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Research Article

Cause Analysis of Hindering On-Site Lean Construction for Prefabricated Buildings and Corresponding Organizational Capability Evaluation

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As prefabricated buildings play a significant role in the global fight against the new coronavirus "COVID-19," they attract more global attention than other types of buildings. Lean construction helps to improve the benefits of enterprises and the working environment of workers. However, prefabricated buildings are encountering various challenges in implementing on-site lean construction. According to a cause-and-effect relationship, it will be more meaningful to explore the critical causes hindering on-site lean construction, namely, the critical barriers. Hence, this paper establishes a research methodology framework based on multimethod collaboration, including the exploratory factor analysis model regarding critical barriers, the exploratory factor evaluation model regarding organizational capabilities, and the important findings and suggestions. Thirty-one critical barriers of on-site lean construction for prefabricated buildings are identified via literature analysis, field survey, and semistructured interview. After pre-exploratory factor analysis, thirty critical barriers are finally retained and prioritized, and six common components are extracted and nominated. A large-scale project using the Engineering, Procurement, and Construction (EPC) mode is selected as a case study to evaluate its construction organizational capability to deal with the six common components. The important findings indicate that the inadequate professional management capability of managers is the most critical barrier, and the construction organization from the project case is fully capable of dealing with the common components during on-site lean construction. Six corresponding substantive suggestions are also proposed according to domain experts, and the most prioritized one of them is that an internal training or external recruitment is suggested to solve the inadequate professional management capability of managers. The internal training should take the form of seminars and training courses that invite senior prefabricated project management experts to participate. The external recruitment needs to focus on the management experience, lean skills, and leadership of managers in prefabricated projects. The established methodology framework proposes a new idea for the barrier analysis and corresponding organizational capability evaluation of on-site lean construction from the perspective of the specific prefabricated construction industry rather than the entire construction industry. Due to the special construction mode of prefabricated buildings, it further expands the current boundary of lean construction methodology. The findings and suggestions will provide a valuable reference and guidance for the prefabricated construction industry to solve the barriers regarding on-site lean construction.

1. Introduction

The sudden outbreak and rapid spread of the new coronavirus "COVID-19" have caused huge losses in lives and economies around the world. Since prefabricated buildings have the advantage of rapid construction, they earn lots of time for humans in the global fight against the new coronavirus "COVID-19," such as Leishenshan Hospital and Huoshenshan Hospital. This emergency-driven mode makes prefabricated buildings win more global attention than other types of buildings. However, the market-driven prefabricated buildings are encountering various challenges, which hinder the sustainable development of prefabricated buildings [1]. In the context of saturated construction market, more and more construction companies are entering the era of low profits. Lots of prefabricated construction companies expect to change the current situation of low profits and enhance their overall competitiveness via lean construction (LC). Solaimani and Sedighi [2] believed that LC was an effective way to increase project benefits and explored "how Lean helps achieve and maintain sustainability in construction sector." Francis and Thomas [3] found that LC and sustainable construction held certain common objectives in improving resource efficiency and minimizing waste. Hence, if prefabricated buildings want to achieve the sustainable development, they need to implement LC.

Many countries and regions are encountering different challenges during the LC implementation, such as United States, United Kingdom, Norway, Brazil, and Chile [4]. Innella et al. thought that the latest challenge of LC is its implementation in prefabricated buildings [5]. A report from the "Annual Meeting of the Architectural Society of China-Construction Management Research Section (2019)" shows that the on-site LC for prefabricated buildings has developed rapidly in Japan, which discovers lean production from the automotive industry. Scholars, such as Innella et al. [5], Heravi and Firoozi [6], Goh and Goh [7], Li et al. [8], Yu et al. [9], Nascimento et al. [10], Bamana et al. [11], and Shewchuk and Guo [12], pay more attention to the on-site LC methods and techniques for prefabricated buildings. However, few scholars explore the causes hindering the on-site LC for prefabricated buildings and the corresponding organizational capability evaluation. Related research regarding other types of buildings may provide value references for the implementation of on-site LC of prefabricated buildings, but prefabricated buildings have their particularities, especially their special construction processes. The problem is that prefabricated buildings have fallen into an eddy in terms of on-site LC: one aspect is that people believe in the good performance of on-site LC [13], but the other aspect is that actual prefabricated projects are difficult to successfully implement on-site LC [14]. Hence, there are some unknown causes hindering the implementation of on-site LC in prefabricated buildings. Alternatively, known causes have not been effectively valued and resolved by scholars and construction organizations. These causes are hereinafter referred to as barriers.

This study aims to identify and analyse the critical barriers to on-site LC for prefabricated buildings and further evaluate the construction organization's capability to solve these critical barriers. This study will have the following contributions. (1) It assists managers make more reasonable and feasible countermeasures according to the identified critical barriers and corresponding weights so as to improve the performance of on-site construction for prefabricated buildings. (2) It makes managers more aware of the organizational capability to deal with these critical barriers so as to identify and improve the vulnerable spot. (3) It expands the theoretical boundary of LC from the perspective of the specific prefabricated construction industry rather than the general construction industry. Other sections of this study are structured as follows. In Section 2, the existing relevant literature is reviewed and analysed. In Section 3, a research methodology framework is proposed. In Section 4, a critical barrier system is established, and then the exploratory factor analysis is implemented to calculate the weight of each barrier and extract a few common components. In Section 5, a typical large-scale project is selected to evaluate its construction organizational capability to deal with the barriers, and then the obtained results are analysed and discussed in depth. In Section 6, the conclusions and future work are summarized.

2. Literature Review

2.1. Barriers to On-Site Lean Construction for Prefabricated Buildings. Lean construction (LC) aims to strive for perfection during project construction, including zero waste, zero accidents, lower pollution, higher quality, and many more. Its core is to eliminate all unnecessary waste rather than accept unsatisfactory events reluctantly. The waste in LC is considered as all nonvalue-added activities, which generate direct or indirect costs but do not add any value to the product [15]. So far, many lean methods (or techniques) have been considered suitable for the construction industry, including just-in-time (JIT), last planner system (LPS), prefabrication, value stream mapping (VSM), total quality management (TQM), concurrent engineering, and 5S and 6S on-site management [16]. They are believed to help improve quality, increase efficiency, reduce waste, enhance the construction management practices, and promote sustainable development [17, 18]. From traditional construction to prefabricated construction is a transformation of construction mode, which needs the reform of supporting management ideas and methods. LC and prefabricated buildings have similarities and collaborative relationships in terms of origin, construction processes, and other aspects, which are compatible with each other. With the adoption of lean concepts and tools in traditional construction, many studies are also exploring their application in prefabricated construction. These studies cover different topics: on-site scheduling [19], lean learning [20], quality improving [21], resources [22], environment [23], and many more. All these studies have shown that LC is suitable for being integrated into the on-site construction of prefabricated buildings. However, the combination of LC and prefabricated on-site construction is still in its infancy, and there are still lots of barriers during its promotion and application. So far, only a few studies discuss the barriers to implementing the on-site LC for prefabricated buildings. In the research of Oral et al., the main barriers to implementing JIT in the Turkish prefabrication sector are the financial difficulties and the demand uncertainties while those in other developing countries are poor demand conditions, poor supply conditions, and unstable economic environments [24]. Their research does not focus on the on-site construction for prefabricated buildings, but is oriented to the Turkish entire prefabrication sector. In addition, their research also shows that it is necessary to explore the LC for prefabricated buildings in developing countries, in which the barriers encountered by these countries are different each other. In the research of Said, the reason for low lean utilization in the United States is that most contractors are still trying and learning the best practices of prefabrication [25]. In the research of Dave et al. and Xu et al., the low adoption of information technology will affect the leanness of prefabricated construction [26, 27]. China is the largest developing country, where prefabricated buildings are in its infant stage. Obviously, given the high consistency and compatibility between LC and prefabricated buildings, it is essential to investigate the feasibility of integrating LC with prefabricated buildings in the context of China, which offers an opportunity for examining effectiveness and barriers of LC in the prefabricated domain.

