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Factors Influencing Modern Timber Structure Building Development in China

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Abstract: In China, modern timber structure (MTS) has great market potential as an advanced architectural technology and corresponds to the direction of construction industrialization. However, the MTS building sector is still developing slowly, despite previous efforts by the Chinese government to promote its development. The development of the MTS building industry involves numerous stakeholders, and the complex relationships and behaviors of stakeholders are regarded as the reason for slow development. Therefore, this study aims to investigate the influencing factors related to MTS building from the stakeholders' perspectives. The social network analysis (SNA) method was used to explore the key factors affecting MTS building development and analyze the interactions of influencing factors. Nine stakeholders were identified, and 23 influencing factors associated with these stakeholders were determined based on a literature review, questionnaire survey and interviews with specialists. The critical factors were government policy, the public's understanding and acceptance, market positioning and development cost. In addition, the relationships of designer, prefabricated component manufacturer, and construction enterprise were very close. Based on the findings, corresponding countermeasures were put forward, including policy incentives and support expansion, technical specification system improvements, public awareness reinforcement, and the strengthening of personnel training, etc. This paper contributes to the developmental improvement of the MTS building sector in China.

Keywords: modern timber structure; influencing factor; stakeholder; social network analysis

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1. Introduction

In recent years, the Chinese government has vigorously promoted the transformation of the traditional construction mode to industrialized building systems in order to reduce energy consumption and upgrade construction quality [1]. As an element of construction industrialization, prefabricated building has been increasingly advocated, owing to its benefits, such as faster construction, reduced construction defects, lower energy consumption, and lower waste production [2,3]. In 2016, the State Council of the People's Republic of China issued the Opinions of the Communist Party of China Central Committee and the State Council on strengthening the management of urban planning and construction, emphasizing prefabricated building development in China [4]. In addition, the Chinese government has actively promoted the application of green building materials. The green building action plan issued by the Chinese Ministry of Housing and Urban Rural Development (MOHURD) encouraged the use of energy-efficient materials in new constructions and guided Urban and Rural Construction with recycling, green and low-carbon concepts [5]. The main building materials in China are concrete, steel, brick, and timber [6].

Timber, as a natural and green building material, is seen as a low-impact material from the perspective of greenhouse gas emissions and solid waste compared with concrete and steel [7]. From a carbon balance perspective, the benefits of using timber as a building

material (e.g., plytimber, cross laminated timber, laminated veneer timber, and oriented strand board) are that it uses less energy in its production than other alternative materials; timber-based products have the characteristics of long-term carbon sequestration and low carbon emission [8,9]. Therefore, increasing timber use in construction would be beneficial in achieving the national policy goals of green and sustainable low-carbon economy development. With the promotion of green building materials and prefabricated buildings in China, modern timber structure (MTS) building has attracted unprecedented attention [10].

MTS building adopts advanced construction techniques, and buildings are generally constructed with industrialized engineered timber products assembled with metal connectors and have certain guidelines and standards for the construction processes and acceptance checks [11]. MTS building can improve construction efficiency and building quality and reduce resource waste and construction site noise/air pollution [12]; MTS has conformity to the orientation of energy conservation and emission reduction in the construction industry [10]. Figure 1 indicates the industrialized construction mode about MTS building. China has a long history of using timber as a construction material. The traditional Chinese timber structure has been widely used in palaces, temples, and residential buildings. Traditional timber structure buildings are usually built with raw materials and processed by mortise-and-tenon connections; the quality basically depends on the craftsman's technique and experience [6]. Figure 2 shows the difference between the connection modes. With MTS building techniques, many shortcomings of the traditional timber structure, such as susceptibility to dampness, rotting, insects, and fire, have been eased. MTS possesses better environmental performances (e.g., lower greenhouse gas emissions) and better well-being advantages (e.g., higher indoor environmental quality (IEQ)) compared with precast concrete structure and steel structure constructions [13,14]. Timber also has low thermal mass when compared to other buildings built with bricks or concrete [15]. Superior seismic, comfort, and thermal insulation performance also reinforces the timber structure to be very suitable for use in cold areas and earthquake-prone areas. In addition, MTS building can be better integrated into the natural landscape with little impact on the environment. Therefore, it is more suitable for application in tourism real-estate development. In 2014, the Guiding Opinions on Vigorously Promoting Modern Timber Structure Construction Technology by the Ministry of Housing and Urban Rural Development (MOHURD) promoted the use of modern timber structure [16]. MTS is suitable for a single or multi-story building structure and has been applied in the construction of new rural areas, tourist attractions, office buildings, kindergartens, etc., in China's economically developed areas [10].

(**a**) (**b**)

Figure 1. Industrial construction mode for MTS building. (**a**) Factory prefabrication; (**b**) Assembly of the large panel on the site.

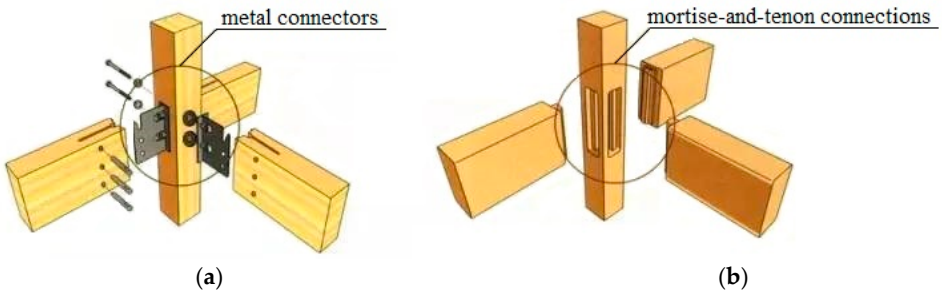

Figure 2. Two connection forms for timber structure Joints. (**a**) MTS building joints; (**b**) Traditional Chinese timber structure joints.

