many factors have been studied from different elements.

A variety of environmental elements have a strong impact on GRBD. The conservatism of environmental policy and legal factors will affect the enthusiasm of developers. Proper implementation of fiscal incentives, preferential policy frameworks, and effective evaluation mechanisms will have beneficial effects on GRBD [32,52]. GRBs are different from general residential buildings, therefore, the natural environment and social environment will restrict site selection, construction, and resource utilization [53]. The implementation of GRB is also affected by the development of the regional economy and green technology [50].

GRBs, similar to general residential buildings, involve many stakeholders in the development process. The standard specification and strictness of examination and approval will promote the operation of the GRB market [54]. Considering the constraints of environmental elements, low cost and energy saving are encouraged from the beginning of design. "Sustainable designing and planning", "education and awareness of GRB", and "economic aspects relating to various costs" are the banks' credit standards for GRBD [45,53]. The shortage and high price of green materials are also barriers for enterprises to develop GRBs [18]. Wong, et al. (2016) [55] proposed that a green material market, which is dominated by the government and cooperates with suppliers and developers, should be

established to promote the implementation of green purchasing, to improve the quality, and to gradually reduce the cost. However, some studies have pointed out that the green purchasing imposed by the government will hinder the development of the green material market [56]. In addition to the government, banks, designers, developers, and material suppliers, effective supervisors do not only ensure the quality of the projects, but also reduce the delay of the process to ensure the confidence of consumers [57]. Consumers' acknowledgement and demand for GRB is an important factor affecting GRBD [47,58]. Paying attention to the marketing of GRB, which is also a positive impact on GRBD, will also improve the public's acquisition of environmental protection and GRB information [32,59].

Although many stakeholders are involved in GRBD, the successful implementation of GRB projects is closely related to the developers [60]. Li, et al. (2011) [44] explored the important GRB project management factors, from the perspective of architectural, engineering, and construction (AEC) firms, which were human resource-oriented factors, technical and innovation-oriented factors, support from designers and senior management, project manager's competence, and coordination of designers and contractors. The critical factors for the success of GRB projects are "coordination of designers and contractors" and "technical and innovation-oriented factors". Marker, et al. (2014) [61] argued that the improvement and change of employees' cognition can effectively influence the development and application of GRB. Hwang, et al. (2016) [62] indicated that workers' experience, technology, design changes, workers' skill level, and planning and sequencing of work were the top five most critical factors affecting GRBD. However, Li, et al. (2014) [63] illustrated "experience and knowledge in GRB", "organizational green culture", and "innovation capability" were more important than other factors. Shen, et al. (2017) [64] confirmed this view with the empirical study in Thailand.

2.2. The Application of SNA in GRBD

SNA, which originated in the 1840s as an important branch of sociology, was used to study the social structure of a small fishing village in Norway in 1954, and to study the British social network in 1957 [65]. The purpose of SNA is to reveal the influence of network structure on group and individual function, starting with the interaction of structure and function. The specific practice is to explore the relationship between the actors in the social network and determine the relationship characteristics, so as to discover the influence of relationships to the organization [66,67].

The two most important components of SNA are the actors and relationships. Therefore, SNA can help us to understand the cooperative relationship between organizations in various fields [68]. There are few studies on the development and application of GRBs on SNA. A few studies are mainly from the perspective of stakeholders to analyze the risk network in the process of GRBD [17,69,70]. In fact, from the perspective of technology and combining BIM and SNA, the analysis of the life cycle energy of building will help to provide effective residential energy-saving design plan [71]. In addition to analyzing the risks in the development of construction projects, SNA can also analyze the factors affecting the development of the projects according to the interdependence of the stakeholders [72].

From the literature review, it can be seen that the studies on the influential factors of GRBD are rather fragmented and lack a systematic nature and unity. Although some studies involve stakeholders in GRBD, the whole life cycle of development is not considered. In addition, it has been proved that the SNA method can analyze the influential factors of the whole life cycle of construction projects, but the existing social network application of GRBs mainly focuses on the risk analysis. This paper, based on the whole life cycle of GRBD, will use SNA to explore relationships of influential factors of GRBs and identify the critical factors affecting GRBD. We expand the application of SNA in the study of GRBD.

3. Research Method

3.1. Identification of Factors Influencing GRBD

This paper, according to the perspective of real estate developers, explores the factors influencing GRBD, from environmental elements, resource elements, and capacity elements. Environmental elements refer to the external factors that are generated in the process of GRBD; resource elements refer to the factors that influence how developers obtain possible resources with personal effort during the whole developing process; and capacity elements refer to developers' evaluation, objective, and ability [44]. The three dimensions are different, but they interact with each other, as shown in Figure 1.
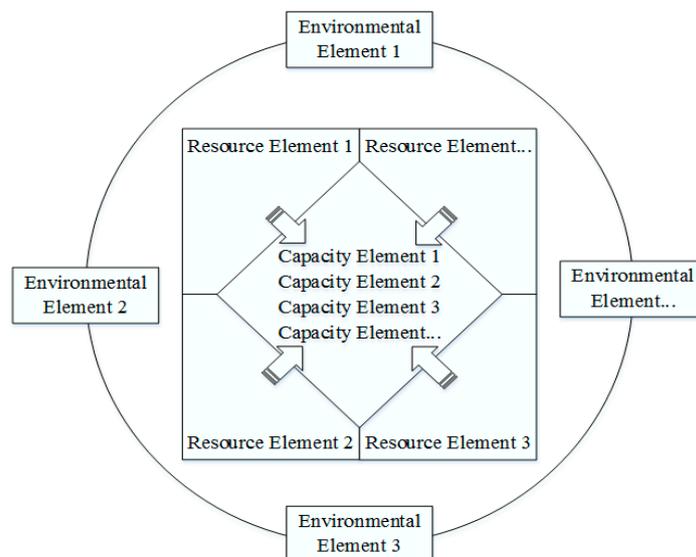
Figure 1. The relationship of elements from three dimensions.

Based on the above three dimensions, from the literature, laws, regulations, and policy standards, 64 preliminary factors affecting GRBD are chosen (Seeing in Appendix A). The questionnaire survey technique is a systematic method of data collection and has been widely adopted to collect professional views on sustainable construction research [73–75]. Two rounds of surveys were performed in this study. The first round of the questionnaire survey was used to select the influential factors from the 64 preliminary factors (the questionnaire is shown in Appendix B). The population of the questionnaires were all stakeholders in GRBD. Therefore, the questionnaires were distributed to professionals in the government, quality supervision departments, real estate development enterprises, research institutes, construction organizations, and relevant organizations. A total of 92 questionnaires were received and 3 invalid responses were removed due to being incomplete responses. The selected 89 valid samples have more than 10 years of experience in residential development and more than 3 years of experience in GRBD. The questionnaire used a 5-point Likert scale, showing that the degree of preliminary factors ranged from "very unimportant" (1) to "very important" (5) [76–78].