2.2. Barriers to Lean Construction Being Not Specifically for Prefabricated Buildings. Prefabricated buildings have many different characteristics in on-site construction compared with other types of buildings. On the one hand, the construction methods similar to assembling building blocks can shorten construction time, improve environmental performance, ease labour requirement, and reduce workload and have other advantages beyond traditional construction methods [28, 29]. On the other hand, compared with the traditional cast-in-place processes, prefabricated construction projects request higher requirements for mechanical equipment (e.g., cranes) [30], work environment [31], higher standardization [32], and information technology [33]. However, prefabricated buildings are also a member of the construction industry and have common attributes. Hence, studies on LC implementation barrier being not specifically for prefabricated buildings may provide valuable reference for this paper, as shown in Table 1.

From the above studies, due to the cultural and economic differences among countries and the special construction process of prefabricated buildings, it is of necessity to make an in-depth analysis of integrating LC with prefabricated buildings in the context of China.

2.3. Organizational Capability Evaluation of Lean Construction for Prefabricated Buildings. Organizational capability is generally positively correlated with the effect of barrier solving. Organizational capability includes employee governance, employee mentality, and employee abilities. An organizational capability evaluation is the premise and basis of overcoming the barriers to implementing on-site LC for prefabricated buildings. Hence, after these barriers have been identified and analysed, it is necessary to assess whether a construction organization has sufficient capabilities to deal with these barriers. However, few directly related studies are found via Web of Science, Engineering Index, and China National Knowledge Infrastructure. Indirectly related studies may provide valuable references. For organizational capabilities in the AEC (Architecture, Engineering, and Construction) industry, previous studies have explored a wide range of topics, including organizational resilience [52], occupational safety and health abilities [53], project management competencies [54, 55], resource allocation capabilities [56], risk management capabilities [57, 58], and contract management capabilities [59]. These research results show that when organizations are in different contexts, the attributes constituting their organizational capabilities are often different and require corresponding evaluation indicators. As the key to ensuring the required performance of construction projects, on-site construction management has higher requirements for organizational capabilities [60]. However, these previous studies on organizational capabilities lacked attention to on-site construction. With the transformation and upgrading of prefabrication technology, prefabricated buildings need more on-site LC management, which puts forward higher requirements for organizational capabilities. In view of the research progress of AEC's organizational capabilities, there is an urgent need for methods that can accurately evaluate organizational capabilities to deal with barriers to LC implementation in prefabricated construction sites.

3. Research Methodology

3.1. Framework Design of Research Methodology. Prefabricated buildings have a unique construction system in the construction industry and are encountering lots of unknown critical barriers in implementing on-site LC. In addition, China also owns its special economic, cultural, and political environment. In terms of applicable conditions, exploratory factor analysis (EFA) is not limited by priori information while confirmatory factor analysis (CFA) requires sufficient priori information. Hence, EFA instead of CFA is selected by this research. EFA is a technique for dimension reduction and classification, which can synthesize many original observable variables with dependent relationships into a few common latent variables with independent relationships [61, 62]. Due to the complexity of on-site construction for prefabricated buildings, a single method cannot fully achieve the identification and analysis of critical barriers, as well as the evaluation of organizational capabilities at the same time. Multimethod collaboration is regarded as an effective way. Hence, a research methodology based on multimethod collaboration is designed, as shown in Figure 1. It consists of three modules, namely, the exploratory factor analysis model regarding critical barriers

Table 1: Countries/regions and their common barriers involved in previous studies [34–51].

Common barriers	Countries/regions
Lack of training and education regarding LC	Bangladesh, Chile, United Kingdom, Pakistan, United States, South Korea, South America, China, Brazil, Singapore, Kingdom of Saudi Arabia, Palestine, and others
Absence of lean awareness/thinking	Bangladesh, Chile, United Kingdom, Palestine, Kingdom of Saudi Arabia Morocco, Malaysia, and others
Lack of appropriate lean technology or tools	Bangladesh, United Kingdom, Palestine, United States, South Korea, South America, Pakistan China, Kingdom of Saudi Arabia, Uganda, Libya, and others
Absence of support from senior leaders	United Kingdom, China, Pakistan, Bangladesh, Malaysia, Palestine, and Morocco
Absence of relevant incentives	Bangladesh, United Kingdom, Palestine, Pakistan
Insufficient funds during construction	Bangladesh, United Kingdom, Palestine Pakistan, Morocco, and others
Inadequate professional skills of workers	Pakistan, Morocco, Uganda
Resistance to changes in LC	Bangladesh, Palestine, United States, United Kingdom, South Korea, South America, Pakistan, China, Morocco, Malaysia, and others
Multilayer subcontracting	Bangladesh, China, Morocco, and others
Cooperation problems	Bangladesh, United Kingdom, Palestine, Pakistan, Uganda, Libya, and Finland
Absence of organizational structure and culture regarding LC	Bangladesh, Chile, United States, United Kingdom, South Korea, South America, Pakistan, China, Kingdom of Saudi Arabia, Morocco, Uganda, Libya, and others
Lack of performance evaluation	Bangladesh, Palestine, Kingdom of Saudi Arabia, Libya, and others
Lack of effective supervision and control	United Kingdom and Morocco
Insufficient standardization	Bangladesh, United Kingdom, Kingdom of Saudi Arabia, Uganda, and Finland
Fierce market competition environment (e.g., no time to adopt new technology)	Bangladesh, United Kingdom, Morocco, and China
Less personal empowerment	United States, United Kingdom, South Korea, South America, and China
Insufficient program planning	Bangladesh, United Kingdom, Uganda, and Morocco

