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Article

The Index System for the Development Level Evaluation of Regional Construction Industrialization: a Case Study in Jiangsu, China

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Abstract: In recent years, there have been concerns raised about construction industrialization in China, which have initiated a wave of policy change in both governmental and industrial organizations in order to change the mode of conventional construction. However, the current development level of regional construction industrialization (RCI) in China has not been well-characterized. This study screened preliminary index systems in five dimensions: technical, economic, sustainable, enterprise development and development environment. Based on the data gathered from the questionnaire surveys and subsequently analyzed, twenty-two critical evaluation indicators were identified. Analytic Hierarchy Process (AHP) was then employed to determine the weighting of each indicator. The evaluation method of the development level was formulated on the basis of the evaluation criteria. Jiangsu Province was used as an example in this study, with the development level of this province being comprehensively examined using a combination of the index system and evaluation method. The results show that Jiangsu has a relatively high RCI development level. The data from analysis scores of five dimensions and twenty-two indicators show that the index system is feasible, with evaluation results being consistent with actual practice. These findings provide a good practical reference for making decisions about how best to guide the development of RCI.

Keywords: construction industrialization; dimensions; index system; evaluation

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1. Introduction

Rapid progress of urbanization in China has created a huge construction market. As a result, based on an average annual increase rate of 1%, the urbanization rate in China is expected to reach a historic high of 60% by 2020. However, conventional construction technologies are still an extensive mode of production due to having construction-related environmental issues, lower labor productivity, serious energy consumption, a lower degree of mechanization in addition to the current shortage of labor. One of the effective solutions is construction industrialization, which has become increasingly important for the entire construction industry. Construction industrialization refers to the practice of producing construction components in a manufacturing factory, transporting complete or semi-complete components to construction sites and finally assembling these components to construct buildings [1]. Compared with conventional construction technologies, construction industrialization not only reduces noise, dust, waste, labor demand and resource depletion, but also provides controlled conditions for bad weather and for maintaining quality, in addition to ensuring the health and safety of workers [2]. Therefore, changing the mode of conventional construction into industrialization is critical for the development of urbanization in China, which has been emphasized through a series of national guidelines and policies, including the National Plan on Construction during the 13th five-year plan [3]. Ji and Zhu predicted that by 2020, more than 200 million m^2 of gross floor area will be built annually through industrialized construction [4]. Consequently, a long-standing and considerable demand for construction industrialization exists because of industrialization during rapid urbanization.

However, most of the previous studies on construction industrialization concentrated on the technical aspects of the system, energy analysis, energy efficiency and Building Information Modeling [5,6], with only a limited number of studies being conducted on the regional development level of construction industrialization. Wang and Ji analyzed various factors they believed were affecting development of construction industrialization in China, before building a system that incorporated these influencing factors. However, these authors did not establish an evaluation model [7] . Bing and Chen established a linear regression model and analyzed the level of construction industrialization of China in 2010, finding out that the construction industrialization level of China at this time was close to that of Japan in the early 1980s [8]. However, there is no clear conclusion about China's construction industrialization level. China's various provinces and cities formulate corresponding policies in accordance with the development level of the region, but there is a lack of studies aiming to evaluate regional development levels. Therefore, it is important to research and create a scientific and reasonable method for evaluating the level of regional construction industrialization. To bridge this gap, this paper aims to propose a method for evaluating the level of regional construction industrialization in order to provide the basis for policy adjustment.

2. Research Objective and Methodology

2.1. Research Objectives

This research aims to provide a reasonable method to evaluate the level of regional construction industrialization (RCI) in order to provide evidence for decision-making and to ensure that subsequent development is comprehensive, coordinated and sustainable. The research objectives include: (1) to determine the index system for the development level evaluation of RCI; (2) to propose an evaluation method for the RCI development level; (3) to examine the index system and evaluation method in a case study, though comparing evaluation results with actual practice to verify the rationality of the method.

2.2. Methodology

Questionnaire surveys, analytic hierarchy process (AHP) and case studies are widely used methods for extracting or identifying evaluation dimensions or indicators [9,10]. Qualitative methods and cases studies are more appropriate for studying new phenomena than quantitative methods, because they provide more accurate and detailed explanations for the occurrence of the new phenomena [11]. In the management of prefabricated construction field, case study and survey are found to be the primary methods for data collection [12].

Based on prior studies, we established a preliminary evaluation index system based on the theory and practice of construction industrialization from five dimensions: technical, economic, sustainable, enterprise development and development environment. Twenty-five indicators were selected through the expert interview method. In addition, the method of questionnaire was designed to ensure the rationality of the preliminary index system. These methods ensured that the final index system would be comprehensive and reliable. Statistical analyses were performed to validate the survey and provide the basis for determining weight. During the process of formulating an evaluation method, AHP was then employed to determine the weighting of each indicator. According to the evaluation index system and evaluation method, we gathered the required data, with a case study being conducted to test whether the evaluation results are consistent with reality. The methodology adopted in this paper is shown in Figure 1.