However, compared with other forms of prefabricated building, MTS building still has a low market share. Figure 3 shows the completed new construction area of prefabricated buildings in 2019, with the statistical data from MOHURD. The completed new MTS building construction area is 2.42 million m^2, accounting for only 0.6%. Both researchers and practitioners agreed the MTS building sector possesses huge development potential [17]. The MTS building sector is emerging but is complex, involves many benefit-based relationships, and each relationship imperceptibly affects the development of MTS building. Therefore, the factors that affect the development of MTS building are very important for industry participants to identify constraints and formulate the response strategies. In addition, different stakeholders have key roles in developing the MTS building sector in China; sufficient attention should be paid to the connections between various stakeholders and the interactions among different influencing factors. In order to improve the market share of MTS in China, some scholars have investigated the influencing factors in MTS development, such as the lack of supportive policies, the absence of public awareness, and the lack of knowledge [6,11,18]. Although scholars, such as Qu et al. (2012) [6], have investigated stakeholders and related factors in their studies, they have not completely explored the connections between influencing factors and stakeholders during the evaluation process. Therefore, this study investigates the factors and their interrelations that affect the development of MTS building in China from the stakeholders' perspective. In specific, the research intends the following two objectives:

(1) Identify the key influencing factors;
(2) Quantify the complex connections among different influencing factors.

In order to achieve these objectives, the social network analysis (SNA) method is used.

The following sections are included: Section 2 provides a detailed literature review on stakeholders and influencing factors in MTS building, and the SNA method. The stakeholders associated with MTS building development are identified; Section 3 describes the SNA methods; Section 4 presents the date acquisition process and result. Then, it shows the social network and the results of the indicators obtained by using the SNA method. Section 5 shows the discussions about the key influencing factors and critical interactions; meanwhile, it puts forward countermeasures for MTS building development. The conclusions are presented in Section 6.

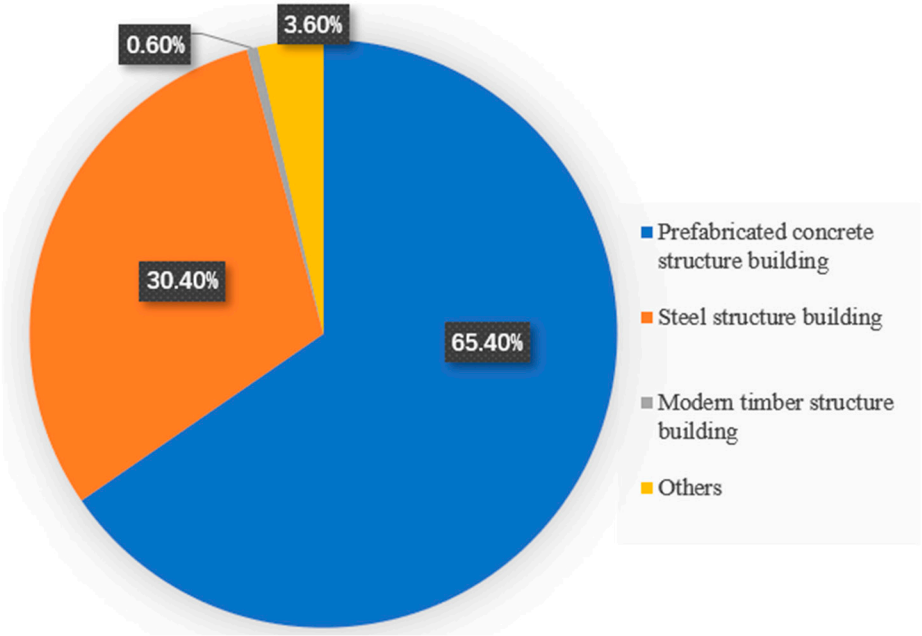

Figure 3. The completed new prefabricated buildings construction area in 2019.

2. Literature Review

2.1. Stakeholders and Influencing Factors in MTS Building

In recent years, many researchers have explored MTS at a technical level [19–22] and health-related characteristics [23–25]. However, MTS research from the perspective of industrial development is very limited. Factor identification is a critical portion in this research. It is hard to acquire a complete list of influencing factors from the literature review, due to the absence of relevant literatures. Relevant studies, such as the exploration of influencing factors in green building development by Huang et al. (2018) [26] and the scheduling of risks in prefabrication housing production by Li et al. (2016) [27], used the perspective of stakeholders to find factors. Therefore, a questionnaire survey and expert interview to stakeholders would become effective complements in obtaining appropriate influencing factors.

The increasing demand for sustainable buildings and further market transformation required the participation of more stakeholders [28]. "Stakeholder" means "any group or individual who can affect or is influenced by the approach to the issue addressed" [29]. Nowadays, the construction industry involves a variety of stakeholders who have different cultural and occupational backgrounds [30]. Generally, these participants have different understandings, operations, and decision-making procedures that can cause complex conflicting interests and produce completely different results [31]. For example, the government can significantly influence the strategy of enterprises by formulating local laws and regulations and special tax conditions [32]. In the Chinese private enterprise, green building construction was seldomly chosen mainly due to the perceived higher upfront cost, the lack of education and awareness, and the lack of fiscal incentives from the government [26]. However, the majority of participants would pay more for green building over the standard building when they knew the direct environmental impact [33]. Therefore, the decision-making behaviors of different stakeholders on MTS building use may play a significant role in shaping its present and future development.