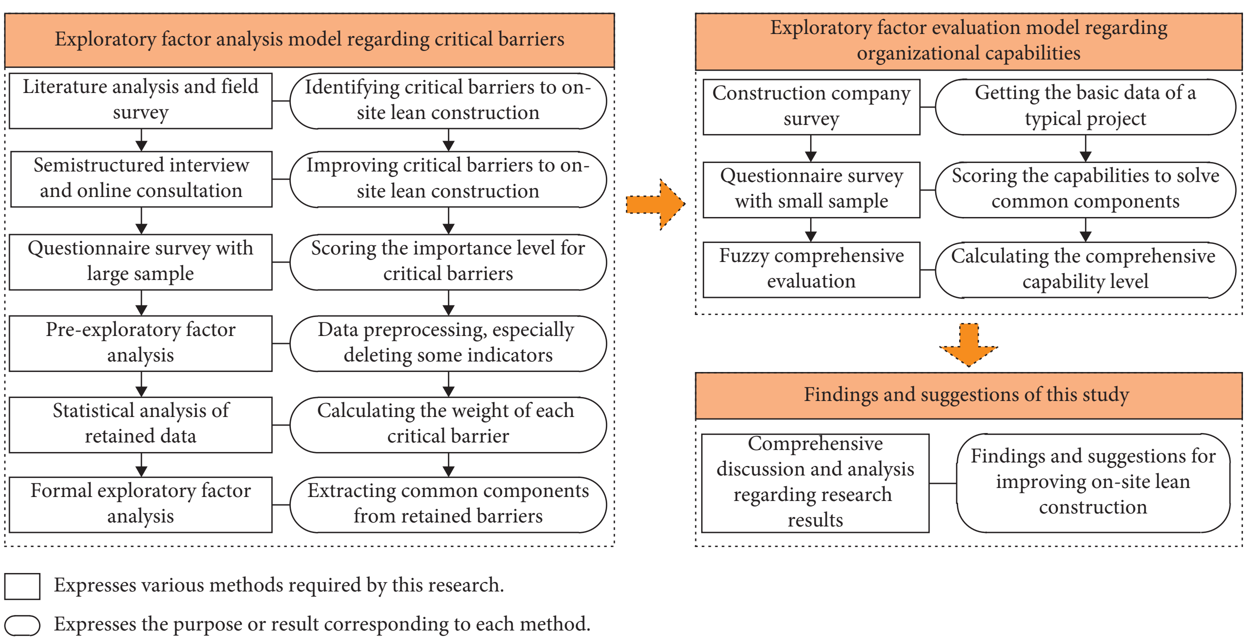

Figure 1: Research methodology based on multimethod collaboration.

and the exploratory factor evaluation model regarding critical barriers, as well as the findings and suggestions of this study.

3.2. Principle Description of Research Methodology. In Figure 1, the multimethod collaboration involves data collection and analysis methods. Data collection methods include literature analysis, field survey, semistructured interview, online consultation, questionnaire survey, and construction company survey. Data analysis methods contain pre-exploratory factor analysis, descriptive statistics analysis, formal exploratory factor analysis, and fuzzy comprehensive evaluation. There is close interactions among them. In the exploratory factor analysis model regarding critical barriers, the combination of literature analysis and previous (or subsequent) field survey is used to preliminarily identify the critical barriers to on-site LC. The previous field survey is the previous project survey experiences rather than the survey conducted just for the critical barriers. The subsequent field survey is that researchers take some initial critical barriers identified from the literature analysis to investigate the project specifically. The combination of the semistructured interview and online consultation is used to further improve the critical barriers. Related documents are sent to the selected experts in advance for better preparation during the interview and consultation. The questionnaire survey with large sample is adopted to gain the scores for all critical barriers. The factor analysis method, including pre-exploratory factor analysis and formal exploratory factor analysis, is used for preprocessing data and extracting several common components (namely, common latent variables) via dimension reduction and classification. The descriptive statistics analysis is adopted to calculate the weight of each critical barrier. Factor analysis method corresponds to a classic mathematical expression [63], as shown in Formula (1). x_i represents an original observable variable; f_j represents a common latent variable; w_{ij} represents the loading of x_i on f_j; ε_i represents a special factor; m and n represent the number of original observable variables and common latent variables, respectively; and m is greater than n. If the data regarding original observable variables are collected reasonably or are standardized, the value of ε_i is zero:

$$x = wf + \varepsilon,$$

$$\begin{cases} x = \left(x_1 \ \ x_2 \ \cdots \ x_i \ \cdots \ x_m \right)', \\ f = \left(f_1 \ \ f_2 \ \cdots \ f_j \ \cdots \ f_n \right)', \\ w = \begin{bmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & w_{ij} & \vdots \\ w_{m1} & \cdots & w_{mn} \end{bmatrix}, \\ \varepsilon = \left(\varepsilon_1 \ \ \varepsilon_2 \ \cdots \ \varepsilon_i \ \cdots \ \varepsilon_m \right)'. \end{cases} \tag{1}$$

In the exploratory analysis evaluation model regarding organizational capabilities, the construction company survey is adopted to collect the detailed data of a prefabricated project. The questionnaire survey with small sample is used to gain the scores for extracted common components. The sample size should not be less than five. Fuzzy comprehensive evaluation (FCM) [64], an evaluation method based on fuzzy mathematics, include the establishment of evaluation index set, comment set, evaluation matrix, index weight vector, and comprehensive evaluation model. Since FCM can better solve some vague and difficult-to-quantify problems, it is selected to measure the capability level of a construction organization in dealing with these common components, as shown in Formulas (2–4). The evaluation index set consists of all common components, including C_1, $C_2, \ldots, C_i, \ldots, C_m$. The comment set is quantified by Likert scale, such as "1 = powerless," "2 = weaker capability," "3 = medium capability," "4 = higher capability," and "5 = fully capable." The S represents the evaluation matrix. The W represents the index weight vector. The E represents the comprehensive evaluation model. The w_i represents the weight of C_i. Suppose N_j represents any element in the evaluation index set. The s_{ij} is the membership, representing the degree to which the evaluation index C_i belongs to the comment N_j. The result of fuzzy comprehensive evaluation is the comment corresponding to the largest element in the E:

$$S = \begin{bmatrix} s_{11} & \cdots & s_{1n} \\ \vdots & s_{ij} & \vdots \\ s_{1m} & \cdots & s_{mn} \end{bmatrix}, \tag{2}$$

$$W = \left[w_1 \ \ w_2 \ \cdots \ w_i \ \cdots \ w_m \right], \tag{3}$$

$$E = W \times S = \left[e_1 \ \ e_2 \ \ e_3 \ \ e_4 \ \ e_5 \right]. \tag{4}$$

4. Exploratory Factor Analysis Regarding Critical Barriers

4.1. Identification of Critical Barriers. On the basis of extensive literature analysis and previous field survey experiences (e.g., Shanghai, Shenzhen, Harbin, Nantong, and Taizhou), some critical barriers are initially identified. The critical barriers identified in previous field surveys have not exceeded those identified in existing literature, which may be attributed to the fact that the authors do not have sufficient project experiences such as domain experts. Therefore, it is necessary to invite experienced domain experts to further improve the identified and unidentified critical barriers. Since prefabricated buildings are still in their infancy, the number of experts with more experience is limited. Therefore, the selection criteria of experts in this study tend to be quality rather than quantity. Four experienced experts are finally selected. The initially identified critical barriers are sent to each expert in advance, which allows the experts enough time to think about the raised questions and decide when it is more appropriate to accept our semistructured interview. Three of them accept online interviews for 30~60 minutes, while one only accepts brief consultation on account of his company's regulations. The basic information related to these experts is shown in Table 2.