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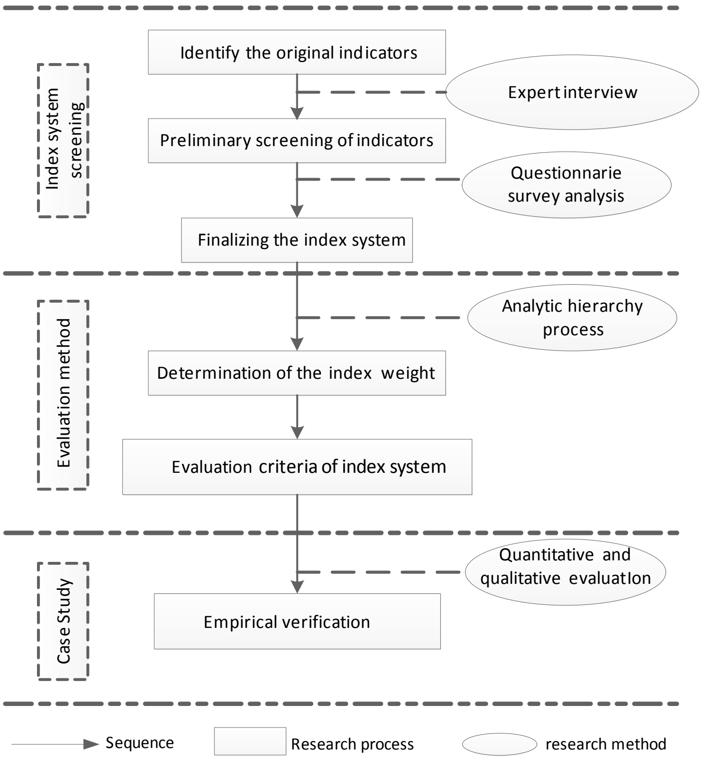

Figure 1. Methodology adopted in this study.

3. Index System Screening

3.1. Preliminary Screening of Indicators

The preliminary screening of indicators was based on whether they directly reflect the development level of RCI. It is necessary to select and include the indicators that can possibly affect this development level. In order to establish a comprehensive evaluation index system, the comprehensive evaluation of the development level should be considered from different views. During the development of construction industrialization, advanced technology is an important embodiment [13]. The inherent superiority of the technology, including, but not limited to, reduced labor demand [14], improved quality control [15], higher standards for health and safety [16], construction waste reduction [17], and low resource depletion [18]. Therefore, the development level of advanced technology is an important guideline to evaluate the development level of construction industrialization. Li et al. reviewed of the research on the management of prefabricated construction during the period from 2000 to 2013 [12], and found that performance evaluation mainly included environmental sustainability performance [16,18,19], economic performance [20,21], and social performance [22,23]. This paper identified the index system of RCI development level using the technical, economic, sustainable and enterprise development dimensions. In addition, support rate of the masses can be used to measure the development environment of the RCI, so it is regarded as the fundamental indicator in influencing the RCI development level. In this paper, we grouped these indicators as the 'development environment dimension'.

The following three methods are adopted for selection of indicators. First, literature analysis and policy research were used to identify the original indicators. Secondly, preliminary indicators were selected based on the expert interview method. The final index system was then determined through the questionnaire survey method. The process of index system screening is shown in Figure 2. Original indicators related to the development level of RCI were identified. Based on literature analysis and policy research, a total of twenty-six related articles and seventeen recent policies were included. According to literature analysis and policy research, thirty-four related original indicators were found. There were some similarities between the thirty-four related original indicators, so interviews were then conducted to discuss the availability of those dimensions and indicators. Nine relevant scholars and eleven government regulators of construction industry were invited to be interviewed. Eventually, the five dimensions were approved, and the original indicators were reduced to twenty five preliminary indicators (Table 1), which were thought to better represent the development level of RCI.

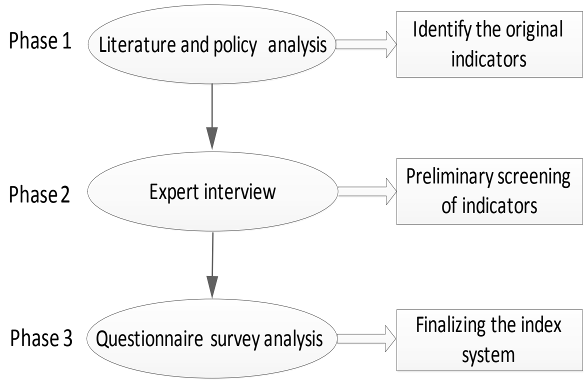

Figure 2. Process of index system screening.

