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Critical Factors Affecting the Quality of Industrialized Building System Projects in China

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Abstract: Whilst the benefits of applying an industrialized building system (IBS) have been well recognized globally in the construction industry, the application of IBS is particularly limited in developing countries such as China, and quality is considered one of the key issues affecting its application. This paper identifies a number of the key quality factors which present barriers to the promotion of IBS within the context of the Chinese construction industry. These include key factors such as "Inaccurate design of the connecting points between core components", "Lack of design norms and standards for IBS components", "Lack of quality criteria for IBS components", "Lack of production norms and standards for IBS components", "Lack of quality management system in production process", and "Lack of technical guidelines for the construction of IBS projects". The data used for analysis are derived from a comprehensive practical survey. The validity of the data is examined by using a statistical method. The findings from the study provide valuable references for formulating effective measures to mitigate the negative effects of these quality factors on IBS application in China, thereby ensuring that practice of the IBS system can be further developed within the country.

Keywords: industrialized building system; critical quality factors; key factor; barrier; China

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1. Introduction

Over past two decades, the industrialized building system (IBS) has been introduced as a major methodology for promoting cleaner production and sustainability performance in the construction industry. IBS has various synonymous terms such as industrialized construction, prefabrication, pre-assembly, modern method of construction, off-site manufacturing, off-site production, and off-site construction. The main contexts of these terms refer to three typical groups of activities, namely, producing building components at a factory within highly controlled environments, delivering prefabricated components to construction sites, and assembling components to form building structures [1]. As an innovative construction method, IBS has been widely applied in many countries and has become a major approach in the construction industry. The promising future of IBS can be explained by the inherent advantages of this innovative construction method. Compared to a conventional construction method, IBS is widely recognized for the advantages of improving building quality, prolonging a building's lifespan, reducing labor, shortening project construction duration, as well as reducing construction site waste and environmental impacts [2,3]. Mydin, Phius [4] concur, arguing that the IBS approach has a lot to offer compared to the conventional system and can derive fruitful benefits such as reduced construction durations, reduced overall costs, reduced labor requirements, better site conditions and the production of components of higher quality, among others. In essence, IBS improves sustainable performance of the construction industry and is thus considered an effective strategy for cleaner production in construction.

Despite the various merits of IBS, it appears that this innovative method for construction has not yet been effectively implemented, particularly in developing countries such as China. It has been reported that, currently, the proportion of buildings constructed through IBS is as low as 3%−5% in China, whereas in Europe and the United States, it is approximately 75% and 80% respectively, and 70% in Sweden and Japan [5]. Previous studies have examined various factors affecting the implementation of IBS in China, including Luo, Mao [6], Mao, Shen [7] and Zhang, Skitmore [8]. Kamar, Alshawi [9] identified the barriers to the implementation of IBS projects in Malaysia, finding that the negative perception of IBS, lack of past experience, extra cost, lack of component testing facilities, lack of regulations and poor IBS knowledge are the main obstacles. In a further study by Din, Bahri [10] within the context of Malaysia, lack of incentives for IBS projects, availability of cheap labor offsetting the cost benefits of IBS, inadequacy of market size, low standardization of components and supply chain management and partnering issues are the significant barriers to implementation of IBS. Blismas, Pendlebury [11] recognized constraints in implementing off-site construction production. Blismas and Wakefield [12] explored the hindrances to the implementation of off-site manufacturing of construction components in Australia, suggesting skill shortages and lack of related knowledge as the most significant barriers. Arditi, Ergin [13] and Polat [14] both studied the factors influencing the utilization of the precast concrete system in the United States. There are also many studies analyzing the factors affecting the development of IBS in China [6–8,15]. Musa, Mohammad [16] illustrated that implementation of IBS is hindered by typical factors such as poor implementation of IBS projects by government agencies, high cost of IBS components, low standardization of components and design solutions, poor IBS knowledge management and human capital development, and no IBS research and development centre. According to Ismail, Yusuwan [17], a good working collaboration, an effective communication channel and team member involvement during the design stage are the top three most influential management-related factors towards the successful implementation of IBS projects. However, when referring to these research studies, there is a consensus that one of the major concerns in implementing IBS is the quality issue. Luo, Mao [6] argued that there is a lack of a quality-monitoring mechanism during the component production process which presents a main quality risk that reduces the confidence among building stakeholders as to the quality of IBS projects. In the studies by [3,18], market demand is one of the critical factors affecting the effective application of IBS, whereas market demand is determined by the quality of IBS projects.