This study grouped preliminary factors into 18 groups from environmental elements, resource elements, and capacity elements (Seeing in Appendix B). In general, reliability is estimated by examining the consistency with which different items express the same concept [79]. In order to test the internal consistency among factors under each category, we used the Cronbach's alpha scale. When the value of Cronbach's alpha is 0.7 or higher, it normally indicates a reliable group classification set [77]. The Cronbach's alpha scores of the 3 elements and 18 categories were calculated (Shown in Table 1). The Cronbach's alpha coefficient for the 18 categories and 3 elements is larger than 0.7. Hence, the structure of survey is considered to be reliable.

Table 1. Cronbach's alpha scores of indexes of green residential building development (GRBD).

Element	Cronbach's Alpha	Category	Number of Questions	Cronbach's Alpha
Environmental Elements	0.707	Political Environment	6	0.771
		Economic Environment	4	0.946
		Social Environment	2	0.770
		Juristic Environment	3	0.842
		Natural Environment	3	0.887
		Technical Environment	2	0.745
Resource Elements	0.705	Government	2	0.738
		Marketing Agency	3	0.847
		Bank	2	0.789
		Research Institute	2	0.917
		Designer	5	0.744
		Builder	6	0.773
		Supervisor	4	0.974
		Supplier	2	0.786
		Certificate Authority	2	0.846
		Consumer	8	0.814
		Local Society	2	0.816
Capacity Elements	0.770	Developer	6	0.770

In the next step, we chose the factor which had a mean score above 4 (meaning "important") as the possible influential factor. The selected influential factors include Mandatory Policy for Developing (I1), Incentive Policy for Developing (I2), Local Economy Development Level (I7), Technology Level of GRBs (I19), Strictness of Examination and Approval (I21), Design Level of GRBs (I32), Technology Application in Design and Construction (I37), Acknowledgement for GRBD (I49), Family Income (I51), Incentive Policy for Purchasing (I52), Local Cooperation (I58), Development Strategy and Innovation Orientation (I60), Acknowledgement and Positioning for GRBD (I61), and Experience and Ability for GRBD (I62) (Seeing in Appendix A). Factor analysis was used to analyze the selected influential factors of GRBD with the SPSS software. The value of KMO is 0.701, and the Sig. of Bartlett's test is 0.000, which satisfies the factor analysis [80]. Then, with the Varimax Rotation in the SPSS, there are 5 components for which the principal component of eigenvalues is greater than 1, and the accumulated variance is 80.862%. The rotated component matrix of influential factors of GRBD is shown in Table 2.

Table 2. Rotated component matrix.

	Component				
	1	**2**	**3**	**4**	**5**
I1	0.866	0.204	0.089	0.254	0.080
I2	0.842	0.229	−0.036	0.217	0.246
I7	0.073	0.124	0.140	0.151	0.903
I19	0.221	0.906	0.103	0.083	0.134
I21	0.830	0.219	0.214	0.177	−0.099
I32	0.221	0.710	−0.001	0.179	0.086
I37	0.132	0.909	−0.087	0.007	0.107
I49	0.095	−0.084	0.136	0.870	−0.120
I51	0.252	0.214	0.080	0.857	0.091
I52	0.283	0.193	0.069	0.729	0.129
I58	0.075	0.155	0.189	−0.098	0.889
I60	0.103	0.096	0.810	0.047	0.242
I61	-0.040	−0.068	0.883	0.108	0.102
I62	0.163	−0.015	0.858	0.106	0.023

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 6 iterations.

Then, based on the factor analysis, 5 primary indexes were named and 14 influential factors were renumbered, as shown in Table 3.

Table 3. Measurement indexes of GRBD.

Primary Indexes	Secondary Indexes
Government	Mandatory Policy for Developing (U1) Incentive Policy for Developing (U2) Strictness of Examination and Approval (U3)
Local	Local Economy Development Level (U4) Local Cooperation (U5)
Technology	Technology Level of GRBs (U6) Design Level of GRBs (U7) Technology Application in Design and Construction (U8)
Consumer	Consumers' Acknowledgement for GRBD (U9) Consumers' Income (U10) Incentive Policy for Purchasing (U11)
Developer	Development Strategy and Innovation Orientation (U12) Developer's Acknowledgement and Positioning for GRBD (U13) Experience and Ability for GRBD (U14)

3.2. A Framework of Influential Factors for GRBD

SNA focuses on the interaction among factors, instead of relationships between factors and processes. According to the characteristics of 14 influential factors in GRBD, we proposed a framework (shown in Figure 2). Five aspects of primary indexes, interacting with each other, have different levels of effect on 5 phases of GRBD separately. The 5 phases include the project acquisition phase, project preparing phase, project designing phase, project constructing phase, and project selling phase [42].
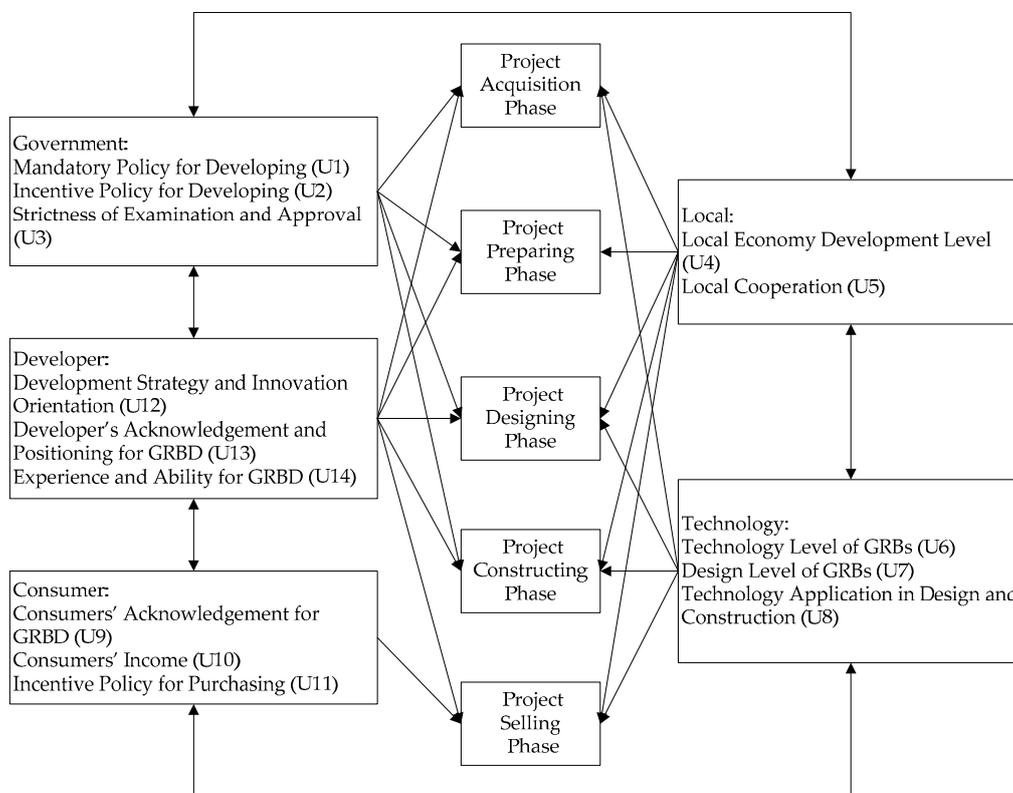
Figure 2. The framework of influential factors for green residential building development (GRBD).