Previous studies have summarized the list of construction industry-related stakeholders. Ma (2018) [31] explored the stakeholders involved in the Chinese construction industry, which included government, suppliers, employees, a sustainable community, and a firm. In reality, MTS building has more participants due to unique characteristics. Qu (2012) [6] adopted the semi-structured questionnaire method to identify relevant stakeholders related

to MTS building in China: timber material-related research institutes, central and local governments, MOHURD, the State Forestry Administration, timber industry enterprises, educational institutions (from schools to universities), and non-governmental organizations (NGOs). At the same time, Qu (2012) [6] specified that:

(1) The first priority was the government organization.
(2) The second priority group was housing investors. Suppliers influenced changes in customer demands, improved information acquisition, and cultivated the learning ability of firms [34].
(3) The third priority group included the end user, media, and residents. User feedback can have a significant impact on the reputation of the product; residents can influence the project reputation by "promote public viewpoint for or against" the project performance [11,35].
(4) Other important and identified target groups were foresters, housing designers, and builders [6].

Based on the existing research, this paper divided the stakeholders into nine categories from the perspective of the MTS building sector promotion, which included: government, developer, designer, prefabricated component factory, construction enterprises, end user, research institution, public, and media.

2.2. Social Network Analysis

The social network analysis theory considers the research issue as a systems environment, which is connected by various relationships [36]. The purpose of SNA is to explore how a relationship structures influence behaviors and to determine both their causes and effects [37]. The SNA method is suitable for framing the structure of social groups. SNA is an endorsed methodology to analyze the interorganizational interactions. This method can not only can be used to describe the overall characteristics of a network structure, but also can be used to reflect the individuals' positions within the whole network and describe the impact degree between them [35]. Compared with other research methods, SNA can explore the complex and abstract connections among project participants [38]. In addition, the impact of stakeholder behavior and their interaction level on the project can be quantified via network measurement [30]. Therefore, scholars can use SNA to recognize the key factors related to stakeholders in their studies.

SNA has been proven to be an effective method in the settling of stakeholder-related issues in the construction industry. For example, Yang and Zou (2014) [39] built a risk network of complex green building projects from the stakeholders' perspective with SNA. Li et al. (2016) [27] applied SNA to build the underlying network of stakeholder-associated schedule risks in prefabrication housing production in Hong Kong. Yuan et al. (2018) [40] explored the social risks of construction projects in high-density urban areas in China based on a two-mode network of SNA. This study also adopted SNA to build the influencing factors network of MTS building in order to identify the critical factors and to explore the factors' interactions based on the stakeholders' perspective.

3. Methodology

In this paper, the purpose of network analysis was to obtain the core stakeholders, the key influencing factors, and their cause-and-effect relationships in the developmental stage of MTS building. This paper follows the general process of SNA and includes five parts: (1) identifying the stakeholders and influence factors, (2) determining the influencing factors' interrelations, (3) visualizing the influencing factor network, (4) deciphering the influencing factor network, and (5) presenting the analysis results [38]. Figure 4 shows the network development process in this study.

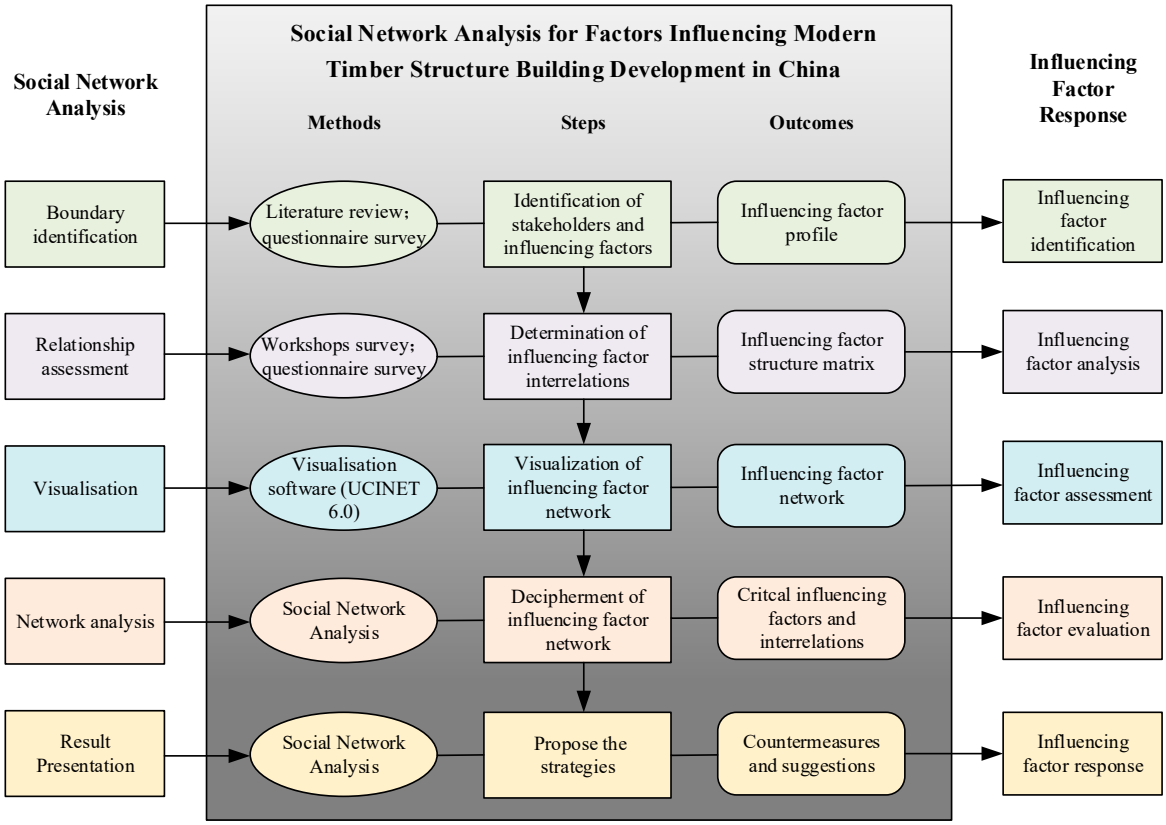

Figure 4. Procedures of the SNA method.