Similarly, Zhang, Skitmore [8] illustrated that quality during the manufacturing process is a critical factor that limits the development of IBS projects. The new IBS Roadmap 2011−2015 in Malaysia identifies four main policy objectives for developing IBS projects, namely, quality, efficiency, competency and sustainability [18]. The Chinese government has issued a policy entitled "The Guideline for Developing IBS in China" (China State, 2016), which requests for quality standard controls whilst promoting the technology. The Ministry of Urban and Rural Development of China has issued a policy for promoting the comprehensive application of information technology in the Chinese construction industry (MURD, 2016). These policies are developed to impose high-level intended outcomes from implementing IBS, thus illustrating the significance of quality for IBS projects.

The quality of building projects commonly refers to satisfying customers' expectations and conforming to quality specifications [19]. These two quality dimensions are met by the provisions of aesthetic and functional elements. Quality, schedule and cost are traditionally referred to as the "management triangle" in the domain of project management. In particular, at present, quality is given additional attention as customers' expectations of quality are increasing. The quality performance of IBS projects presents concerns in the Chinese market as this type of project is at the initial stage of development [20]. Therefore, it is essential, to uncover the factors contributing to the quality of IBS projects in order to identify the solutions to improving quality. This will in turn lead to effective implementation of IBS projects in China.

Extensive studies have been conducted in the past to identify factors affecting the quality of building projects when a conventional construction method is adopted. For example, in examining the factors affecting the quality in the life-cycle process of building projects, Arditi and Gunaydin [21] identified factors such as management commitment, management leadership, labor training, efficient cooperation between departments at the corporate level and effective teamwork at the project level. Chan and Tam [22] have examined the factors affecting the quality of building projects referring to Hong Kong construction and suggested that management action by the project team is the most significant quality factor, followed by the effectiveness of the construction team leader and the emphasis on quality by client. Jha and Iyer [23] have conducted a study on critical factors influencing quality performance in construction projects in India, and found project managers' competence and the support from top management to be the most critical factors affecting project quality.

However, there are many differences between IBS projects and conventional building projects. For example, the prefabrication phase is very prominent in IBS projects, whereas conventional building projects do not engage this phase. Therefore, the factors affecting the quality of IBS projects are different from those of conventional building projects. On the other hand, whilst there are a many studies about the application of IBS projects, these studies mainly focus on the issues of the implementation process of IBS projects.

A clear lack of research on the factors affecting the quality of IBS projects is thus evident. Therefore, this paper aims to investigate the factors affecting the quality of IBS projects with reference to the Chinese construction industry.

2. Research Methodology

Research methods are properly selected for conducting this study. A comprehensive literature review on the topic of this research is firstly carried out to build up theoretical understanding on the subject of IBS projects and their quality management. Journals, research theses, official policies and standards, in addition to books relating to this research topic are the main literature sources. Further, the literature review forms a solid basis to develop questionnaires to conduct the practical survey in order to collect research data.

Existing literature has presented various factors affecting the quality of conventional building projects and the implementation of IBS projects, such as, [8,22,23]. The quality factors are also among the key issues in various official policies and criteria for construction products within the context of China. In particular, the Ministry of Urban and Rural Development of China has issued the Criteria for the Evaluation of Industrialized Building in 2015, which highlights the importance of quality aspects in the process of promoting IBS in China. These factors are important references for examining the quality factors in implementing IBS projects. Consequently, an initial list of factors affecting the quality of IBS projects is formed. As the factors selected preliminarily are from literature reviews, their adequacy from the perspectives of IBS projects is refined and adjusted through carrying out a pilot study. The pilot study is conducted in the form of semi-structured interviews by presenting the preliminary list of factors to three professionals and inviting them to give comments and suggestions on the suitability of the factors. Finally, a revised list of factors is formulated, which is used to formulate the formal questionnaires for collecting the data about professionals' views on the relative significance among these factors. As an effective rating method, the five-point Likert scale method is applied for indicating the degree of significance of factors [24].

The data collected is analyzed by using statistical techniques for understanding the relative significance among the factors and the concordance of respondents' perceptions of the relative significance of these factors. Firstly, the reliability of the collected data is checked by the computing tool Statistical Package for the Social Sciences (SPSS). Then, the average value and standard variance for each quality factor are calculated, leading to the identification of critical quality factors. In further analysis, the *t*-test and one-dimensional variance test are undertaken to check the consistency of the views among different groups of professionals who have participated in the questionnaire survey process. Furthermore, the three experienced professionals who have participated in the pilot study for questionnaire survey are invited for engaging further discussions on the survey results.