3.3. Social Network of Influential Factors

3.3.1. Correlation Analysis of Influential Factors for GRBD

In order to use the SNA method to determine the relationship between influential factors and identify the critical factors, the first step is to determine the relationships between the 14 factors through association analysis. In this paper, we use the combination of the survey method and expert evaluation method to collect relevant data and establish a network analysis matrix. The network analysis matrix, known as the adjacency matrix, reflects whether a pair of actors are associated with the same matter, or whether a pair of subordinations are associated with each other due to a common actor. But the adjacency matrix must be transformed from the incidence matrix, that is, an "actor-actor" adjacency matrix must be transformed from an "actor-event" incidence matrix [65]. This paper is to establish the "actor-actor" adjacency matrix to express the close ties and interaction between the 14 factors. We construct the "actor-event" incidence matrix through the expert evaluation method.

In order to ensure the rigor of the results of the second questionnaire survey, the respondents to the second survey were the same as the respondents to the first survey. A total of 89 directional questionnaires were sent out to the respondents of the first questionnaire who produced valid samples, and all of them were received, with no invalid responses, in the second-round survey. The respondents have more than 10 years of experience in residential development and more than 3 years of experience in GRBD. In the second survey, we mainly asked respondents to evaluate the degree of impact of the 14 influential factors on the 5 developing phases (shown in Figure 2). Five matrixes were established for experts to score. Scores 0, 1, 2, and 3 corresponded to "no link", "weak link", "medium link", and "strong link". The data of the relation matrix of the 14 influential factors and development phases are shown in Table 4.

Table 4. Relation matrix of influential factors and development phases.

0: No Relation, 1: Weak Relation, 2: Moderate Relation, 3: Strong Relation	Project Acquiring Phase	Project Preparing Phase	Project Designing Phase	Project Constructing Phase	Project Selling Phase
Mandatory Policy for Developing (U1)	2.56	1.89	2.11	1.67	1.00
Incentive Policy for Developing (U2)	1.89	1.67	1.59	1.15	1.30
Strictness of Examination and Approval (U3)	2.48	2.22	2.22	1.89	1.30
Local Economy Development Level (U4)	2.26	1.74	1.70	1.41	1.70
Local Cooperation (U5)	1.89	1.78	1.63	1.48	1.44
Technology Level of GRBs (U6)	1.56	1.33	2.37	2.00	1.15
Design Level of GRBs (U7)	1.37	1.33	2.56	1.78	1.11
Technology Application in Design and Construction (U8)	1.26	1.15	2.26	2.41	1.26
Consumers' Acknowledgement for GRBD (U9)	1.22	1.00	1.44	1.11	2.11
Consumers' Income (U10)	1.04	0.89	0.85	0.78	2.52
Incentive Policy for Purchasing (U11)	1.37	0.89	0.93	0.67	2.19
Development Strategy and Innovation Orientation (U12)	2.19	1.78	1.93	1.59	1.48
Developer's Acknowledgement and Positioning for GRBD (U13)	2.19	1.74	1.93	1.26	1.63
Experience and Ability for GRBD (U14)	1.78	1.89	1.93	1.70	1.59

In order to determine the in-degree and out-degree of each factor, we transformed the "actor-event" incidence matrix into an "actor-actor" adjacency matrix. U1, U2, U3 . . . U14 in the rows and columns represent the influential factors, and the numbers represent the degree of impact, for example, the number in the i row and j column is the impact degree of Ui to Uj (i, j = 1, 2, 3 . . . 14). It is calculated by the following formula:

$$V_{ij} = X_{i1}X_{j1} + X_{i2}X_{j2} + X_{i3}X_{j3} + X_{i4}X_{j4} + X_{i5}X_{j5} \tag{1}$$

V_{ij}: The impact degree of Ui to Uj;
X_{i1} (X_{j1}): The impact degree of Ui (Uj) in the acquiring phase in the relation matrix;
X_{i2} (X_{j2}): The impact degree of Ui (Uj) in the preparing phase in the relation matrix;
X_{i3} (X_{j3}): The impact degree of Ui (Uj) in the designing phase in the relation matrix;
X_{i4} (X_{j4}): The impact degree of Ui (Uj) in the constructing phase in the relation matrix;

X_{i5} (X_{j5}): The impact degree of Ui (Uj) in the selling phase in the relation matrix.

Since we concentrate on the relationships among factors, we ignore the direction of impact between two factors, which means the impact degree of Ui to Uj equals that of Uj to Ui [65,81]. Thus, the adjacency matrix is a symmetric matrix, shown in Table 5.

Table 5. Adjacency matrix of influential factors in GRBD.