3.1. Identification of Stakeholders and Influencing Factors

The social network consists of two components: nodes and links. The purpose of this step is to determine the network nodes, that is, to identify the stakeholders and related development-influencing factors of MTS. Notably, the researchers of this study explored and identified the stakeholders and the developmental influencing factors of MTS building by collecting a substantial number of academic documents, publications, policy documents, and enterprise reports. Then, an expert questionnaire survey was used to make the results comprehensive and easy to understand. The advantages of this identification method are: (1) the collection of relevant data can be precise and complete, and (2) for most questions, experts can give quick and accurate answers. This step is used to build a complete stakeholder list and correlative influencing factors. All influencing factors associated with stakeholders are digitally coded with S#F※, in which # symbolizes the serial number of associated stakeholders, and ※ is the influence factor serial number related to this stakeholder. For example, S6F3 is the third influence factor related to the sixth stakeholder. At this step, the nodes in the network are established.

3.2. Determination of Influencing Factors' Interrelations

This step defines the links that shows the effect between each node in the influencing factor network. Steward (1981) [41] adopted the method of designing a structure matrix to establish the relations between each two nodes. This method can effectively and succinctly reflect the connection between nodes. There are three basic relationships between each risk factor in the organizational structure:

(1) Dependent relationship: direct connection exists between two influencing factors;
(2) Independent relationship: no connection exists between two influencing factors;
(3) Interdependent relationship: no direct connection exists between two influencing factors, but they have indirect connection through the network [39].

This study was not focused on single influencing factor analysis but from the perspective of stakeholders to explore the influencing relationships and the likelihood of interactions between influencing factors. In this paper, the 0-1 matrix format was used to describe and assess the relationship between nodes. In the 0-1 matrix format, the degree of relationships is assessed by a two-points scale, where "1" represents that the horizontal node can directly affect the vertical node, where "0" means that the vertical node is not affected by the horizontal node. The method outcomes construct the links in the network, which represent the impact between two nodes. The accuracy of the relationship between the influencing factors can be improved by conducting research with key stakeholders, workshops with relevant experts, and conducting questionnaire surveys.

3.3. Visualization of Influencing Factor Network

After identifying the nodes and their interrelationship, importing the determined 0-1 matrix format into UCINET 6.0 [42], the influencing factor network for MTS building can be generated. The network can be presented by a graph G (N, M) in which the identified influencing factors are mapped into N nodes connected by an M arrow line [43]. In the network, different colors of the nodes represent factors associated with different stakeholders. The arrows line with values in the network are the interrelations among the factors.

3.4. Decipherment of Influencing Factor Network

The researchers analyzed the network diagram from the macro and micro perspectives. There are usually two useful measures to analysis network: network measures and node/link measures. The following six indicators were selected to evaluate the influencing factor network.

3.4.1. Network Measures

Density and cohesion are two network measure indicators, which are used to evaluate the characteristics of the whole network.

(1) Density is defined as the ratio of existing links in a network to the maximum number of links possible if all network participants are connected with each other [39]. The value of network density ranges from 0 to 1. The higher the density of the whole network, the more relational connections are within the network, and the closer the relationships between network nodes.
(2) Cohesion is defined as the network complexity. This complexity is expressed by measuring the distance or the number of links to reach nodes within a network. The distance between nodes can be quantized by defining a reasonable the unit length, which is based on the shortest path [44]. The higher the cohesion, the more walks are required from each node to reach everyone else, and the higher degree of network complexity.

3.4.2. Node/Link Measures

There are four main indicators to measure node/link: degree of nodes, betweenness centrality, status centrality, and brokerage, which can be used to identify the role of single factors by immediate or mediate relationships.

(1) The degree of nodes is defined as the immediate connectivity characteristic of a factor. "In-degree" and "out-degree" are, respectively, represented by the incoming relations (impacted by) and outcoming relations (impact to) [45]. The value and degree of nodes indicate the links between risk factor S#F※ and its adjacent factors all over the network. The degree of each node can be calculated by the weight sum of links. The higher the "in-degree" value, the heavier impact of the factor suffered from the others. Correspondingly, the higher the "out-degree" value, the greater impact of the factor to the others.

(2) Betweenness centrality indicates the frequency of occurrence in which an assigned node/link is situated between the two other nodes/links. The node/link with a strong value of betweenness centrality has a high level of domination of the impact passing through it. Such a node/link acts as a mediator between different parts of the network, and feebleness at these key points may lead to global decomposition [40].
(3) Status centrality shows the overall influence of a stakeholder issue on the whole network [27]. This measure calculates the number of direct successors and predecessors of this node, and all other nodes in the network link to the node via these direct near neighbors. Status centrality is further classified into in-status centrality and out-status centrality; they, respectively, represent the degree to which a factor is affected by others, and a factor can influence the others [39]. Out-state centrality is used as the result measure, because it is considered to have a larger influence level. The higher the out-status centrality value, the greater the influence factor.
(4) Brokerage describes the role of a node in the network and its ability to connect different subgroups in a specific grouping situation [46]. After determining a grouping category, the five types of brokerage relationships (to include the number of times listed; coordinator, gatekeeper, representative, consultant, and liaison) in each node are counted. Nodes with high brokerage values need more attention, because they have key roles in extending communication impacts and promoting the overall network complexity.

3.5. Identification of the Critical Influencing Factors

Briefly, we should pay more attention to the influencing factors, which have higher out-degree, higher degree difference, higher betweenness centrality, higher status centrality, and higher brokerage values.