3. Research Data

3.1. Development of the Preliminary List of Quality-Related Factors

After conducting a comprehensive literature review, typical factors affecting the quality of IBS projects are summarized in Table 1, which are classified into three categories: design-related, production-related and construction-related.

Table 1. Preliminary list of factors affecting the quality of industrialized building system (IBS) projects.

Code	Factors
	Design-related quality factors (F1)
F1-1	Lack of design norms and standards for IBS components
F1-2	Limited design time imposed by project clients
F1-3	Inaccurate and incomplete information provided by project clients
F1-4	The difference of understanding by designers on the project client's requirements
F1-5	Severely low cost of the product design defined in the contract
F1-6	Lack of experienced designers of the IBS components
F1-7	Lack of coordination and communication between different groups of designers
F1-8	Lack of coordination and communication between product designers and manufacturers
F1-9	Lack of coordination and communication between product designers and builders
F1-10	Lack of coordination between the design for conventional construction and the design for industrialized components
F1-11	Lack of consideration for the selection and position of special equipment for the transportation and handling of IBS components
F1-12	Improper design for the lifting point of the IBS components
F1-13	Inaccurate design of the connecting points between core components
F1-14	No building information modeling (BIM) application for checking the collision between IBS components
F1-15	Too many design changes for IBS components
	Production-related quality factors (F2)
F2-1	Lack of production norms and standards for IBS components
F2-2	Lack of production quality management system in manufacturer's production process
F2-3	Obsolescent production technology and equipment
F2-4	Lack of experienced workers for IBS component production
F2-5	Limited production time imposed by project clients
F2-6	Lack of coordination and communication between the production staff
F2-7	Severely low cost for production defined in contract
F2-8	Poor quality of raw materials
F2-9	Poor quality moulds for IBS component production
F2-10	Lack of quality assurance measures for the storage and transportation of IBS components
F2-11	Lack of coordination between component manufacturers and construction team
F2-12	Lack of experienced supervisors during the component production process
F2-13	Poor equipment for quality testing
F2-14	Lack of quality criteria for component products

Table 1. *Cont.*

Code	Factors
	Construction-related quality factors (F3)
F3-1	Lack of technical guidelines for the construction of IBS projects
F3-2	Lack of experienced project managers in the construction of IBS projects
F3-3	Lack of skilled workers in the construction of IBS projects
F3-4	Lack of coordination and communication between on-site management personnel
F3-5	Lack of coordination and communication between on-site construction workers
F3-6	Obsolescent construction technology and equipment
F3-7	Limited construction time imposed by project clients
F3-8	Severely low cost of the construction defined in contract
F3-9	Receipt of poor-quality components due to lack of on-site checking measures
F3-10	Damage of the components in the process of on-site loading and unloading
F3-11	Collision damages in the process of stacking and lifting due to limited on-site space
F3-12	Inadequate construction of the connecting points between cast-in and prefabricated units
F3-13	Inadequate construction of the connecting points between the core components
F3-14	Inaccurate installation of IBS components
F3-15	Lack of experienced supervisors in the construction process
F3-16	No corrective action on the poor-quality components because of the disputes between different project parties
F3-17	Lack of construction quality criteria for IBS components

3.2. Questionnaire Design and Distribution

Based on the list of factors in Table 1, a questionnaire is designed to collect professionals' views on the relative importance of these factors in referring to the quality of IBS projects. The effectiveness of the questionnaire has been tested through a pilot study. Accordingly, the questionnaire is developed and finalized for distribution to experts.

The practitioners who have knowledge or experience in engaging IBS projects are the targeted respondents in the questionnaire survey, including project clients, designers, component manufacturers, supervisors and contractors. The Likert-scale method is used for assessing the importance of each factor, in which '1' refers to 'negligible', '2' 'insignificant', '3' 'average', '4' 'significant' and '5' 'most important'. The questionnaires are distributed through multiple channels including mail post, on-line post and individual contacts in order to ensure that a sufficient number of effective responses is received. Mail and on-line posts are addressed to those managers in quality management departments in a number of selected construction businesses in Beijing, Shanghai, Chongqing, Xiamen, Shenzhen and Hefei where IBS practice has been well received. Individual contacts are those professionals who have been well known to this research team with expert knowledge and experience in applying IBS. The snowballing method is adopted through individual contacts in order to increase the number of respondents.