The semistructured interview mainly involves three aspects. (1) The nonlean phenomena or behaviours of on-site construction for prefabricated buildings. (2) The critical barriers to on-site LC for prefabricated buildings. (3) Follow-up feedback and auxiliary data collection. The latter expert is allowed to see the opinions of the previous expert during the interview and consultation. In addition to improve the barrier system of on-site LC, a preliminary scoring using Likert scale is performed simultaneously for a pilot test. The comprehensive treatment results of all experts are shown in Table 3.

4.2. Characteristics for Questionnaires. A questionnaire is designed to collect more professionals' views on the importance of critical barriers to on-site LC. In the questionnaire, these professionals are set as the respondents who have the experience or knowledge of on-site construction for prefabricated buildings. The impact level is evaluated by the

Table 2: Basic information from the four experts interviewed and consulted.

Code	Company category	Position in construction	Number participating in prefabricated projects	Years engaged in prefabricated projects
Expert 1	Group companies (design, production, and construction)	Technical consultant	50	10
Expert 2	Enterprise-type research institute	Technical director	10	6
Expert 3	Privately-owned construction company	General manager	80	10
Expert 4	State-owned construction company	Project manager	4	4

5-point Likert Scale: 1 for "negligible," 2 for "lower," 3 for "medium," 4 for "higher," and 5 for "very high." All questionnaires are distributed via the Internet rather than on site. A total of 185 questionnaires are returned from March 6, 2020, to April 27, 2020. In order to further ensure the quality of data, this research excludes some questionnaires from the respondents who have no experience or knowledge of on-site construction for prefabricated buildings. Finally, the number of valid questionnaires is 154, which is more than the 150 needed for exploratory factor analysis [66]. The sample size of questionnaires used in this study is not large enough although it meets the basic requirements of exploratory factor analysis. This is mainly due to the fact that prefabricated buildings account for a relatively small proportion in the construction market. Figure 2 shows the distribution information of respondents' work units, while Figure 3 indicates the distribution information of the years that these respondents study or engage in on-site construction for prefabricated buildings. For a prefabricated project, owners, supervision units, design units, construction units, and precast-component factories stay at the construction site for a long time, and their proportion is 77.273%. The parameter x represents the number of experience years. The respondents with more than two years of experience account for 61.688%. Hence, the statistics show that the majority of respondents have sufficient qualifications, which ensure the quality of the data collected.

4.3. Reliability and Validity Test for Questionnaires. Reliability refers to the stability of the collected data, which means the results of multiple measurements for the same object are similar. Reliability is divided into internal reliability and external reliability. Internal reliability is used to determine whether multiple items in the questionnaire measure the same concept or content. Cronbach's alpha coefficient (see Formula (5)), a common approach, is adopted to verify the internal reliability. α represents the Cronbach's alpha coefficient, and its value greater than 0.7 is acceptable [67]. k is the number of items on a scale. x_i is the i^{th} item, and x is the set of all items. σ_x^2 is the variance of the total sample, which represents the variance among the total score of each item scored by each respondent on a scale. $\sigma_{x_i}^2$ is the variance of the observation sample, which represents the variance among each respondent's score on a certain item:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_{x_i}^2}{\sigma_x^2}\right). \tag{5}$$

SPSS (Statistical Product and Service Solutions), a professional statistical software, is used to calculate the reliability of questionnaires. Table 4 shows the results of reliability analysis of questionnaires using SPSS. Cronbach's alpha is 0.946. Therefore, these collected questionnaires are very good in terms of reliability.

Validity refers to the degree to which the measured result reflects what people want to examine. The more the measurement result matches what people want to examine, the higher the validity is. Validity is further divided into content validity, structure validity, and standard validity. The Kaiser–Meyer–Olkin (KMO) and Bartlett's ball test, an integrated method for measuring structural validity, is adopted to verify the validity of questionnaires. The KMO test is to examine the correlation and partial correlation among variables, as shown in Formula (6). $A(x_i, x_j)$ represents the sum of squares of correlation coefficients between all variables. $B(x_i, x_j)$ represents the sum of squares of partial correlation coefficients between all variables. KMO owns the following levels: excellent (KMO >0.9), good (KMO >0.8), acceptable (KMO >0.7), questionable (KMO >0.6), and unacceptable (KMO <0.5) [68]. Bartlett's ball test is used to examine whether each variable is independent. If the significance (Sig.) in Bartlett's ball test is less than 0.05, then there is a correlation among the variables. This means that common latent variables can be extracted from the original variables:

$$\mathrm{KMO} = \frac{A(x_i, x_j)}{A(x_i, x_j) + B(x_i, x_j)}. \tag{6}$$

The SPSS is adopted again for calculating the validity of questionnaires. Table 5 indicates the results of validity analysis of questionnaires using SPSS. The result shows that KMO is 0.918 with the significance (Sig.) 0.000. This means that there is a strong correlation among the variables. Hence, these collected data are appropriate for exploratory factor analysis.

4.4. Result Analysis of Screening and Ranking for Critical Barriers. Data preprocessing aims to remove some unimportant barriers from the thirty-one original barriers. It will be achieved through pre-exploration factor analysis. In pre-exploration factor analysis, the principal component analysis (PCA) method is used for component extraction. Since the number of all components is equal to that of all original observable variables (namely, all original barriers), the initial commonality of each variable is one. A variable with

Table 3: Barriers to on-site lean construction (LC) for prefabricated buildings.

Code	Barriers	Sources	Explanations/examples
B1	Complexity of work	[65]	The higher the complexity of work, the greater the resistance to on-site LC in prefabricated buildings
B2	Severity of weather	[65]	Sudden gale will affect the hoisting of precast components, which is not conducive to on-site LC
B3	Lower prefabrication	Interview	Lower prefabrication will result in a lot of concrete pouring and steel tying
B4	Multilayer subcontracting	[36]	More multilayer subcontracting is not conducive to collaboration between teams in prefabricated buildings
B5	Poor materials	[13]	Poor materials (e.g., accuracy of precast components) will adversely affect on-site LC
B6	Fierce market competition environment	[45]	Too fierce market competition is not conducive to on-site LC (e.g., no time to adopt new technology)
B7	High turnover of workforce	[35]	The high turnover of workforce is detrimental to their conscientiousness and skills of on-site LC
B8	Absence of lean awareness/thinking	[38]	The absence of lean awareness is not conducive to the refined operation of precast components
B9	Inadequate professional skills of workers	[40]	The inadequate professional skills mean that workers lack the skills to match the on-site LC
B10	Inadequate professional management capability of managers	[35]	The inadequate professional management capability means that managers lack the capability to match the on-site LC
B11	Absence of support from senior leaders	[46]	On-site LC has not received enough attention from project managers and even the government
B12	Resistance to changes in LC	[46]	Due to time pressure, lack of skills, and adherence to old habits, employees are resistant to LC
B13	Tolerance of untidy workplaces	[35]	The 5S, an on-site LC technique, requires tidy workplaces
B14	Nonrecognition of LC advantages	[41]	The nonrecognition of LC advantages may bring resistance to the implementation of on-site LC
B15	Lack of appropriate lean technology or tools	[44]	The operation of precast components lacks corresponding lean tools
B16	Insufficient standardization	[42]	Prefabricated buildings are insufficient in the standardization of process, equipment, and operation
B17	Absence of organizational structure and culture regarding LC	[47]	The promotion and application of LC need corresponding organizational structure and culture
B18	Absence of relevant incentives	[34]	Since LC breaks the usual habitual practice, its promotion and application need relevant incentives
B19	Lack of training and education regarding LC	[37]	The installation, grouting, and caulking training of precast components are necessary for on-site LC
B20	Lower informatization	[4]	Informatization is conducive to the dynamic tracking of precast components
B21	Insufficient program planning	[48]	The insufficient program planning may cause a delay in the lifting schedule of precast components
B22	Lack of effective supervision and control	[49]	Lack of effective supervision and control may cause the quality problems of precast component installation
B23	Excessive cost savings during construction	Interview	The excessive cost savings are not conducive to the promotion and application of LC
B24	Insufficient funds during construction	[41]	The insufficient funds affect the sustainability of on-site construction in prefabricated buildings
B25	Less personal empowerment	[39]	The less personal empowerment may affect the performance of employees' on-site LC
B26	Avoid making decisions and taking responsibility	[35]	Prefabricated buildings require professional teams and managers with a high sense of responsibility
B27	Lack of performance evaluation	[50]	The lack of performance evaluation affects the enthusiasm of employees
B28	Insufficient attention to green and environmental protection	[41]	The green and environmental protection is also a requirement of on-site LC in prefabricated buildings
B29	Lack of transparency	[38]	Transparent and accurate information is conducive to accurate decisions and actions
B30	Cooperation problems outside the construction department	[50]	Suppliers supply precast components on time to avoid the idleness in on-site construction
B31	Cooperation within the construction department	[51]	Teams compete for a tower crane during the on-site construction of prefabricated buildings