Table 1. Preliminary index system of development level evaluation.

Target layer	Dimension layer	Index layer
Regional construction industrialization development level	Technical dimension (A1)	Application of modular design (A11); Application of standardized products (A12); Application of prefabricated part (A13); Proportion of finished housing (A14); Application of information technology (A15); Ratio of new buildings assemblage (A16); Application of "four new techniques" (A17); 3D printing technology (A18).
	Economic dimension (A2)	Labor productivity (A21); Regional per capita GDP (A22); Building materials prices index (A23); The construction industry output value' share of GDP (A24); Investment in fixed assets of construction and installation engineering (A25).
	Sustainable dimension (A3)	Application of clean energy (A31); The efficiency ratio of building energy(A32); Number of green buildings(A33); The utilization of land resources(A34)
	Enterprise development dimension (A4)	Number of regional construction company (A41); Number of the national industrial bases (A42); The value of newly signed contracts (A43); Number of the employees in the regional construction industry (A44).
	Development environment dimension (A5)	The rate of urbanization (A51); Market competition intensity (A52); Support rate of the masses (A53); Regional per capita housing area (A54).

3.2. Finalizing the Index System

3.2.1. Questionnaire Survey

The questionnaire was designed to test the preliminary indicators of the RCI development level, in particular from the angle of reasonability and operability. We designed the questionnaires to consist of twenty-five indicators with a 5-point Likert scale (1 = can be ignored or not important, 2 = somewhat important, 3 = important, 4 = very important and 5 = extremely important). Six-hundred survey questionnaires were distributed to personnel in construction companies as well as to government regulators of construction industry. In the first part of the questionnaire, respondents were asked to answer questions about their job title and years of construction industrialization project experience. In the second part, they were asked to make their own judgments on the indicators of RCI development level according to experience. This survey was conducted from September to November 2015. Finally, 152 completed responses were received. The respondent rate was 25.3%, consistent with the criterion of 20–30% for questionnaire surveys in engineering management studies [24]. Table 2 presents the profile of the data collected via the questionnaires.

Table 2. Profile of the data collected from the questionnaires.

Respondents' characteristics	Description	N	%
Construction companies (N = 67)	Senior manager	35	52.2
	Project manager	21	31.3
	Project engineer	11	16.5
Government regulators (N = 85)	Leader	62	72.9
	Staff	23	27.1
Years of experience (N = 152)	<5	19	12.5
	5–9	31	20.4
	10–20	74	48.7
	>20	28	18.4
Regions (N = 152)	Jiangsu Province	91	59.9
	Zhejiang Province	17	11.2
	Shanghai	14	9.2
	Others	30	19.7

3.2.2. Reliability Analysis

Reliability analysis was performed on the 152 valid questionnaires, with the results indicating a high reliability (Cronbach's α = 0.834). Shen et al. noted that the threshold value of Cronbach's alpha for a reliable questionnaire is 0.70 [25].

3.2.3. Mean Value and Ranking of the Indicators

The scores and rankings of the twenty-five RCI development level indicators were examined by descriptive statistics (Table 3). The mean values for these twenty-five indicators range from a minimum of 2.473 (A44) to a maximum of 4.685 (A16). Nearly half (48%) of the indicators' mean values are over 4.00 (12 indicators), with just three being below 3.0 (A18, A34, A44). This indicates that most of the indicators are very important and can be used as a representation of the RCI development level in China. Of the top five indicators with the highest mean values, three belong to the technical dimension (A1). The result shows that the technological level of construction industrialization could strongly influence the RCI development.

Table 3. Scores and ranking of the indicators.

Dimension	Indicator	Mean	Std. dev	CV	Rank	Group mean	Group Rank	Verification
Technical dimension (A1)	A11	4.540	0.61	0.13	4	4.383	1	Pass
	A12	4.628	0.58	0.13	2			Pass
	A13	4.211	0.78	0.19	9			Pass
	A14	4.352	0.82	0.19	7			Pass
	A15	4.171	1.21	0.29	10			Pass
	A16	4.685	0.46	0.10	1			Pass
	A17	4.095	0.86	0.21	11			Pass

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	A18	2.875	1.14	0.40	23			No
Economic dimension (A2)	A21	4.376	0.49	0.11	6	3.774	4	Pass
	A22	3.157	0.78	0.25	22			Pass
	A23	3.866	0.50	0.13	15			Pass
	A24	3.925	0.83	0.21	14			Pass
	A25	3.548	0.71	0.20	17			Pass
Sustainable dimension (A3)	A31	3.430	0.83	0.24	19	3.892	3	Pass
	A32	3.961	0.66	0.17	13			Pass
	A33	4.285	0.87	0.20	8			Pass
	A34	2.601	0.81	0.31	24			No
Enterprise development dimension (A4)	A41	3.361	0.74	0.22	20	4.002	2	Pass
	A42	4.587	1.05	0.23	3			Pass
	A43	4.059	0.67	0.17	12			Pass
	A44	2.473	0.71	0.29	25			No
Development base dimension (A5)	A51	3.774	0.48	0.13	16	3.742	5	Pass
	A52	3.471	0.85	0.24	18			Pass
	A53	4.469	0.45	0.10	5			Pass
	A54	3.254	0.62	0.19	21			Pass