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14
U1	-	14.57	19.69	16.72	15.55	16.00	15.51	15.45	12.02	9.96	10.46	17.18	16.70	16.63
U2	14.57	-	15.79	13.71	12.71	12.73	12.37	12.30	10.28	8.98	9.17	13.93	13.68	13.61
U3	19.69	15.79	-	18.12	16.93	17.36	16.84	16.89	13.28	11.19	11.55	18.60	18.08	18.17
U4	16.72	13.71	18.12	-	14.67	14.64	14.16	14.23	12.10	10.73	10.89	16.09	15.81	15.69
U5	15.55	12.71	16.93	14.67	-	13.79	13.36	13.49	11.11	9.72	9.83	14.94	14.59	14.68
U6	16.00	12.73	17.36	14.64	13.79	-	14.81	15.12	11.29	9.28	9.38	15.24	14.70	15.09
U7	15.51	12.37	16.84	14.16	13.36	14.81	-	14.73	11.01	8.97	9.06	14.78	14.31	14.68
U8	15.45	12.30	16.89	14.23	13.49	15.12	14.73	-	11.28	9.31	9.23	14.86	14.21	14.88
U9	12.02	10.28	13.28	12.10	11.11	11.29	11.01	11.28	-	9.57	9.27	12.12	12.03	12.08
U10	9.96	8.98	11.19	10.73	9.72	9.28	8.97	9.31	9.57	-	9.05	10.47	10.56	10.51
U11	10.46	9.17	11.55	10.89	9.83	9.38	9.06	9.23	9.27	9.05	-	10.69	10.76	10.54
U12	17.18	13.93	18.60	16.09	14.94	15.24	14.78	14.86	12.12	10.47	10.69	-	16.03	16.04
U13	16.70	13.68	18.08	15.81	14.59	14.70	14.31	14.21	12.03	10.56	10.76	16.03	-	15.65
U14	16.63	13.61	18.17	15.69	14.68	15.09	14.68	14.88	12.08	10.51	10.54	16.04	15.65	-

3.3.2. Centrality of Influential Factors for GRBD

The social network centrality can identify the critical factors in the social network of factors influencing GRBD, that is, the critical factors are closely linked to the other factors and have a greater impact on the other factors. The second step of this study is to identify the critical factors from 14 influential factors through the method of degree centrality, closeness centrality, and betweenness centrality.

Degree centrality, known as Freeman's degree centrality, reflects how a factor is contacted in the social network local environment. This method calculates the number of factors directly connected to the specific factor, and neglects the indirect influence. Degree centrality expresses the extent to which each factor is connected with a specific factor in the local environment. It is calculated by the following formula [82,83]:

$$C_D(i) = \sum_{k=1}^{g} x_{ij}(i \neq j; \ k = 1, 2 \cdots g - 1) \tag{2}$$

$\sum_{k=1}^{g} x_{ij}$: The number of direct correlation between factor i and other factors k (the number of factors k is g−1).

Closeness centrality measures the distance between one factor and other factors in the social network. Closeness centrality is based on the proximity between the factors. The closer one factor is to other factors, the less it depends on other factors, for which the closeness centrality is high. It is calculated by the following formula [83,84]:

$$C_C(a) = \sum_{i=1}^{n} l(i, a) \tag{3}$$

$l(i, a)$: The length of the shortest path between factor i and factor a.

Betweenness centrality is a measure of the intermediate degree of a factor located in other factors of the network, that is, the betweenness centrality represents the activity and importance of the factor in the network. A factor which has low degree centrality or closeness centrality may play an important role in mediating or coordinating. It means that the factor plays the role of the key channel and becomes the center of the network. Therefore, betweenness centrality can determine which factors

become the center of the GRBD network and could be the critical factor by controlling more resources. It is calculated by the following formula [85,86]:

$$C_B(a) = \sum_{i=1}^{n} \sum_{j=1}^{n} g_{ij}(a) \tag{4}$$

$g_{ij}(a)$: The number of the shortest path of factors i and j passing factor a.

4. Results

4.1. Sociogram of Factors Influencing GRBD

Based on the adjacency matrix (shown in Table 3), we use the software Ucinet 6 to draw the sociogram and analyze the results of SNA. The operation steps are as follows. Firstly, we used the "Data-Spreadsheets-Matrix" to establish the adjacency matrix. Secondly, we used "NetDraw-File-Open-Ucinet dataset-Network" to draw the sociogram (the sociogram is shown in Figure 3). Every node represents a factor, and every line between two nodes represents the relation of these two factors. The thickness of the line represents the tightness of two factors. The thicker the line, the tighter the two factors are.
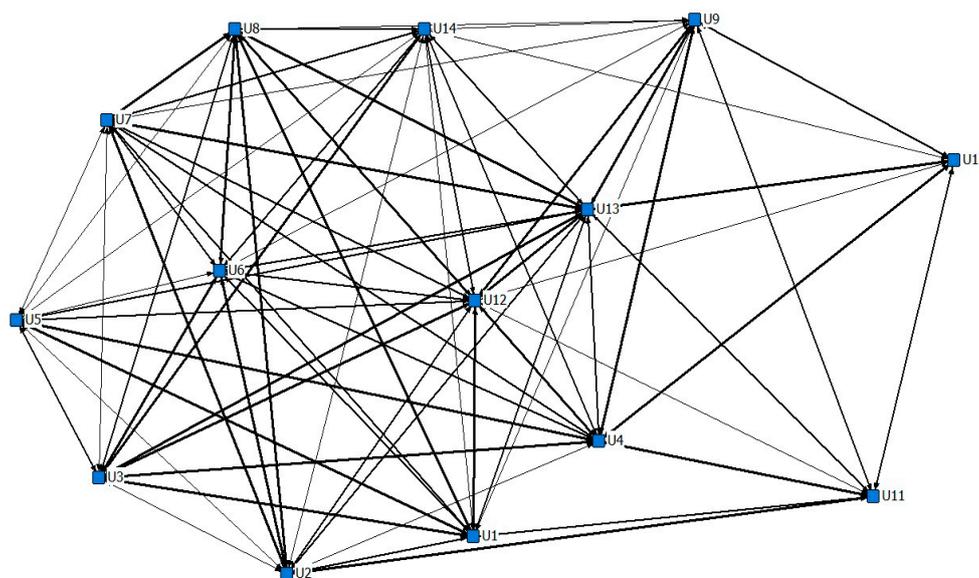
Figure 3. Sociogram of influential factors for GRBD.

Figure 3 can reveal the relationship and tightness of factors, however, it is impossible to determine the critical factors affecting GRBD. We should further analyze the centrality of the social network.

4.2. Critical Factors for GRBD

For identifying the critical factors for GRBD, we take the centrality tests of 14 influential factors. Degree centrality, closeness centrality, and betweenness centrality are tested separately.

We used "Network-Centrality-Degree" to draw the degree centrality sociogram and analyze the result of degree centrality. The sociogram and result of degree centrality are shown in Figure 4 and Table 6.