3.3. Feedback of the Questionnaire Survey and the Quality of the Responses

The survey was conducted during the period of November 2015 to April 2016. In total, 500 questionnaires were distributed, and 179 responses were received, which gives an effective response rate of 35.8%. A total of 91.29% of the respondents hold a bachelor's degree or above in terms of academic level; 61.3% have more than five years of work experience; 72.9% have experience in engaging IBS application. Among the respondents, 16.23% are project clients (Group A); 29.74% designers (Group B); 16.23% producers/manufacturers (Group C); 22.97% on-site construction teams (Group D); and 14.83% project supervision engineers (Group E).

Furthermore, the 72.9% respondents with both knowledge of and experience in IBS projects are referred to as Tier I respondents, and the 27.1% with the knowledge but without practical experience in IBS projects have been named Tier II respondents.

The quality of the responses has been checked to ensure their effectiveness. The coefficient of Cronbach's alpha (α) is a commonly applied method to check the reliability of the data collected through the questionnaire survey. In using this method, α assumes a value within the range (0, 1). The following outcomes are commonly accepted for the value of Cronbach's alpha: "$\alpha > 0.9$—Excellent, $\alpha > 0.8$—Good, $\alpha > 0.7$—Acceptable, $\alpha > 0.6$—Questionable, $\alpha > 0.5$—Poor, and $\alpha < 0.5$—Unacceptable" [25,26]. By using the computing tool SPSS (IBM SPSS Statistics, New York, NY, USA), the value of α in this survey is obtained as 0.921. This value clearly concludes that the data received from the questionnaire survey are reliable for further analysis. A significant majority (72.9%) of respondents possesses both the required knowledge and experience in IBS projects, which is for the reason behind this excellent set of reliable data.

4. Data Analysis

4.1. Overall Results from Statistics Analysis

By using 179 effective responses, the mean value and standard deviation for each factor are calculated and results are presented in Table 2. All indicators are ranked within the three separate groups (design-related, production-related, and construction-related) according to the respective mean value, as shown in Table 2.

Table 2. Statistics results for each factor.

Code	Mean Value	Standard Deviation	Ranking
Design-related quality factors (F1)			
F1-1	3.34	0.932	2
F1-2	3.04	1.071	9
F1-3	2.56	1.202	14
F1-4	2.50	1.344	15
F1-5	3.20	1.010	5
F1-6	3.22	0.997	4
F1-7	2.86	1.159	11
F1-8	3.19	1.096	6
F1-9	3.16	0.924	7
F1-10	3.05	1.130	8
F1-11	2.98	1.079	10
F1-12	2.78	1.153	12
F1-13	3.47	0.819	1
F1-14	3.30	0.979	3
F1-15	2.67	1.320	13
Production-related quality factors (F2)			
F2-1	3.29	1.009	2
F2-2	3.27	1.070	3
F2-3	2.52	1.229	14
F2-4	3.08	1.076	6
F2-5	3.00	1.154	9
F2-6	2.75	1.261	11
F2-7	3.20	1.051	5
F2-8	3.01	1.077	7
F2-9	2.54	1.247	13
F2-10	2.85	1.225	10
F2-11	3.01	1.127	8
F2-12	3.21	1.112	4
F2-13	2.58	1.140	12
F2-14	3.40	0.991	1

Table 2. *Cont.*

Code	Mean Value	Standard Deviation	Ranking
Construction-related factors (F3)			
F3-1	3.25	0.887	3
F3-2	3.22	0.983	4
F3-3	2.86	1.135	13
F3-4	3.20	0.977	7
F3-5	2.61	1.273	17
F3-6	3.11	1.056	10
F3-7	3.01	1.262	11
F3-8	3.22	1.040	5
F3-9	3.00	1.212	12
F3-10	2.75	1.262	15
F3-11	3.14	1.148	9
F3-12	3.15	1.076	8
F3-13	3.54	0.740	1
F3-14	2.79	1.309	14
F3-15	3.22	1.053	6
F3-16	2.68	1.191	16
F3-17	3.36	0.854	2

The analysis is conducted on the top five factors under each group. It can be seen from Table 2 that the top five design-related factors include: F-13, F1-1, F1-14, F1-6, and F1-5. The top five production-related factors are F2-14, F2-1, F2-2, F2-12, and F2-7, whereas the top five construction-related factors are F3-13, F3-17, F3-1, F3-2, and F3-8. According to the table, the mean value for design-related factors ranges from 3.47 to 2.50; for the production-related factors, the range is from 3.40 to 2.52; and for construction-related factors, it ranges from 3.54 to 2.75. The mean value ranges are quite similar for design-related and production-related factors, which suggests that the respondents have comparatively higher focus on those two sets of factors in general.