4. Results

4.1. Data Collection Results

In this paper, the literature review methods were firstly used to clarify the connotation and characteristics of MTS building, and then the preliminary list of main stakeholders and associated influencing factors were identified. In the process of identifying the developmental influencing factors of MTS building, this paper mainly focuses on the following two aspects: (1) the background of China's construction industry development and (2) differences between MTS building projects and other types of building projects. The next step started in April 2020. A total of 60 questionnaires were delivered via e-mail to relevant experts. The experts included government officials, developers, designers, prefabricated component manufacturers, builders, end users, publics, and media; all were engaged in the construction and timber industries. The e-mail content included the background and purpose of this study, as well as the influencing factors collected through the literature. These experts were invited to further screen and optimize the collected influencing factors through their suggestions. In this stage, the final list of developmental influencing factors was established; a total of nine stakeholders were identified. Along with the major stakeholders, 23 stakeholder-associated influencing factors were also determined. The influencing factors and related stakeholders are as shown in Table 1.

Table 1. The stakeholders and related influencing factors.

No.	Influencing Factors	Stakeholders	Sources
S1F1	Investment inclination	Developer	[6]
S1F2	Market positioning on MTS building		Interview
S1F3	Development cost of MTS building		[47]
S1F4	Comprehensive benefits of developing MTS building		Interview
S1F5	Management experience and ability		Interview
S2F6	Experience and ability on MTS building design	Designer	[6]
S2F7	Number of people engaged in MTS building design		Interview
S3F8	Timber raw material acquisition	Prefabricated component manufacturer	Interview
S3F9	Production technology and operation process		[6]
S3F10	Production innovation capacity		Interview
S3F11	Number of suppliers		[26]
S3F12	Logistics transportation technology		Interview
S4F13	Experience and ability on MTS building Construction	Construction enterprise	[6]
S4F14	Number of technical professionals		Interview
S5F15	Post-occupancy evaluation on MTS building	End user	Interview
S6F16	Promulgation of supportive policy	Government	[6]
S6F17	Technological specifications on MTS building		[39]
S7F18	Research input on MTS building	Research institution	[6]
S7F19	Experience on MTS building research and development		[26]
S7F20	Conversion rate of scientific research achievements		Interview
S8F21	Understanding about MTS building	Public	[11]
S8F22	Acceptance and publicity on MTS building		[27]
S9F23	Purchase tendency of MTS building	Media	[11]

After obtaining a list of influencing factors in MTS building based on the literature review and questionnaire survey, an expert interview was further conducted to identify the relationship between each pair of influencing factors. The interviews were conducted during June 2020. Twenty experts of MTS building, consisting of two government officials (from Xi'an housing and Urban Rural Construction Bureau), two developers (from Greenland Group), two designers (from Shaanxi Construction Engineering Group Corporation), two manufacturers (from Xi'an Construction Engineering Green Building Group Corporation), two builders (from Shaanxi Construction Engineering Group Corporation), three end users (from households who have been using timber villas for 3 years), five members of the public, and two media individuals were invited to conduct on-line workshops. In order to ensure the accuracy of the results, all experts had more than 10 years of work experience and had a deep understanding of MTS building. Subsequently, the influencing factors–interrelationship matrix was established, and then UCINET 6.0 [42] was used to establish the social network. UCINET 6.0 is a very popular social network data analysis tool, which can identify and process data and draw social network graphics [42].

4.2. SNA Analysis Results

4.2.1. Network Level Results

The visualization influencing factors network Graph (23, 164) is shown in Figure 5. Visual inspection of the network diagram can be used to preliminarily understand the whole network structure. The nodes indicate the stakeholder-associated influencing factors,

while the colors represent the stakeholders. The factors with more connections are located closer to the center of the network, while the factors with less links are distributed near the network boundary. Figure 5 shows that red, orange, and blue nodes are largely concentrated in the center of network diagram, which indicate that the stakeholders represented by these three colors have more important roles in MTS building development.

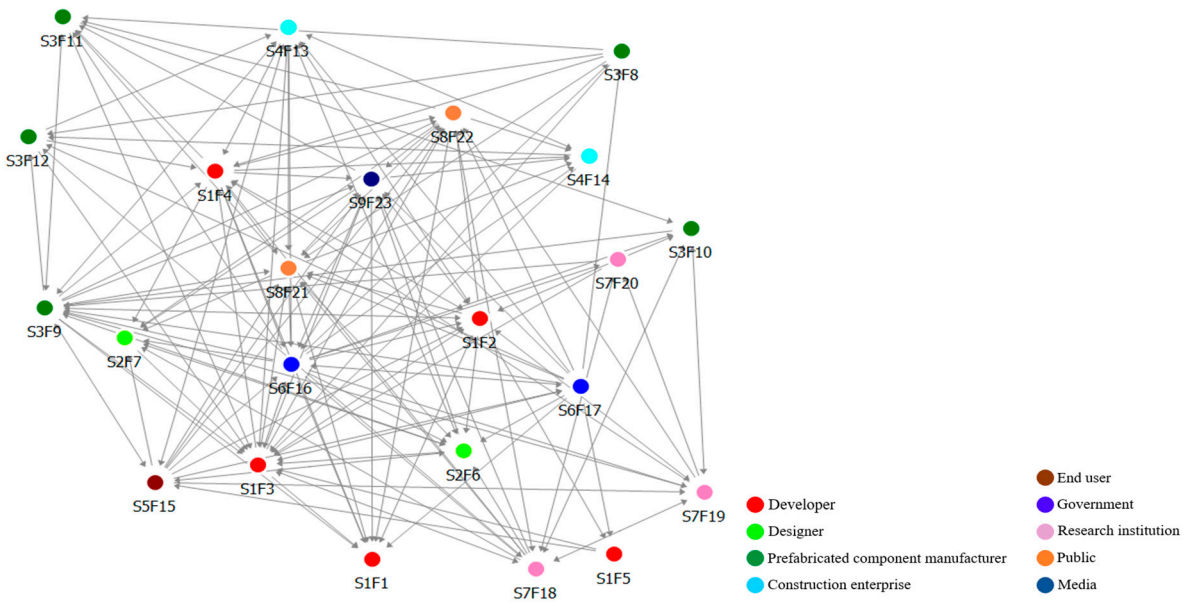

Figure 5. Stakeholder-associated influencing factors network.