The degree centrality of the network is 21.79% and the ratio of standard deviation to average is 1.917/10.571 = 18.135%, which means that the local integration degree of the network is good. But the degree of some factors is too low or too high, which should be analyzed. In Figure 4, the degree is higher and the node is bigger. Firstly, the development strategy and innovation orientation (U12) and

developer's acknowledgement and positioning for GRBD (U13) have the most frequent connections with other factors, as shown by their high scores. Secondly, local economy development level (U4) and experience and ability for GRBD (U14) have more frequent connections with other factors because of their relatively high scores (the NrmDegree are over 90). Finally, both incentive policy for purchasing (U11) and consumers' income (U10) have the lowest scores, that is, they have weak links with other factors.
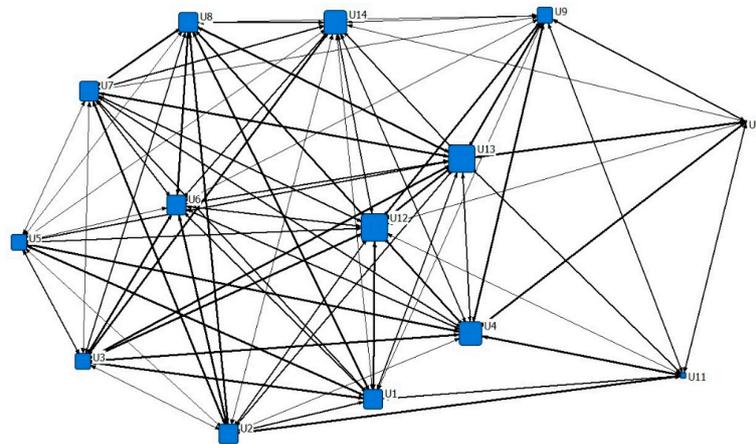
Figure 4. Degree centrality sociogram of influential factors for GRBD.

Table 6. Degree centrality of influential factors for GRBD.

FREEMAN'S DEGREE CENTRALITY MEASURES				
		Degree	**NrmDegree**	**Share**
U12	Development Strategy and Innovation Orientation	13.000	100.00	0.088
U13	Developer's Acknowledgement and Positioning for GRBD	13.000	100.00	0.088
U4	Local Economy Development Level	12.000	92.308	0.081
U14	Experience and Ability for GRBD	12.000	92.308	0.081
U2	Incentive Policy for Developing	11.000	84.615	0.074
U1	Mandatory Policy for Developing	11.000	84.615	0.074
U8	Technology Application in Design and Construction	11.000	84.615	0.074
U6	Technology Level of GRBs	11.000	84.615	0.074
U7	Design Level of GRBs	11.000	84.615	0.074
U3	Strictness of Examination and Approval	10.000	76.923	0.068
U5	Local Cooperation	10.000	76.923	0.068
U9	Consumers' Acknowledgement for GRBD	10.000	76.923	0.068
U11	Incentive Policy for Purchasing	7.000	53.846	0.047
U10	Consumers' Income	6.000	46.154	0.041
DESCRIPTIVE STATISTICS				
		Degree	**NrmDegree**	**Share**
1	Mean	10.571	81.319	0.071
2	StdDev	1.917	14.743	0.013
3	Sum	148.000	1138.462	1.000
4	Variance	3.673	217.365	0.000
5	SSQ	1616.000	95,621.305	0.074
6	MCSSQ	51.429	3043.111	0.002
7	Euc Norm	40.200	309.227	0.272
8	Minimum	6.000	46.154	0.041
9	Maximum	13.000	100.000	0.088
Network Centralization = 21.79%				

From the local network, development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), local economy development level (U4), and experience and ability for GRBD (U14), which are the four critical factors affecting GRBD.

In order to determine the degree of dependence and information exchange in the whole network, this paper carried out a closeness centrality test. We used "Network-Centrality-Closeness" to draw the

closeness centrality sociogram and analyze the result of closeness centrality. The sociogram and result of closeness centrality are shown in Figure 5 and Table 7.
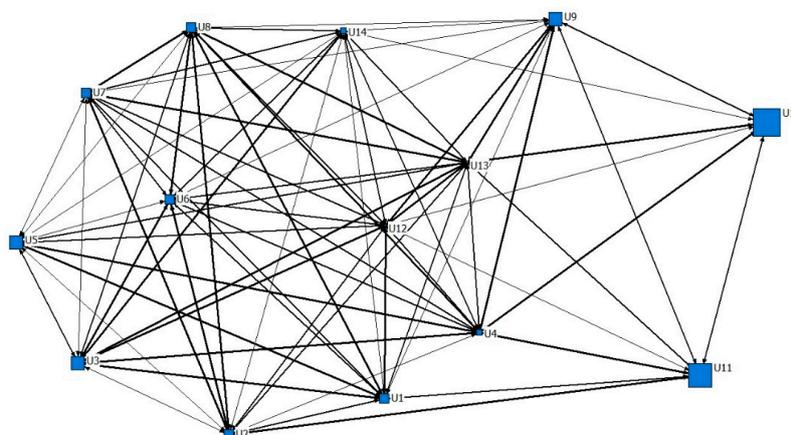
Figure 5. Closeness centrality sociogram of influential factors for GRBD.

Table 7. Closeness centrality of influential factors for GRBD.

CLOSENESS CENTRALITY		Farness	nCloseness
U12	Development Strategy and Innovation Orientation	13.000	100.000
U13	Developer's Acknowledgement and Positioning for GRBD	13.000	100.000
U4	Local Economy Development Level	14.000	92.857
U14	Experience and Ability for GRBD	14.000	92.857
U1	Mandatory Policy for Developing	15.000	86.667
U2	Incentive Policy for Developing	15.000	86.667
U6	Technology Level of GRBs	15.000	86.667
U7	Design Level of GRBs	15.000	86.667
U8	Technology Application in Design and Construction	15.000	86.667
U3	Strictness of Examination and Approval	16.000	81.250
U5	Local Cooperation	16.000	81.250
U9	Consumers' Acknowledgement for GRBD	16.000	81.250
U11	Incentive Policy for Purchasing	19.000	68.421
U10	Consumers' Income	20.000	65.000

DESCRIPTIVE STATISTICS		Farness	nCloseness
1	Mean	15.429	85.444
2	StdDev	1.917	9.642
3	Sum	216.000	1196.219
4	Variance	3.673	92.975
5	SSQ	3384.000	103,511.578
6	MCSSQ	51.429	1301.645
7	Euc Norm	58.172	321.732
8	Minimum	13.000	65.000
9	Maximum	20.000	100.000
Network Centralization = 32.66%			

The closeness centrality of the network is 32.66% and the ratio of standard deviation to average is 1.917/15.429 = 12.425%, which means that the network has the characteristic of congregation. But we should notice that, in Figure 5, the size of the node represents Farness, that is, the nCloseness of the factor is higher, and the node is smaller. Therefore, if the node is smaller, the value and impact are greater, and the factor is located more centrally in the whole network.