4.2. Consistency Test

As stated above, the respondents are grouped from two perspectives. From the perspective of extent of knowledge in IBS, respondents are classified into Tier I and Tier II groups. As the two tiers have different knowledge and experience on IBS projects, it is necessary to check whether the analysis results from the two tiers of responses are consistent. For this purpose, *T*-test is conducted. On the other hand, the respondents are divided into five groups from the perspective of business nature, as mentioned before, namely, project client (Group A), designers (Group B), producer/manufacturer (Group C), on-site construction team (Group D), and project supervision engineer (Group E). It is also considered important to check whether the perceptions from the five groups are consistent. For this purpose, on-way ANOVA analysis is conducted.

4.3. T-Test

The *t*-test is commonly used to examine whether the mean values of a specific variable from two independent groups are significantly consistent, or whether they are significantly different [27,28]. The value of a parameter "Sig" needs to be established to indicate the level of difference between two groups of professionals about their perceptions of the importance of a specific variable. When Sig ≤ 0.05, it is considered that two groups are significantly different, otherwise the two groups are reasonably consistent about their perceptions. The *t*-test is applied here to check whether the respondents in Tier I and Tier II have significant difference in expressing their perceptions of the importance of individual quality factors in the application of IBS projects. The computing tool SPSS is used for the calculation. The results are obtained and reported in Table 3.

Table 3. Consistency test results for Tier I and Tier II.

Code	Mean Value			Sig	Significant Difference (N/Y)?
	Overall	**By Tier I**	**By Tier II**	**0.183**	**N**
F1-1	3.34	3.34	3.35	0.846	N
F1-2	3.04	3.10	2.87	0.183	N
F1-3	2.56	2.48	2.76	0.684	N
F1-4	2.50	2.49	2.52	0.928	N
F1-5	3.20	3.30	2.94	0.068	N
F1-6	3.22	3.26	3.11	0.993	N
F1-7	**2.86**	**3.02**	**2.43**	**0.039**	**Y**
F1-8	3.19	3.29	2.93	0.137	N
F1-9	3.16	3.24	2.96	0.349	N
F1-10	3.05	3.15	2.80	0.284	N
F1-11	2.98	2.99	2.97	0.958	N
F1-12	2.78	2.81	2.71	0.859	N
F1-13	**3.47**	**3.60**	**3.13**	**0.038**	**Y**
F1-14	**3.30**	**3.44**	**2.92**	**0.036**	**Y**
F1-15	2.67	2.70	2.59	0.723	N
F2-1	3.29	3.29	3.29	0.983	N
F2-2	3.27	3.31	3.14	0.294	N
F2-3	2.52	2.47	2.67	0.438	N
F2-4	3.08	3.11	2.99	0.267	N
F2-5	3.00	3.02	2.95	0.758	N
F2-6	2.75	2.78	2.69	0.693	N
F2-7	3.20	3.27	3.03	0.383	N
F2-8	3.01	3.05	2.88	0.447	N
F2-9	2.54	2.51	2.60	0.296	N
F2-10	2.85	2.90	2.71	0.680	N
F2-11	3.01	3.10	2.77	0.138	N
F2-12	3.21	3.26	3.08	0.648	N
F2-13	2.58	2.58	2.56	0.972	N
F2-14	**3.40**	**3.50**	**3.13**	**0.042**	**Y**
F3-1	3.25	3.32	3.13	0.836	N
F3-2	3.22	3.24	3.17	0.892	N
F3-3	2.86	2.90	2.75	0.678	N
F3-4	3.20	3.10	3.47	0.182	N
F3-5	2.61	2.60	2.64	0.947	N
F3-6	3.11	3.11	3.11	0.936	N
F3-7	3.01	3.04	2.93	0.875	N
F3-8	3.22	3.24	3.17	0.959	N
F3-9	3.00	3.00	3.00	0.928	N
F3-10	2.75	2.76	2.73	0.959	N
F3-11	3.14	3.21	2.95	0.147	N
F3-12	3.15	3.23	2.96	0.158	N
F3-13	**3.54**	**3.68**	**3.16**	**0.033**	**Y**
F3-14	2.79	2.79	2.80	0.983	N
F3-15	3.22	3.34	2.89	0.058	N
F3-16	2.68	2.75	2.50	0.283	N
F3-17	3.36	3.42	3.21	0.382	N