The network level indicators provide a clear and macroscopic perspective for the quantitative analysis of the overall network situation. The network density is equal to 0.3241, showing that the network is relatively dense compared to the density value in Ref. [43]. On average, the influencing factors are connected via 1.324 walks. The cohesion value of the risk network is equal to 0.838, which is higher than the network density. This shows that the relationships between factors are more complex when considering the transmission effect of the entire network.

4.2.2. Node and Link Level Results

In order to identify the key influencing factors and important stakeholders, this section discusses the direct impacts and propagation impacts of single nodes and their roles in the network. The purpose of this section is to probe into the influencing degree and their node functions in the network from the micro level. A node with a more central position in the network is often directly or forced to approach more resources. The analysis of key nodes and links are mainly based on the calculation of out-degree, degree difference, betweenness, out-status centrality, and brokerage values, which are from the network graph. These indicators show the features and impacts of nodes and links from different perspectives. Figure 6 shows the status centrality map that depicts the relative outgoing impact of all stakeholder-related factors. The factors related to the developer, government, designer, manufacturer, and public are relatively and centrally located in the status centrality map. The node impacts decrease along with the distance between the node and the center of the circle. This finding illustrates the high impact of these stakeholders on the MTS developmental process.

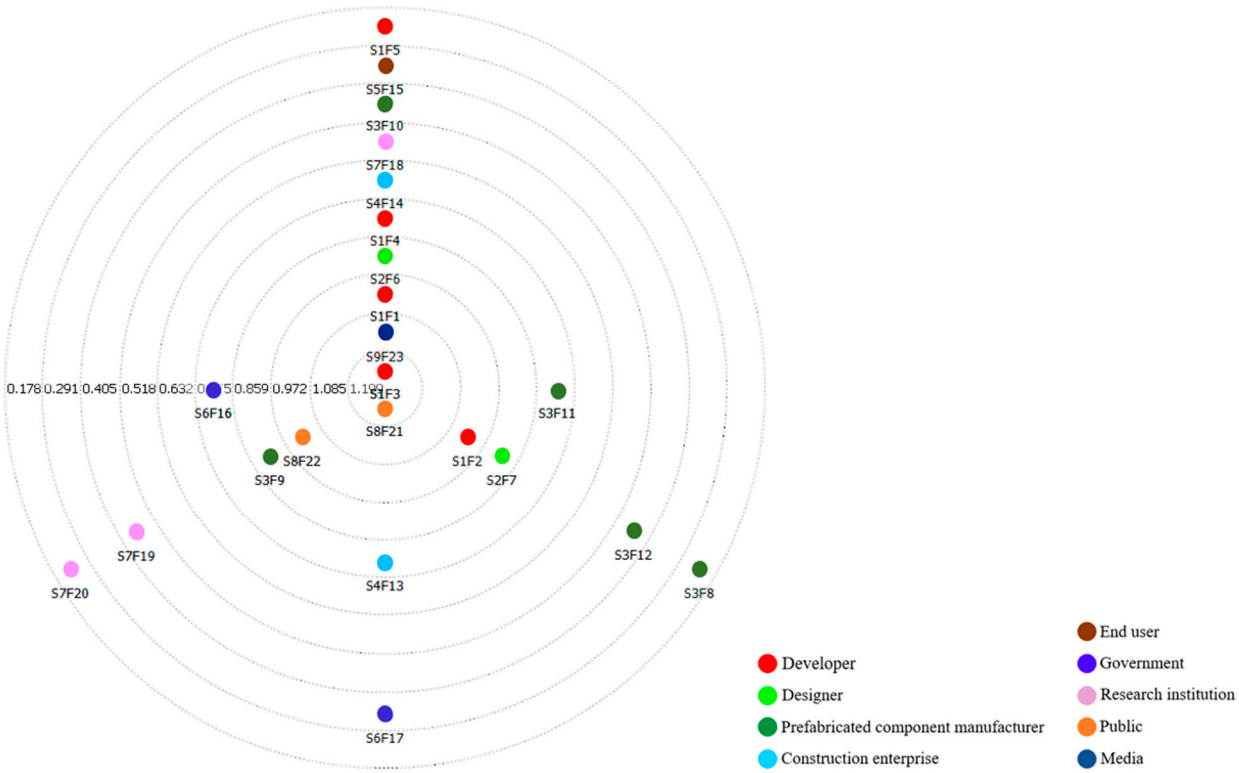

Figure 6. Status centrality map.

Table 2 displays the out-degree and degree difference of influencing factors. Ten factors are selected and sorted in the chart, because they either have a direct impact on many other factors or show a high degree difference. With regard to out-degree indicator, S6F16 ("promulgation of supportive policy", related to the government), S1F2 ("market positioning on MTS building", related to the developer), and S6F17 ("level of market supervision on MTS building", related to the government) are considered to be the three most significant risk factors. These three factors have the greatest and most direct impact on other factors in the network. In addition, S6F17 ("technological specifications on MTS building", related to the government), S1F1 ("investment inclination", related to the developer), and S5F15 ("post-occupancy evaluation on MTS building", related to the end user) have greater degree difference. These nodes make a significant impact on their neighboring nodes and the network transitivity.

Table 2. Top stakeholder-associated factors based on network size nodal degree analyses.