From Figure 5 and Table 7, similar to the degree centrality analysis, development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), local economy development level (U4), and experience and ability for GRBD (U14) are the more

independent factors in the whole network. They depend less on other factors and have strong connections with others. Incentive policy for purchasing (U11) and consumers' income (U10) are further from other factors and their communication of information is restricted by the mediators. Therefore U12, U13, U4, and U14 are the critical factors affecting GRBD.

In order to determine which factors in the study can control more resources and play an important role in mediation or coordination, we carried out the betweenness centrality test. We used "Network-Centrality-Freeman betweenness-node betweenness" to draw the betweenness centrality sociogram and analyze the result of betweenness centrality. The sociogram and results of betweenness centrality are shown in Figure 6 and Table 8.
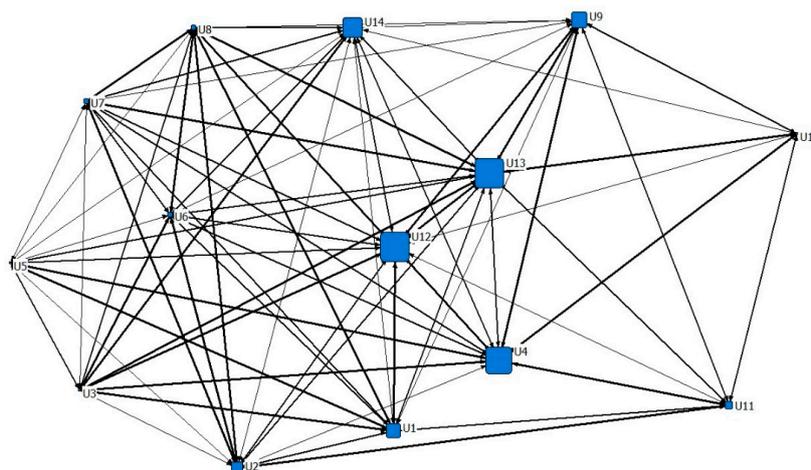
Figure 6. Betweenness centrality sociogram of influential factors for GRBD.

Table 8. Betweenness centrality of influential factors for GRBD.

BETWEENNESS CENTRALITY		Betweenness	nBetweenness
U12	Development Strategy and Innovation Orientation	2.995	3.840
U13	Developer's Acknowledgement and Positioning for GRBD	2.995	3.840
U4	Local Economy Development Level	2.704	3.467
U14	Experience and Ability for GRBD	1.952	2.503
U9	Consumers' Acknowledgement for GRBD	1.534	1.966
U1	Mandatory Policy for Developing	1.404	1.800
U2	Incentive Policy for Developing	1.134	1.454
U11	Incentive Policy for Purchasing	0.602	0.772
U6	Technology Level of GRBs	0.452	0.580
U7	Design Level of GRBs	0.452	0.580
U8	Technology Application in Design and Construction	0.452	0.580
U10	Consumers' Income	0.143	0.183
U3	Strictness of Examination and Approval	0.091	0.117
U5	Local Cooperation	0.091	0.117
DESCRIPTIVE STATISTICS		Betweenness	nBetweenness
1	Mean	1.214	1.557
2	StdDev	1.036	1.329
3	Sum	17.000	21.795
4	Variance	1.074	1.766
5	SSQ	35.682	58.648
6	MCSSQ	15.039	24.719
7	Euc Norm	5.973	7.658
8	Minimum	0.091	0.117
9	Maximum	2.995	3.840
Network Centralization Index = 2.46%			

The betweenness centrality of the network is 2.46% and the ratio of standard deviation to average is $1.036/1.214 = 85.338\%$, which means that the dispersion degree of the network is large and the

betweenness centrality is poor. The ability of most nodes to control information is poor, and only a few nodes, which are located in the important information path to control the main resources, are the hub of the whole network.

Table 8 illustrates that, firstly, development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), local economy development level (U4), and experience and ability for GRBD (U14), which are located on the major paths, are the key junctions of the network. Secondly, consumers' income (U10), strictness of examination and approval (U3), and local cooperation (U5) have the lowest scores, that is, they do not control any resources.

From the result of betweenness centrality, the four factors which are the critical factors affecting GRBD are development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), local economy development level (U4), and experience and ability for GRBD (U14).

Based on the results of the three centrality tests, the results of degree centrality and closeness centrality are the same, but the result of betweenness centrality is slightly different. We conclude that the critical factors affecting GRBD are development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), local economy development level (U4), and experience and ability for GRBD (U14). It is worth noting that, although degree centrality and closeness centrality of consumers' acknowledgement for GRBD (U9) are low, the betweenness centrality is high. This means some factors do not have a strong impact on other factors, and information exchange of these factors is subject to other factors, but they may occupy an important path in the network and have a certain capacity to control resources (such as U9). For such factors, we should focus on their ability to control resources, so as to keep the social network access among factors smooth.

5. Discussion

Generally, this paper determined the relationships of 14 factors influencing GRBD by SNA, and then identified four critical factors from the influential factors by the social network centrality test. These factors and the findings are discussed hereinafter.

From the central test results, development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), and experience and ability for GRBD (U14) are all the critical factors of GRBD, which coincide with the results of successful implementation of construction projects [60]. The results confirm the importance of innovation factors for GRBD, but the argument that the improvement and change of employees' cognition is the critical factor is not verified [61]. In the literature review, "experience and knowledge in GRB" (similar to U14), "organizational green culture" (similar to U13), and "innovation capability" (similar to U12) are more important than other influential factors [63], and the results confirm this view.

Local economy development level (U4) is a critical factor affecting GRBD. But technology level of GRBs (U6) is not a critical factor, which is in different from the results of Vyas and Jha (2016) [50]. "Sustainable designing and planning" (similar to U7 and U8) and "education and awareness of GRB" (similar to U13) have impacts on the credit of GRBD. However, from the results of critical factors, "education and awareness of GRB" seems to have a greater impact [53]. Therefore, similar to GRBD in Singapore, the technical design and construction knowledge of GRBs in China are not lacking [45]. This means that the technical factors have some influence on GRBD, but they are not the critical factors.

From the perspective of policy, mandatory policy for developing (U1) and incentive policy for developing (U2) also have considerable impacts on GRBD, which is similar to previous research results) [32,52]. Strictness of examination and approval (U3) is a new influential factor we put forward, but the key to GRBD is not obvious. Incentive policy for purchasing (U11) and consumers' income (U10) have low centrality on GRBD, but the betweenness centrality of consumers' acknowledgement for GRBD (U9) is high. It illustrates that this factor, U9 plays an important role in information communication, which explains the reason for the formation of consumers' environmental protection

and the importance of information acquisition on GRBD [32,59]. This is a further development of the existing research.