Table 3 suggests that Tier I and Tier II respondents are considerably consistent in judging the significance of quality factors, except the significant difference of perception of several factors, including the design-related factors F1-7, F1-13, F1-14; the production-related factor F2-14; and the construction-related factor F3-13. Tier I respondents put much more weight on the significance of factor F1-7 "Lack of coordination and communication between different groups of designers" than as was perceived by Tier II respondents. This is probably because that Tier I respondents have both knowledge and working experience and understand the importance of the coordination and communication between different groups of designers. Similarly, for F1-13 "Inaccurate design of the connecting points between core components" and F1-14 "No BIM application for checking the collision between IBS components", Tier I respondents consider these factors more important in contributing to the quality of a project than was perceived by Tier II respondents. It is noteworthy that both these factors require on-site experience to evaluate the impact on IBS projects. In referring to factor F2-14 "Lack of quality criteria for component products", Tier I considered it highly important to the quality of products. Interestingly, however, Tier II thought of it as negligible. Furthermore, in regards to the construction-related factor F3-13 "Inadequate construction of the connecting points between the core components", Tier I respondents also consider it more important than the Tier II respondents. In general, Tier I respondents tend to give more weight to the significance of all quality factors than Tier II respondents. This is particularly significant in design-related quality factors. Three out of 15 quality factors received significant differences in responses between the two tiers, including factor F1-13 which is the highest-ranked of the design-related quality factors. Further, since the majority of the respondents, i.e., 72.9%, is in Tier I, the differences in response perceptions of quality factors between the two tiers can be considered due to the fact that IBS practice is still in its early development stage in China, and experience is thus considered essential in promoting the practice.

4.4. One-Way ANOVA Test

When it is required to check whether the mean values of a specific variable from more than two independent groups are significantly consistent, the one-way ANOVA test is normally conducted [29,30]. Similar to the *t*-test, the value of a parameter "Sig" needs to be established when conducting the ANOVA test in order to read the level of difference between more than two groups of professionals about their perceptions of a specific variable's importance. When Sig ≤ 0.05, it is considered that there is a significant difference of the perceptions between different groups; otherwise, all the groups are reasonably consistent in their perceptions of a specific variable's importance. The on-way ANOVA test is applied here to check whether the respondents in Groups A, B, C, D and E have significant difference in expressing their perceptions of the importance of individual quality factors in the application of IBS projects. The computing tool SPSS is used to carry out the calculation. The results are obtained and reported in Table 4.

Table 4. One-way ANOVA test.

Code	**Mean Value**						**Sig**	**Significant Difference (N/Y)**
	Overall	**Group A**	**Group B**	**Group C**	**Group D**	**Group E**		
F1-1	3.34	3.47	2.92	3.41	3.18	3.58	0.596	N
F1-2	3.04	3.06	2.83	3.14	3.09	3.08	0.966	N
F1-3	2.56	2.45	2.48	2.44	2.78	2.84	0.741	N
F1-4	2.50	2.41	2.42	2.41	2.65	2.78	0.710	N
F1-5	3.20	3.59	2.67	3.41	3.08	2.91	0.059	N
F1-6	3.22	3.47	2.91	3.27	3.09	3.08	0.734	N
F1-7	2.86	2.94	2.67	2.91	2.91	2.83	0.907	N
F1-8	3.19	3.53	2.75	3.27	2.91	3.25	0.300	N
F1-9	3.16	3.18	2.91	3.27	3.09	3.27	0.848	N
F1-10	3.05	3.06	2.83	3.14	3.09	3.08	0.966	N
F1-11	2.98	3.12	2.83	2.95	3.00	2.92	0.970	N
F1-12	2.78	2.71	2.73	2.68	2.91	3.09	0.747	N
F1-13	**3.47**	**3.35**	**3.68**	**3.76**	**3.26**	**3.09**	**0.01**	**Y**
F1-14	3.30	3.47	3.27	3.05	3.64	3.18	0.618	N
F1-15	2.67	2.69	2.70	2.35	2.77	3.06	0.582	N
F2-1	3.29	3.41	3.27	3.27	3.09	3.36	0.952	N
F2-2	3.27	3.24	3.09	3.32	3.45	3.18	0.859	N
F2-3	2.52	2.45	2.42	2.44	2.65	2.78	0.693	N