Rank	Factor ID	Out-Degree	Rank	Factor ID	Degree Difference
1	S6F16	18	1	S6F16	11
2	S1F2	12	2	S6F17	9
3	S6F17	12	3	S1F1	8
4	S3F9	12	4	S5F15	6
5	S7F18	11	5	S2F7	6
6	S5F15	11	6	S9F23	5
7	S1F4	9	7	S7F18	5
8	S1F3	9	8	S1F3	5
9	S8F22	8	9	S3F11	4
10	S4F13	8	10	S3F8	3

Table 3 lists the top 10 influencing factors and node links with the highest betweenness centrality. Through the results' contrastive analysis of node and link betweenness centrality, it can be found that the factors with the highest betweenness centrality, such as S1F3

("developmental cost of MTS building", associated with the developer), S1F2 ("market positioning on MTS building", associated with the developer), and S6F16 ("promulgation of supportive policy", associated to the government) become the hub connecting a significant number of influencing factors, which have strong abilities to control factor communication. More attention should be paid to the source influencing factors of the links in Table 3. By comparing the factors in Tables 2 and 3, the results show that although S1F1 ("investment inclination", associated with the developer) does not have a high and direct impact, it still has as a significant role in network connectivity.

Table 3. Key stakeholder-associated factors and interactions according to the betweenness centrality.

Rank	Factor ID	Node Betweenness Centrality	Link ID	Link Betweenness Centrality
1	S1F3	17.468	S1F1 → S1F2	23.386
2	S1F2	12.489	S1F3 → S6F16	19.869
3	S6F16	11.792	S1F2 → S1F5	17.315
4	S3F9	8.186	S1F3 → S7F18	16.888
5	S7F18	5.152	S3F11 → S1F3	16.662
6	S1F4	4.780	S6F16 → S3F8	15.964
7	S5F15	4.303	S4F14 → S1F3	14.304
8	S4F13	3.678	S1F5 → S5F15	13.095
9	S8F21	3.549	S1F4 → S6F16	12.499
10	S2F6	2.931	S8F21 → S6F16	11.804

Table 4 shows the top 10 factors according to their breakage values. Stakeholder categories are selected as the partition vector to group the risks. The results show that the top three nodes are S1F3 ("developmental cost of MTS building", associated with the developer), S6F16 ("promulgation of supportive policy", associated with the government), and S3F9 ("production technology and operation process", associated with the prefabricated component manufacturer). These nodes have great significance in connecting various stakeholder groups.

Table 4. Top stakeholder-associated factors based on brokerage analysis.

Factor ID	Partition Value	Coordinator	Gatekeeper	Representative	Consultant	Liaison	Total
S1F3	Developer	3	25	9	0	49	86
S6F16	Government	0	4	8	3	53	68
S3F9	Prefabricated component manufacturer	3	14	18	0	32	67
S1F2	Developer	6	19	18	3	20	66
S1F4	Developer	0	8	7	1	28	44
S8F21	Public	0	5	1	0	35	41
S7F18	Research institution	1	5	14	1	18	39
S8F22	Public	0	2	1	0	30	33
S9F23	Media	0	0	2	0	27	29
S4F13	Construction enterprise	0	6	6	1	14	27

5. Discussion

5.1. Critical Challenges and Obstacles during the Developmental Stage of MTS Building

This study identifies some key influencing factors for the successful and widespread application of MTS building in China. Subsequently, we discuss the results presented in Section 4.

First, market positioning is a necessary influencing factor that developers must consider in the early stage of a project. The purpose of market positioning is to determine

the product characteristics that the company should provide to customers in a specific market segment [48]. The developer needs to consider which (a) segments to serve, (b) competitors to face, and (c) product features to choose [49]. MTS building has various characteristics and can be applied in many fields. In the United States, 95% of the low-rise buildings and 50% of the commercial buildings adopt a timber structure; in Canada, timber structure accounts for more than 80% of the new single and multistorey buildings; in Sweden, 95% of the independent houses and villas are timber structures. However, due to the characteristics of large population density and small space in Chinese cities, it is difficult to popularize timber structure low-rise residential villas in China on a large scale. According to China's national conditions, multi-story and high-rise building will become the development direction of MTS building in China [50]. Simultaneously, the local government should provide policies to guide and encourage the development of timber structure in the public building field. Compared with other forms of building, MTS building is greener, produces low carbon, and is an ideal choice for people's leisure and health. Therefore, culture, tourism, health care, and education will also become the new developmental fields. In addition, there are great differences in architectural features and living habits between the south and the north of China; it is important to select suitable MTS building types according to local conditions.

Second, cost is a key influencing factor that can restrict the development of MTS buildings. The one-time investment in the early stage of MTS building construction is generally higher than that in traditional building. At this stage, due to the contradiction between standardization and diversification, the imperfect construction of industrial chain, and other problems, enterprises usually need to invest significant funds for technology, research and development (R&D), and production line construction. In addition, the value-added tax of timber prefabricated component products is up to 17%, which is 13% higher than other traditional construction products. High initial investment delays the growth number of prefabricated component plants. Government subsidies for the development of the MTS building industry are insufficient to offset the incremental costs of raw material production and building construction. Under a high-cost environment, most developers locate green building projects in the high-end market and set high project prices. High prices will narrow the customer base; however, developers will lose money and reduce investment willingness under a very low price. High cost is detrimental to MTS building development. Therefore, cost control will become a particularly important factor.