6. Conclusions and Recommendation

This paper, based on the whole life cycle of GRBD and the perspective of real estate developers, identified 14 factors affecting development from 64 preliminary factors of three main elements, and established a framework. The 14 influential factors including the following: Mandatory policy for developing (U1), incentive policy for developing (U2), strictness of examination and approval (U3), local economy development level (U4), local cooperation (U5), technology level of GRBs (U6), design level of GRBs (U7), technology application in design and construction (U8), consumers' acknowledgement for GRBD (U9), consumers' income (U10), incentive policy for purchasing (U11), development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), and experience and ability for GRBD (U14).

The tightness and relationships between 14 factors are tested by SNA. According to the method of the social network centrality test, degree centrality, closeness centrality, and the betweenness centrality of the local economy development level (U4), development strategy and innovation orientation (U12), developer's acknowledgement and positioning for GRBD (U13), and experience and ability for GRBD (U14) are all higher than other influential factors. This shows that these four factors, which control most resources in the social network, are critical factors. However, we should consider consumers' acknowledgement for GRBD (U9) as an important influential factor. The betweenness centrality of U9 is higher than other factors (except the critical factors). This shows that even if U9 is not the key to control and influence in GRBD in the whole network, it may be a node with higher activity and more frequent information transmission in the network.

The relationships between these factors and the determination of critical factors will help real estate developers to better understand how to improve their business capabilities on GRBD. The results also reveal that the support of local governments will promote GRBD, but we should know more about the local economy to avoid unnecessary economic losses because of blindly following. This paper also provides some references for policymakers. The effective implementation of mandatory policies and incentive policies can promote GRBD in real estate developers. However, in the process of examination and approval, the technology, experience, and management ability of the developers need to be strictly determined to avoid losses caused by a lack of developers' capacity. At the same time, the government, developers, and non-governmental organizations should encourage the public to know more about GRBD, and enhance the understanding of GRBs. It will promote the demands for GRBs to improve the supply by real estate developers.

The limitation of this paper is mainly due to the limited scope of the investigation and the limited number of questionnaires, so the results may have some limitations. But the analysis method has a certain value for research in other areas. In the future, a larger and different sample should be used to test the universality of the method. Further analysis by SNA, such as the structure tree, should be used to excavate the influential factors for GRBD. We will conclude with the more universal influential factors and critical factors for GRBD.

In the future, the main points of our research include the use of the SNA method to analyze the stakeholder relationships of GRBD, or to analyze the factors in the development of GRBs from the perspective of different stakeholders. In fact, there are many methods to analyze the influential factors and critical factors of GRBD. Therefore, we may compare the different methods of factor analysis to get a more suitable method to select and analyze the factors affecting GRBD. In addition, we may also study dynamic evolution management of GRBD based on the dynamic network.

Author Contributions: X.Y. put forward this research idea, conducted literature review, and established the framework. J.Z. participated in the data analysis and collated the draft manuscript. X.Z. contributed to the Author method of this research and provided some comments. All authors participated in final manuscript preparation and agreed to publish this paper.

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

Appendix A.

Table A1. Preliminary factors affecting GRBD.

Primary Indexes	Secondary Indexes	Preliminary Factors	Sources
Environmental Elements	Political Environment	Mandatory Policy for Developing (I1)	[46,48,55,87]
		Incentive Policy for Developing (I2)	[41,48,56,64]
		Industrial Policy (I3)	[64,87]
		Industrial Standard (I4)	[40,53,55,87]
		Monetary Policy (I5)	[47,61,88]
		Tax Policy (I6)	[47,50]
	Economic Environment	Local Economy Development Level (I7)	[53,64]
		Supply and Demand in Market of GRBs (I8)	[40,61]
		Supply and Demand in Market of GRBs (I9)	[49,61]
		Inflation (I10)	[18,89]
	Social Environment	City Planning (I11)	[40,53]
		Social Acknowledgement of GRBs (I12)	[55,90]
	Juristic Environment	Law Health (I13)	[48,64]
		Enforcement Strictness (I14)	[48]
		Land System and Policy (I15)	[53,64]
	Natural Environment	Geological Condition (I16)	[32,53]
		Climate Condition (I17)	[21,62]
		Acquisition of Natural Resource (I18)	[32,53]
	Technical Environment	Technology Level of GRBs (I19)	[32,47,54,88]
		Popularization and Application of Green Technology (I20)	[32,53]
Resource Elements	Government	Strictness of Examination and Approval (I21)	[55,64,87]
		Reliability of Quality Control (I22)	[18,64,87]
	Marketing Agency	Acknowledgement of GRBs (I23)	[90]
		Judgement Ability of GRBs (I24)	[55,88]
		Marketing Ability of GRBs (I25)	[88]
	Bank	Credit Policies for Developing (I26)	[18,47,48,88]
		Credit Policies for Purchasing (I27)	[18,48,88]
	Research Institute	Driving Force of Economy (I28)	[40,44]
		Research Ability of GRBs (I29)	[40,87]
Resource Elements	Designer	Driving Force of Economy (I30)	[40,55]
		Reconnaissance of Construction Site (I31)	[91,92]
		Design Level of GRBs (I32)	[40,62,69]
		Technology and Material Application (I33)	[21,55,87,88]
		Social Responsibility (I34)	[21,87]
	Builder	Acknowledgement of Green Construction (I35)	[44,91]
		Management Ability of Green Construction (I36)	[21,57,87]
		Technology Application in Design and Construction (I37)	[21,87]
		Biding Price (I38)	[55,62]
		Coordination with Designer (I39)	[91]
		Appointed Subcontractors (I40)	[21,55]
	Supervisor	Acknowledgement of Green Construction (I41)	[44,47]
		Regulation Ability of Green Construction (I42)	[87]
		Regulation Experience of Green Construction (I43)	[21,55,87]
		Professional Ethic (I44)	[87]
	Supplier	Prices of Building Material and Facilities (I45)	[87,93]
		Quality of Building Material and Facilities (I46)	[21,54,87]
	Certificate Authority	Evaluation Ability of GRBs (I47)	[44,87]
		Professional Ethic (I48)	[87]
	Consumer	Acknowledgement for GRBD (I49)	[42,44,90]
		Environmental Conscious (I50)	[33,53,55]
		Family Income (I51)	[58,94]
		Incentive Policy for Purchasing (I52)	[41,47,48]
		Information Acquisition of GRBs (I53)	[18,44,88]

Table A1. *Cont.*

Primary Indexes	Secondary Indexes	Preliminary Factors	Sources
		Living Habit (I54)	[40,49]
		Education Level (I55)	[40,58]
		Personality Characteristics (I56)	[40,58]
	Local Society	Location and Strategy of Local Development (I57)	[47–49,64]
		Local Cooperation (I58)	[47,49,64,87]
Capacity Elements	Developer	Driving Force of Economy (I59)	[37,44,55]
		Development Strategy and Innovation Orientation (I60)	[53–55,62]
		Acknowledgement and Positioning for GRBD (I61)	[47,55,90]
		Experience and Ability for GRBD (I62)	[21,44,90]
		Financing of the Project (I63)	[44,62]
		Management for GRBD (I64)	[21,44,90]

Appendix B. Questionnaire on Factors Affecting GRBD

Dear madam or sir,

It is appreciated to fill out the questionnaire on factors affecting the green residential building development (GRBD). The private information you have completed is only for academic study, and will not be disclosed to the public. Thank you very much for your support and cooperation!