Table 4. *Cont.*

Code	Mean Value						Sig	Significant Difference (N/Y)
	Overall	Group A	Group B	Group C	Group D	Group E		
F2-4	3.08	3.00	2.91	3.18	3.00	3.09	0.955	N
F2-5	3.00	3.12	3.18	2.64	3.18	3.27	0.427	N
F2-6	2.75	2.88	2.50	2.91	2.55	2.67	0.786	N
F2-7	3.20	2.94	3.09	3.27	3.45	3.27	0.776	N
F2-8	3.01	3.00	2.92	2.91	3.18	3.17	0.922	N
F2-9	2.54	2.45	2.48	2.44	2.65	2.84	0.722	N
F2-10	2.85	2.59	2.33	3.14	3.45	2.67	0.102	N
F2-11	3.01	3.00	2.92	2.91	3.18	3.17	0.922	N
F2-12	3.21	3.47	2.75	3.24	2.82	3.67	0.257	N
F2-13	2.58	2.65	2.64	2.32	2.64	3.00	0.506	N
F2-14	3.40	3.59	2.83	3.55	3.00	3.75	0.109	N
F3-1	3.25	3.12	3.25	3.23	3.36	3.33	0.976	N
F3-2	3.22	3.47	2.75	3.24	2.82	3.67	0.257	N
F3-3	2.86	2.82	3.09	2.64	2.64	3.55	0.199	N
F3-4	3.20	3.12	2.75	3.36	3.27	3.42	0.471	N
F3-5	2.61	2.65	2.64	2.32	2.64	3.00	0.506	N
F3-6	3.11	2.82	3.36	3.05	3.18	3.33	0.741	N
F3-7	3.01	3.12	3.18	2.64	3.18	3.27	0.427	N
F3-8	3.22	3.18	3.10	3.32	3.18	3.17	0.984	N
F3-9	3.00	2.88	2.82	3.00	2.73	3.45	0.409	N
F3-10	2.75	2.71	2.73	2.68	2.91	3.09	0.747	N
F3-11	3.14	3.18	2.91	3.32	3.09	2.91	0.699	N
F3-12	3.15	3.24	2.91	3.09	3.64	2.91	0.373	N
F3-13	3.54	3.94	3.08	3.73	3.27	3.58	0.259	N
F3-14	2.79	2.71	2.73	2.68	2.91	3.09	0.747	N
F3-15	3.22	3.47	2.91	3.27	3.09	3.08	0.734	N
F3-16	2.68	2.69	2.76	2.35	2.77	3.06	0.546	N
F3-17	3.36	3.24	3.18	3.41	3.27	3.64	0.874	N

Table 4 demonstrates that five types of respondents are in consent with the significance of all quality factors except F1-13, which is "Inaccurate design of the connecting points between core components". It is interesting to note that factor F-13 is the most significant factor in the design-related group according to the mean values. However, the difference exists between different groups of professionals on the importance of this factor. The mean value perceived by Group E (production enterprise respondents) on this factor is far lower than that given by other professional groups. It may indicate that the professionals working in manufacturing underestimate the difficulty of on-site connecting between the manufactured components.

5. Discussions

With reference to the design-related factors, the top quality factor is identified as F1-13: "Inaccurate design of the connecting points between core components". The suggestions by the three interviewees support this analysis result, indicating that this is the most significant factor affecting application of IBS projects in China. One of the interviewees points out that the builders lacking design experience for IBS components can result not only in poor buildability but also in reworking of design. Further, it is interesting to note that the results of the *t*-test and the ANOVA table about this factor are different. According to the *t*-test, there is a significant difference of perception between Tier 1 and Tier II. The mean value given by Tier I is considerably higher than that by Tier II. As Tier I respondents, representing 72.9% of the sample respondents, have both knowledge and experience, the importance of factor F1-13 is clearly spelled out in the practical implementation. In other words, the importance of this factor is relatively overlooked by the respondents with less or no experience in the practical implementation of IBS projects. On the other hand, in the ANOVA test, the highest mean value for factor F1-13 is obtained for producers/manufacturers (Group C), suggesting that manufacturers are more concerned than other groups of professionals about the quality of the design for the connecting points between core components. The discussions with the interviewees support this notion that, for manufacturers, the design of the connecting points between core components is essential for ensuring the product quality in the prefabrication process.