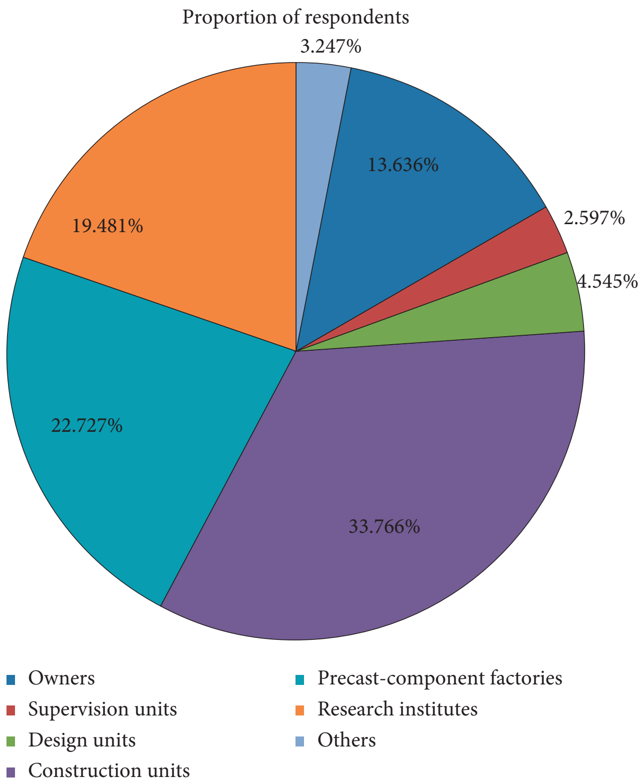

Figure 2: Distribution information of respondents' work units.

Figure 3: Distribution information of respondents' experience years.

Table 4: Reliability analysis of questionnaires.

Reliability statistics		
Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.946	0.948	31

extraction communality below 0.5 should be ignored [69]. Hence, the variable B12 with extraction communality 0.451 should be deleted. After data preprocessing, the number of original observable variables is reduced from 31 to 30.

Table 5: Validity analysis of questionnaires.

KMO and Bartlett's test		
Kaiser–Meyer–Olkin measure of sampling Adequacy		0.918
Bartlett's test of sphericity	Approx. chi-square	2796.966
	df	465
	Sig.	0.000

Table 6 shows the weights and rankings of thirty original observable variables.

According to Tables 3 and 6, the following analysis and discussion are carried out on the barriers to implementing on-site LC for prefabricated buildings. Thirty critical barriers to on-site LC are identified and analysed from the perspective of the specific prefabricated buildings rather than all types of buildings, and the top five barriers are "inadequate professional management capability of managers" (weight = 3.657%), "insufficient standardization" (3.628%), "absence of lean awareness/thinking" (3.611%), "inadequate professional skills of workers" (3.589%), and "lack of appropriate lean technology/tools" (3.543%). Hence, the professional management capability of managers is the primary factor affecting the on-site LC. This finding is consistent with the culture of the construction industry in China, where managers are the key to the success of a task. Existing managers are mostly transferred from nonfabricated buildings (e.g., cast-in-place concrete buildings) to prefabricated buildings and lack the professional management capability to match the on-site LC of prefabricated buildings. According to the previous field surveys and semistructured interviews, internal training or external recruitment is suggested to solve the inadequate professional management capability of managers. Compared with nonfabricated buildings, the standardization is a prominent feature of prefabricated buildings, such as process standardization, equipment standardization, and operation standardization. However, standardization is difficult to achieve in real life so that prefabricated buildings do not show its lean advantages in terms of on-site construction. The suggestion from consulted experts is that the standardization of on-site construction should be based on a sufficient understanding of construction process. The absence of lean awareness/thinking is roughly consistent with the previous study which thinks the lack of a long-term philosophy is a very important factor [35]. Hence, how to make employees have the awareness/thinking of LC is the focus of the future. In addition, the training of workers' professional skills and the adoption of lean technology should be taken seriously. Lean construction education/training is considered as an effective solution to overcome the inadequate professional skills of workers, such as the installation training, grouting training, and caulking training of precast components. In order to solve the lack of appropriate lean technology/tools, the introduction of related advanced technologies is a good choice. The barriers that rank 6th to 10th are "lack of effective supervision and control" (weight = 3.543%), "absence of support from senior

Table 6: Weights and rankings of thirty original observable variables.

Code	Weight (%)	Ranking
B1	3.170	24
B2	2.660	30
B3	3.153	26
B4	3.221	21
B5	3.351	16
B6	3.283	19
B7	3.045	28
B8	3.611	3
B9	3.589	4
B10	3.657	1
B11	3.532	7
B13	3.045	29
B14	3.249	20
B15	3.543	5
B16	3.628	2
B17	3.391	15
B18	3.407	13
B19	3.492	8
B20	3.289	18
B21	3.424	12
B22	3.543	6
B23	3.430	11
B24	3.475	9
B25	3.068	27
B26	3.181	23
B27	3.306	17
B28	3.221	22
B29	3.158	25
B30	3.470	10
B31	3.407	14

leaders (e.g., project manager and government)" (3.532%), "lack of training and education regarding LC" (3.492%), "insufficient funds during construction" (3.475%), and "cooperation problems outside the construction department" (3.470%). The barriers that rank 6th to 8th still require improvements in terms of management and training. Besides, we recommend maintaining a certain amount of reserves and establishing a good collaboration mechanism among all units. Other barriers after ranking 10th also need to be valued according to the time and costs to be paid.