This questionnaire is divided into two parts. The first part is your private information, and the second part is degree of the factors affecting GRBD. In accordance with the importance of each factor, you should tick in the corresponding space with **single election**. The degree of importance is divided into "very unimportant"(1), "unimportant"(2), "average"(3), "important"(4), and "very important"(5).

Part 1:

1. Nature of work:

□Government □Quality supervision department □Real estate development enterprises
□Research institutes □Construction organizations □Relevant organizations
2. Years of experience in residential development:
□Below 10 years □ 10 years–20 years □Above 20 years
3. Years of experience in the green residential building development.
□Below 3 years □ 3 years–5 years □Above 5 years

Part 2:

Please fill in the information according to your work experience and actual situation of development of green residential buildings (GRBs). Please make a comparison between the scores after completing the questionnaire to ensure the differences between the factors.

Table A2. The scale of preliminary factors affecting GRBD.

Elements	Category	No.	Preliminary Factors	1	2	3	4	5
Environmental Elements	Political Environment	1	Mandatory Policy for Developing	□	□	□	□	□
		2	Incentive Policy for Developing	□	□	□	□	□
		3	Industrial Policy	□	□	□	□	□
		4	Industrial Standard	□	□	□	□	□
		5	Monetary Policy	□	□	□	□	□
		6	Tax Policy	□	□	□	□	□
	Economic Environment	7	Local Economy Development Level	□	□	□	□	□
		8	Supply and Demand in Market of GRBs	□	□	□	□	□
		9	Supply and Demand in Market of GRBs	□	□	□	□	□
		10	Inflation	□	□	□	□	□
	Social Environment	11	City Planning	□	□	□	□	□
		12	Social Acknowledgement of GRBs	□	□	□	□	□
	Juristic Environment	13	Law Health	□	□	□	□	□
		14	Enforcement Strictness	□	□	□	□	□
		15	Land System and Policy	□	□	□	□	□

Table A2. *Cont.*

Elements	Category	No.	Preliminary Factors	1	2	3	4	5
	Natural Environment	16	Geological Condition	☐	☐	☐	☐	☐
		17	Climate Condition	☐	☐	☐	☐	☐
		18	Acquisition of Natural Resource	☐	☐	☐	☐	☐
	Technical Environment	19	Technology Level of GRBs	☐	☐	☐	☐	☐
		20	Popularization and Application of Green Technology	☐	☐	☐	☐	☐
	Government	21	Strictness of Examination and Approval	☐	☐	☐	☐	☐
		22	Reliability of Quality Control	☐	☐	☐	☐	☐
	Marketing Agency	23	Acknowledgement of GRBs	☐	☐	☐	☐	☐
		24	Judgement Ability of GRBs	☐	☐	☐	☐	☐
		25	Marketing Ability of GRBs	☐	☐	☐	☐	☐
	Bank	26	Credit Policies for Developing	☐	☐	☐	☐	☐
		27	Credit Policies for Purchasing	☐	☐	☐	☐	☐
	Research Institute	28	Driving Force of Economy	☐	☐	☐	☐	☐
		29	Research Ability of GRBs	☐	☐	☐	☐	☐
	Designer	30	Driving Force of Economy	☐	☐	☐	☐	☐
		31	Reconnaissance of Construction Site	☐	☐	☐	☐	☐
		32	Design Level of GRBs	☐	☐	☐	☐	☐
		33	Technology and Material Application	☐	☐	☐	☐	☐
		34	Social Responsibility	☐	☐	☐	☐	☐
Resource Elements	Builder	35	Acknowledgement of Green Construction	☐	☐	☐	☐	☐
		36	Management Ability of Green Construction	☐	☐	☐	☐	☐
		37	Technology Application in Design and Construction	☐	☐	☐	☐	☐
		38	Biding Price	☐	☐	☐	☐	☐
		39	Coordination with Designer	☐	☐	☐	☐	☐
		40	Appointed Subcontractors	☐	☐	☐	☐	☐
	Supervisor	41	Acknowledgement of Green Construction	☐	☐	☐	☐	☐
		42	Regulation Ability of Green Construction	☐	☐	☐	☐	☐
		43	Regulation Experience of Green Construction	☐	☐	☐	☐	☐
		44	Professional Ethic	☐	☐	☐	☐	☐
	Supplier	45	Prices of Building Material and Facilities	☐	☐	☐	☐	☐
		46	Quality of Building Material and Facilities	☐	☐	☐	☐	☐
	Certificate Authority	47	Evaluation Ability of GRBs	☐	☐	☐	☐	☐
		48	Professional Ethic	☐	☐	☐	☐	☐
	Consumer	49	Acknowledgement for GRBD	☐	☐	☐	☐	☐
		50	Environmental Conscious	☐	☐	☐	☐	☐
		51	Family Income	☐	☐	☐	☐	☐
		52	Incentive Policy for Purchasing	☐	☐	☐	☐	☐
		53	Information Acquisition of GRBs	☐	☐	☐	☐	☐
		54	Living Habit	☐	☐	☐	☐	☐
		55	Education Level	☐	☐	☐	☐	☐
		56	Personality Characteristics	☐	☐	☐	☐	☐
	Local Society	57	Location and Strategy of Local Development	☐	☐	☐	☐	☐
		58	Local Cooperation	☐	☐	☐	☐	☐
Capacity Elements	Developer	59	Driving Force of Economy	☐	☐	☐	☐	☐
		60	Development Strategy and Innovation Orientation	☐	☐	☐	☐	☐
		61	Acknowledgement and Positioning for GRBD	☐	☐	☐	☐	☐
		62	Experience and Ability for GRBD	☐	☐	☐	☐	☐
		63	Financing of the Project	☐	☐	☐	☐	☐
		64	Management for GRBD	☐	☐	☐	☐	☐

Note: Green residential buildings (GRBs); Green residential building development (GRBD).

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