Third, government policy has a critical role in guiding investment tendency, market positioning, research direction, and research institution investment. Meanwhile, it is critical to improve the public's knowledge and awareness of MTS building. At present, the cost of MTS building is relatively high; the MTS building market has not had a decisive role in resource allocation; it still needs to rely on governmental guidance. In addition, if the government implements the "positive incentive" strategy, more enterprises and scientific research institutions will be encouraged to participate in the production and construction of MTS building and key R&D technologies [51]. Supportive governmental policy is conducive to improving the related technology system and ensuring the MTS building industry has healthy and sustainable development, which is the direct driving force and a powerful measure for the construction and development of MTS building [52]. Therefore, the government has an irreplaceable role in the early stage of MTS building development. Simultaneously, the incentive intensity of government policies is significantly affected by the social benefits, environmental benefits, incentive costs, and other factors, which are produced by MTS building development. In order to promote its rapid development, the government cannot just consider the incentive costs paid to promote the R&D of MTS technology; more attention should be paid to the social progress, environmental improvement, and government image improvement brought by MTS building development.

Fourth, the results of SNA show that the publics' understanding and acceptance of MTS are considered as an important influencing factor. When it comes to timber structure building in China, most people first think of traditional Chinese timber structure buildings,

such as temples and timber towers. The traditional Chinese timber structure is flammable and is easily affected by dampness and pests; other shortcomings have been deeply rooted in people's minds. Although MTS technology has successfully mitigated these problems, the MTS concept is relatively novel for most Chinese people. Some within the public believe that MTS has the same disadvantages as traditional Chinese timber structure and hold a negative attitude towards timber structure due to a lack of sufficient understanding. In addition, developers always publicize timber houses (in the form of villas) in the current Chinese market, which result in the public's impression that timber houses are high-end and expensive, reducing people's purchase desire. These situations have hindered MTS development. Better knowledge, more available information, and higher exposure will increase consumers' desire to purchase [11].

5.2. Stakeholder Relationships

From the network analysis, the designer, prefabricated component manufacturer, and construction enterprise maintain close contacts. MTS building adopts the industrialized construction mode of standardized design, prefabrication, and on-site assembly. The lack of collaboration ability and overall concept of design, production, and construction can extend the construction period, consume more materials, and increase the project quality risk. The technical factors related to the three stakeholders have higher rank among all influencing factors, and they are the key to determining the degree of connections between the three stakeholders. Due to the late start of MTS research in China, the technical specifications of design, production, and construction are not perfect. For example, product fire and heat resistance are not mentioned in most engineering wood product specifications. In addition, medium and high-rise residential development is a future developmental orientation of MTS building in China, which requires the prefabricated component factory to produce engineering wood products that match the requirements of mechanical properties and seismic design. Therefore, technology can significantly affect the developmental process of MTS buildings.

5.3. Countermeasures to MTS Building Development

According to the research results, some suggestions are put forward to promote the development of the MTS building sector, based on the literature review and interviews with experts.

5.3.1. Increase Policy Incentives and Support

First, the government at various levels shall formulate more sound policies according to local conditions, determine the development planning and objectives of MTS building within each region, organize specific and feasible implementation measures, and promote MTS building development through policy constraints. Simultaneously, the government is supposed to increase supportive efforts to small and medium-sized enterprises engaged in MTS building; it is necessary to give certain preferential policies to enterprises, such as land support, area award, financial subsidies, and tax incentives [52]. Second, the government needs to increase support for scientific research and innovation in MTS building, initiate special scientific research funds and awards for scientific and technological innovation, and improve the mechanism of intellectual property protection and achievements transformation.

5.3.2. Improve Technical Specification System

Policy support alone is insufficient. Enterprises should unite high-quality scientific research institutions to implement systematic R&D of key technologies, processes, and equipment for MTS, improve the standards of component production, pricing basis, environmental protection supervision, earthquake resistance, fire protection, building evaluation, etc. [12]. They should also establish and perfect national and local industrial standards. Meanwhile, in the process of MTS building construction, the application of

the Engineering Procurement Construction (EPC) general contracting model and Building Information Modeling (BIM) technology should be actively promoted in the whole life cycle management and provide a collaborative platform for design, manufacturing, and construction enterprises.

5.3.3. Enhance Publicity

Intensifying the pilot construction of MTS projects, which focus on civil and public construction in combination with the key work of new rural and tourism construction in China is critical. The government and enterprises need to hold more activities, such as industrial development forums and expert special meetings. They should also publicize the advantages and benefits of wood structure to the public by using existing media (networks, television, newspapers, and other mass media), creating a positive and social atmosphere for public opinion, and promoting the industrialization and marketization of wood structure construction [6].

5.3.4. Innovative Development Mode

The coordinated development of scientific research institutions, design units, manufacturers and construction enterprises shall be vigorously promoted. At the same time, leading enterprises will be actively cultivated, the mode of MTS building industrial alliance will be explored and the industrial layout improved. The government should introduce special personnel training policies and measures of MTS building to strengthen the training and education of workers, and improve the appraisal of vocational skills. Meanwhile, the college is supposed to carry out a relevant professional course education of MTS building, and cultivate technical and management talents through a school enterprise alliance [50].

6. Conclusions

Based on the social network analysis and the stakeholder theory, this paper constructed a potential network of influencing factors in MTS and identified the key influencing factors and their interactions. Several important findings of this study include: (1) public understanding and acceptance on MTS building are very important factors that affect its development. Reasonable market positioning can enhance the public's awareness and purchase desire. (2) As an important gatekeeper and liaison, the cost of MTS building development has a strong role in controlling and mediating the information transmission in the network. (3) The government has a vital role, especially in the early stages of development. (4) The designer, prefabricated component factory, and construction enterprise are closely related, and their technical capability can influence the promotion and progress of MTS building.

The MTS building sector in China is currently at a low level of development. Due to the characteristics of energy saving and the low carbon of MTS building and the current sustainable development of construction industry governmental policies, the sector has a great, developmental prospect. In order to further promote green building development in China, knowledge and information dissemination, education dealing with timber construction technology, and the properties and benefits of MTS building need to be promoted at different levels. This paper provides a strong reference for MTS building stakeholders and can be used as a reference for greener and more sustainable construction within China.

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