4.5. Result Analysis of Common Component Extracting and Naming. After data preprocessing, a formal exploratory factor analysis begins to be implemented. Table 7 indicates the commonality before and after data preprocessing. In the formal exploratory factor analysis, the extraction commonality of each variable is greater than 0.5. Cronbach's alpha and KMO change to 0.945 and 0.919, separately. The significance (Sig.) is still 0.000.

All components and the common components from them are extracted via the principal component analysis (PCA) method, as shown in Table 8. The eigenvalue of a component refers to the sum of squared loadings of all original observable variables on this component, namely, the variance of this component. The percentage of variance for a component is equal to its eigenvalue divided by the sum of eigenvalues of all components. For the extracted thirty components, their total variance is 30. If the eigenvalue of a component is not greater than 1, this means that the component can only explain no more than one original observable variable. Hence, the six components with the eigenvalue greater 1 should be selected as the common components, including Component 1, Component 2, Component 3, Component 4, Component 5, and Component 6. The common components are also known as the common factors or the common latent variables. In the column "Rotation Sums of Squared Loadings" of Table 8, the six common components account for 64.668% of the total variance explained, which is greater than the 60% required by sufficient construct validity [70, 71]. Scree plot (see Figure 4) is adopted to test the rationality of common component extraction. Since the curve in Figure 4 begins to converge from the sixth component, it is appropriate to retain the first six components as common components.

Compared with the initial thirty barriers, the extracted six common components have weaker correlations. Moreover, these common components will save lots of time and effort in exploratory factor evaluation. However, only when the six common components have specific names and contents can they be used for subsequent exploratory factor evaluation. Hence, the original barriers are correspondingly classified into the six common components via the varimax rotation method, which changes the axis position to redistribute the percentage of variance explained by each component. The varimax rotation method will make the component structure simpler and does not change the cumulative percentage of the six common components. The rotated component matrix is shown in Table 9.

According to Table 9, the results of common component extracting and naming are analysed as follows:

(1) Common component 1 includes "B29 = lack of transparency," "B27 = lack of performance evaluation," "B26 = avoid making decisions and taking responsibility," "B25 = less personal empowerment," "B31 = cooperation within the construction department," "B28 = insufficient attention to green and environmental protection," "B30 = cooperation problems outside the construction department," "B22 = lack of effective supervision and control," "B23 = excessive cost savings during construction," "B24 = insufficient funds during construction," "B14 = nonrecognition of LC advantages," and "B20 = lower informatization," Hence, common component 1 is named "management-related barriers."

(2) Common component 2 includes "B16 = insufficient standardization," "B15 = lack of appropriate lean technology or tools," "B9 = inadequate professional skills of workers," "B19 = lack of training and education regarding LC," "B10 = inadequate professional management capability of managers," "B17 = absence of organizational structure and culture regarding LC," "B18 = absence of relevant

Table 7: Commonality before and after data preprocessing.

	Communalities before data preprocessing						Communalities after data preprocessing					
	Initial	Extraction		Initial	Extraction		Initial	Extraction		Initial	Extraction
B1	1.000	0.676	B17	1.000	0.737	B1	1.000	0.683	B18	1.000	0.693
B2	1.000	0.642	B18	1.000	0.677	B2	1.000	0.658	B19	1.000	0.692
B3	1.000	0.620	B19	1.000	0.670	B3	1.000	0.634	B20	1.000	0.630
B4	1.000	0.634	B20	1.000	0.630	B4	1.000	0.666	B21	1.000	0.608
B5	1.000	0.591	B21	1.000	0.605	B5	1.000	0.616	B22	1.000	0.660
B6	1.000	0.556	B22	1.000	0.658	B6	1.000	0.557	B23	1.000	0.692
B7	1.000	0.690	B23	1.000	0.681	B7	1.000	0.691	B24	1.000	0.611
B8	1.000	0.511	B24	1.000	0.603	B8	1.000	0.510	B25	1.000	0.655
B9	1.000	0.589	B25	1.000	0.652	B9	1.000	0.590	B26	1.000	0.704
B10	1.000	0.594	B26	1.000	0.703	B10	1.000	0.556	B27	1.000	0.713
B11	1.000	0.616	B27	1.000	0.711	B11	1.000	0.599	B28	1.000	0.714
B12	1.000	0.451	B28	1.000	0.716	B13	1.000	0.536	B29	1.000	0.695
B13	1.000	0.535	B29	1.000	0.697	B14	1.000	0.597	B30	1.000	0.635
B14	1.000	0.612	B30	1.000	0.624	B15	1.000	0.653	B31	1.000	0.743
B15	1.000	0.651	B31	1.000	0.745	B16	1.000	0.666	—	—	—
B16	1.000	0.671	—	—	—	B17	1.000	0.744	—	—	—

Extraction method: principal component analysis.

Table 8: Information regarding all components and the common components.

Total variance explained									
Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	12.239	40.795	40.795	12.239	40.795	40.795	6.758	22.526	22.526
2	2.224	7.412	48.207	2.224	7.412	48.207	4.553	15.175	37.701
3	1.380	4.598	52.805	1.380	4.598	52.805	3.142	10.472	48.173
4	1.273	4.244	57.049	1.273	4.244	57.049	1.755	5.851	54.023
5	1.211	4.035	61.085	1.211	4.035	61.085	1.698	5.661	59.685
6	1.075	3.583	64.668	1.075	3.583	64.668	1.495	4.983	64.668
7	0.947	3.157	67.824	—	—	—	—	—	—
8	0.851	2.835	70.660	—	—	—	—	—	—
9	0.792	2.641	73.301	—	—	—	—	—	—
10	0.761	2.537	75.838	—	—	—	—	—	—
11	0.695	2.316	78.154	—	—	—	—	—	—
12	0.667	2.222	80.376	—	—	—	—	—	—
13	0.624	2.080	82.456	—	—	—	—	—	—
14	0.518	1.728	84.184	—	—	—	—	—	—
15	0.494	1.647	85.831	—	—	—	—	—	—
16	0.461	1.538	87.369	—	—	—	—	—	—
17	0.441	1.469	88.837	—	—	—	—	—	—
18	0.412	1.372	90.209	—	—	—	—	—	—
19	0.375	1.251	91.460	—	—	—	—	—	—
20	0.346	1.153	92.612	—	—	—	—	—	—
21	0.306	1.019	93.632	—	—	—	—	—	—
22	0.282	0.939	94.571	—	—	—	—	—	—
23	0.275	0.918	95.489	—	—	—	—	—	—
24	0.260	0.868	96.358	—	—	—	—	—	—
25	0.220	0.734	97.092	—	—	—	—	—	—
26	0.215	0.717	97.808	—	—	—	—	—	—
27	0.196	0.652	98.461	—	—	—	—	—	—
28	0.177	0.589	99.050	—	—	—	—	—	—
29	0.147	0.489	99.539	—	—	—	—	—	—
30	0.138	0.461	100.000	—	—	—	—	—	—

Extraction method: principal component analysis.