Another important factor is identified as F1-1 "Lack of design norms and standards for IBS components". It is common knowledge that proper construction works will not be produced without design standards and norms. The discussions with the interviewees indicate that many quality problems for IBS projects are due to the lack of design guidance, thus some technical problems can easily be resolved by discussion among operatives. Furthermore, as there is no design standard for IBS projects at a national level, the practice of IBS project design is different between regions. In this regard, it is recommended that government departments help to integrate IBS design experiences gained in different regions to develop a set of design standards and norms applicable at the national level in China. Furthermore, factor F1-14 "No BIM application for checking the collision between IBS components" is considered important as the interviewed experts point out that collision between IBS components can be effectively checked before construction by using BIM. Other important design-related factors include F1-6 "Lack of experienced designers of the IBS components" and F1-5 "Severely low cost for product design defined in the contract". The negative effects of these factors on the quality of IBS projects are well appreciated by the interviewees.

With reference to the production-related factors, the top quality factor is F2-14 "Lack of quality criteria for component products". The interviewees argue that the quality of component products will not be guaranteed if there are no quality criteria in the production process, thus affecting the quality of the final construction projects. Factor F2-1 "Lack of production norms and standards for IBS components" is identified as an important factor affecting the quality of IBS projects. The standardization of production can lead to better control over the product quality. Moreover, quality control cannot be assured without a unified production standard. Factor F2-2 "Lack of production quality management system in manufacturer's production process" is also perceived as important, as echoed by the interviewees claiming that quality management within manufacturers who produce IBS components is essential. Currently, individual production enterprises in China have their own different quality management methods, which cannot ensure the consistency of the quality standards applied among producers. Other important quality factors within the production-related group include F2-12 "Lack of experienced supervisors during the component production process" and F2-7 "Too low cost for production defined in contract", and their significance to the quality of IBS projects are also highly supported by the interviewees.

Considering the construction-related factors, the top quality factor is identified as F3-13 "Inadequate construction of the connecting points between the core components", which is similar to factor F1-13. Its importance has been addressed previously. Another important factor, F3-17 "Lack of construction quality criteria for IBS components", can be interpreted due to the fact that product quality cannot be ensured or checked without criteria, as appreciated by all the interviewees. Other important construction-related quality factors include F3-1 "Lack of technical guidelines for the construction of IBS projects"; F3-2 "Lack of experienced project managers in the construction of IBS projects"; and F3-8 "Excessively low cost for the construction defined in contract". The significance of these factors to the quality of IBS projects is well supported by the interviewees. For example, it was explained during the interview that the lack of on-site experienced project managers often leads to poor on-site planning and coordination for addressing on-site problems, thus causing the quality of the final product to suffer.

6. Conclusions

This study presents the quality factors affecting the implementation of industrialized building system (IBS) projects within the context of China in three categories, namely, design-related, production-related and construction-related. The top five design-related factors include: F-13 (Inaccurate design of the connecting points between core components), F1-1 (Lack of design norms and standards for IBS components), F1-14 (No building information modeling (BIM) application for checking the collision between IBS components.), F1-6 (Lack of experienced designers of the IBS components) and F1-5 (Severely low cost for the product design defined in the contract). The top five production-related factors are F2-14 (Lack of quality criteria for component products), F2-1 (Lack of production norms and standards for IBS components), F2-2 (Lack of production quality management system in manufacturer's production process), F2-12 (Lack of experienced supervisors during the component production process) and F2-7 (Severely low cost for production defined in contract). Finally, the top five construction-related factors are F3-13 (Inadequate construction of the connecting points between the core components), F3-17 (Lack of construction quality criteria for IBS components), F3-1 (Lack of technical guidelines for the construction of IBS projects), F3-2 (Lack of experienced project managers in the construction of IBS projects) and F3-8 (Severely low cost for construction defined in contract). The findings of this study help both construction professionals and government departments to understand the key areas wherein the quality of IBS projects may suffer, ensuring that proper actions and quality management measures can be planned and implemented for ensuring good quality of IBS projects. The adoption of these measures can therefore assure the promotion and effective development of IBS projects in China. The study enriches the development of research in the field of quality management in IBS projects. In our further study, effective measures for managing these quality factors will be investigated. Although this study is conducted within the Chinese context, the research method adopted can be a good reference for studying the quality practice of IBS projects in construction industries of other countries.

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