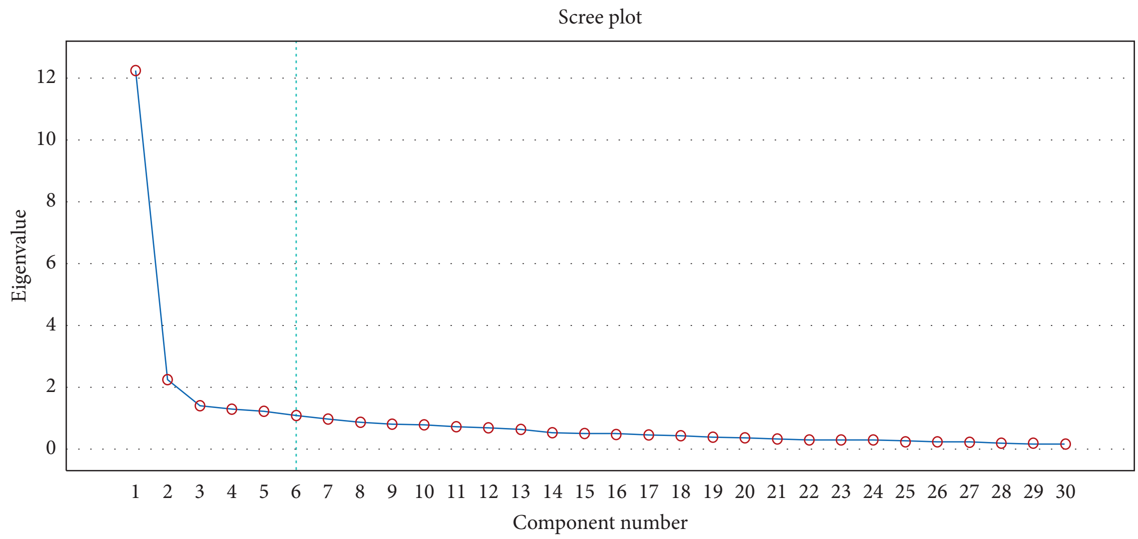

FIGURE 4: Scree plot for testing common component extraction.

TABLE 9: Rotated component matrix.

Rotated component matrix[a]						
	Component					
	1	2	3	4	5	6
B29	0.789	0.220	0.094	0.040	−0.017	0.112
B27	0.765	0.172	0.125	−0.081	0.019	0.276
B26	0.746	0.234	0.123	0.021	0.229	0.153
B25	0.724	0.176	0.153	0.147	0.232	0.014
B31	0.713	0.372	−0.002	0.180	0.092	−0.236
B28	0.698	0.101	−0.016	0.171	−0.069	0.427
B30	0.672	0.304	0.139	−0.029	0.206	−0.166
B22	0.640	0.393	0.252	0.104	0.147	−0.008
B23	0.615	0.231	0.456	0.179	−0.070	−0.125
B24	0.509	0.302	0.419	0.139	0.032	−0.254
B14	0.502	0.265	0.058	0.191	0.451	0.176
B20	0.467	0.380	0.221	0.189	−0.265	0.337
B16	0.322	0.722	0.150	−0.007	0.134	0.029
B15	0.345	0.675	0.110	0.056	0.242	−0.063
B9	0.097	0.655	0.215	0.158	0.174	0.223
B19	0.340	0.637	0.238	0.175	−0.167	0.235
B10	0.290	0.581	0.040	0.209	0.285	0.088
B17	0.432	0.577	0.388	−0.135	−0.046	0.230
B18	0.485	0.541	0.347	0.015	−0.180	0.107
B21	0.450	0.482	0.039	0.254	0.206	0.254
B8	0.351	0.448	0.377	0.071	0.191	−0.055
B7	−0.012	0.217	0.774	0.199	0.061	−0.015
B6	0.087	0.187	0.699	0.070	0.040	0.138
B13	0.283	0.047	0.578	0.250	0.217	0.104
B4	0.209	0.077	0.549	0.010	0.507	0.240
B1	0.047	0.179	0.130	0.794	−0.015	−0.029
B2	0.177	0.011	0.274	0.697	0.237	0.098
B5	0.006	0.365	0.214	0.338	0.565	0.066
B11	0.395	0.353	0.351	0.000	0.442	0.020
B3	0.063	0.209	0.143	0.021	0.159	0.735

Extraction method: principal component analysis. Rotation method: Varimax with Kaiser Normalization.[a] Rotation converged in 9 iterations.

incentives," "B21 = insufficient program planning," and "B8 = absence of lean awareness/thinking." Hence, common component 2 is named "skills and knowledge-related barriers."

(3) Common component 3 includes "B7 = high turnover of workforce," "B6 = fierce market competition environment," "B13 = tolerance of untidy workplaces," and "B4 = multilayer subcontracting." Hence, common component 3 is named "barriers regarding the construction industry itself."

(4) Common component 4 includes "B1 = complexity of work" and "B2 = Severity of weather." Hence, common component 4 is named "barriers regarding objective construction conditions."

(5) Common component 5 includes "B5 = poor materials" and "B11 = absence of support from senior leaders (e.g., project manager and government)". Hence, common component 5 is named "barriers regarding materials and leaders."

(6) Common component 6 only includes "B3 = lower prefabrication." Hence, common component 6 is named "barriers related to prefabrication rate."

5. Capability Evaluation of Resolving Critical Barriers

5.1. Basic Information of Project Case. Different construction organizations have different abilities to deal with the thirty critical barriers encountered by on-site LC for prefabricated buildings. A construction organization is formed temporarily based on an engineering project. Once a project is over, the employees will return to their original companies or departments. Hence, the capability evaluation of a construction organization in dealing with the barriers should be based on a specific project case. The relevant findings related to this specific project case will provide a reference for similar projects in the future. A large-scale project case with detailed information is provided by a construction company in China. This project with a total construction area of 250,000 square meters adopts a general contracting mode called EPC (Engineering Procurement Construction). The "cast-in-place + prefabricated" frame structure is one of its three structural systems. The main structure of 1#, 2#, 4#, and 6# in this project is a prefabricated structure, and the prefabrication rate is 50%. Precast concrete components include beams, stairs, and semiprecast slabs. Figure 5 shows some scenario information for the project case. Figure 5(b) is one of the many buildings in this project and adopts "cast-in-place + prefabricated" frame structure. The construction organization attaches great importance to the on-site construction, which establishes a smart construction site cloud platform, a remote video monitoring system, a security risk self-checking system, a dust monitoring and reduction system, and many more. They aim to strive for perfection rather than accept unsatisfactory events reluctantly during the construction.

5.2. Result Analysis of Capability Evaluation for Construction Organization. In project practice, simple and effective methods are often favoured by construction organizations. If project members evaluate the capability of the construction organization to deal with the thirty barriers one by one, it is very time consuming and laborious. Moreover, there is a very strong correlation between these thirty barriers, which is not conducive to obtaining a scientific evaluation value. In order to solve these problems, the six common components with specific names instead of the thirty barriers are scored by six project members. The positions of the six project members are the project chief engineer, the project technical manager, the manager of company's engineering department, the construction quality controller, the project chief engineer of subcontractors, and the project executive manager of subcontractors. These project members have sufficient qualifications in the whole construction organization. The evaluation and calculation results are shown in Formulas (7–9). The evaluation matrix S represents the scoring of the six project members. The weight vector W is obtained by normalizing the rotated variance percentage corresponding to each common component. The largest element in the comprehensive evaluation model E is 0.670, which corresponding to the level "fully capable." According to the maximum membership principle, the capability level of the construction organization is determined as "fully capable":

$$S = \begin{bmatrix} 0 & 0 & 0.167 & 0.167 & 0.666 \\ 0 & 0 & 0.167 & 0.333 & 0.500 \\ 0 & 0 & 0 & 0.333 & 0.667 \\ 0 & 0 & 0 & 0.167 & 0.833 \\ 0 & 0 & 0 & 0.167 & 0.833 \\ 0 & 0 & 0.167 & 0 & 0.833 \end{bmatrix}, \quad (7)$$

$$W = [\,0.348 \;\; 0.235 \;\; 0.162 \;\; 0.090 \;\; 0.088 \;\; 0.077\,], \quad (8)$$

$$E = W \times S = [\,0 \;\; 0 \;\; 0.110 \;\; 0.220 \;\; 0.670\,]. \quad (9)$$

According to Tables 8 and 9 and (7)–(9), the following analysis and discussion are carried out on the capability evaluation of construction organization. A total of six common components are extracted and nominated, namely, "management-related barriers" (% of variance = 22.526%), "skills and knowledge-related barriers" (15.175%), "barriers regarding the construction industry itself" (10.472%), "barriers regarding objective construction conditions" (5.851%), "barriers regarding materials and leaders" (5.661%), and "barriers related to prefabrication rate" (4.983%). Their cumulative percentage is 64.668%, which is greater than the 60% required by sufficient construct validity. Then, the fuzzy comprehensive evaluation method is used to evaluate the capability of the construction organization to deal with all thirty critical barriers. The six common components extracted from the thirty barriers are scored by six employees from the project case, and the comprehensive

FIGURE 5: Some scenario information for the project case. (a) Panorama of the project. (b) Partial construction scenario of the project.

evaluation result indicates that this construction organization is fully capable of dealing with the barriers to on-site LC. The worst level given by the six project employees owns a membership of 0.110, which is not lower than "medium ability." Based on the original data provided by the construction company, the reasons for the higher overall evaluation are as follows: (1) use of EPC mode; (2) establishment of standardized management system; and (3) attention and investment in advanced technology. The EPC mode gives the general contractor greater powers, which only needs to be responsible to the owner and can manage all subcontractors in a unified manner. This makes the construction organization more capable to solve some challenges in construction (e.g., the barriers to on-site LC). However, not every construction company has such a high capability. In addition to the contracting mode, the implementation effect and organizational capability of on-site LC are also related to the property (e.g., state-owned or privately owned) and scale (e.g., large or small) of construction companies [3, 42].

6. Conclusion and Future Work

In order to solve the barriers of on-site LC for prefabricated buildings, this study develops a methodology framework based on multimethod collaboration. The methodological framework include three models, namely, the exploratory factor analysis model regarding critical barriers, the exploratory factor evaluation model regarding organizational capabilities, and the important findings and suggestions. Various data collection and analysis methods in these models cooperate with each other to achieve the effect of "$1 + 1 > 2$." Some complex mathematical formulas are also integrated into these models to increase the rigor and scientificity of the research. A large amount of data is calculated and analysed via the first two models to obtain many original results, which lay the foundation for making corresponding suggestions.

In the exploratory factor analysis model regarding critical barriers, the thirty-one critical barriers of on-site LC for prefabricated buildings are identified through literature analysis, field survey, and semistructured interview. After conducting a pre-exploratory factor analysis, the "resistance to changes in lean construction" is deleted. After conducting a formal exploratory factor analysis, the retained thirty barriers are prioritized, and the top five barriers are "inadequate professional management capability of managers" (weight = 3.657%), "insufficient standardization" (3.628%), "absence of lean awareness/thinking" (3.611%), "inadequate professional skills of workers" (3.589%), and "lack of appropriate lean technology/tools" (3.543%). Besides, the six common components accounting for 64.668% of the total variance are extracted and named, including "management-related barriers" (% of variance = 22.526%), "skills and knowledge-related barriers" (15.175%), "barriers regarding the construction industry itself" (10.472%), "barriers regarding objective construction conditions" (5.851%), "barriers regarding materials and leaders" (5.661%), and "barriers related to prefabrication rate" (4.983%).

In the exploratory factor evaluation model regarding organizational capabilities, it uses a few common components instead of a large number of initial observable variables. This evaluation model not only eliminates the interference of correlation but also saves a lot of time and effort of evaluators. In order to demonstrate this evaluation model, a large-scale prefabricated project case is selected to measure its construction organization's capability to solve on-site LC barriers represented by the six common components. The capability level of this construction organization is determined as "fully capable."

For the barriers within the top five and the comprehensive evaluation result of case, this study conducts an in-depth analysis. The corresponding substantive suggestions are provided by domain experts as follows (listed in the order of priorities):

(1) An internal training or external recruitment is suggested to solve the inadequate professional management capability of managers. The internal training should take the form of seminars and training courses that invite senior prefabricated project management experts to participate. The external recruitment needs to focus on the management experience, lean skills, and leadership of managers in prefabricated projects.

(2) The standardization of on-site construction needs to be based on a sufficient understanding of the construction process: Firstly, the overall construction process needs to be scientifically and reasonably divided. Secondly, the main tasks of each functional department within a project are clearly defined. Thirdly, the standardized subprocesses need to be explained further. Finally, the process executors are trained to deepen their understanding of all standardized subprocesses.

(3) How to make employees have the awareness/thinking of LC is the focus of the future. If necessary, LC should be enforced by inserting LC clauses in a contract.

(4) Lean construction education/training is considered as an effective solution to overcome the inadequate professional skills of workers. After the education/training, it is necessary to assess the professional skills of workers and incorporate the assessment results into the performance related to wages and promotions.

(5) It is also feasible to introduce LC technologies by visiting and learning some advanced foreign companies to continuously enrich the on-site LC of domestic prefabricated buildings.

(6) In view of the excellent performance of EPC mode in promoting on-site LC of the project case, the EPC mode is suggested to be encouraged and promoted in future prefabricated projects.

The established methodology framework integrating various methods and mathematical formulas proposes a new idea for the barrier analysis and corresponding organizational capability evaluation of on-site LC from the perspective of the specific prefabricated construction industry. Since prefabricated buildings have particularity in terms of the construction mode compared with other buildings, the methodology framework further expands the current boundary of LC methodology. The findings and suggestions will provide a valuable reference and guidance for the prefabricated construction industry to solve the barriers regarding on-site LC. For prefabricated construction projects, this study will improve the utilization rate of on-site lean construction and the capability level of construction organization. However, this study only selects the construction organization adopting the EPC mode as a case, which may be slightly insufficient in terms of convincing. Hence, the capability evaluation regarding different types of construction organizations may be a direction for future research.

Data Availability

All data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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