3.2.4. The Final Index System

According to the analysis of questionnaire results, the large majority of indicators have been proven to be effective. We filtered out the indicators (A18, A34, A44) with mean values below 3.0, which indicated that 3D printing technology (A18), the utilization of land resources (A34) and number of the employees (A44) are relatively less important for evaluating the development level of RCI with regards to reasonability and operability. The final composition of the index system is shown in Figure 3.

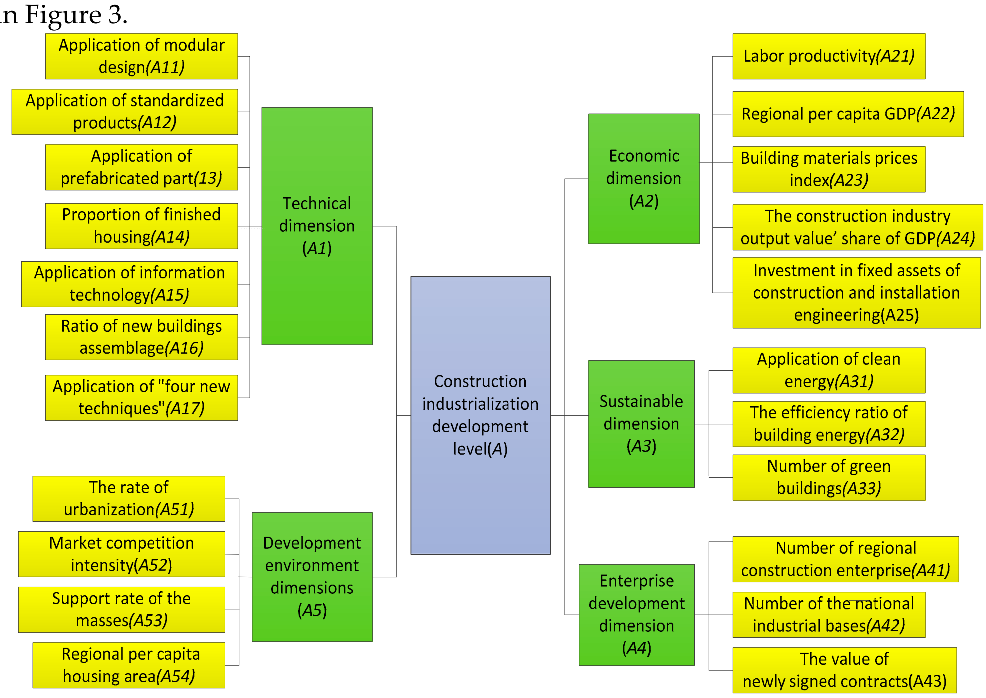

Figure 3. The final index system for construction industrialization development level.

4. Evaluation Method of Index System

4.1. Determination of the Index Weight

Weight determination is one of the most critical components for evaluating RCI development level. AHP is a common decision-making method with multiple criteria. It was developed by Saaty in the 1970s to assist in solving complex decision problems by capturing both subjective and objective evaluation measures [26]. The fundamental approach of AHP is based on defining the big problem as a hierarchical structure, with the small problems being located in the lower levels. Thus, the solutions to the small problems are aggregated to form a solution for the big problem [27]. The steps are as follows [28]:

(1) Construction of a hierarchy-type structure: As mentioned above, divide the evaluation object into a target layer (A), a dimension layer (Ai), and an index layer (Aij), as shown in Figure 3.

(2) Pairwise comparison: AHP uses a pair-wise comparison of the criteria importance with respect to the goal. In this paper, we compared the importance of the different dimensions and indicators using the importance scale suggested by Saaty [26], as shown in Table 4. Through analysis of questionnaire results combined with the experts' evaluation of this field, we built a judgment matrix. The size of the comparison matrix (A) is $n \times n$, where n is the number of criteria relative to a specific criterion.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

The pairwise comparison matrix is indicated as $A = (a_{ij})_{n\times n}(i, j = 1,2,\cdots n)$, and satisfies:

$$a_{ij} = \begin{cases} 1/a_{ji} & i \neq j \\ 1 & i = j \end{cases} \quad (2)$$

where a_{ij} represents the relative importance of a_i over a_j

Table 4. Description of importance.

Score	Importance description
1	"i" is equal important to "j"
3	"i" is weakly more important to "j"
5	"i" is strongly important to "j"
7	"i" is very strongly important to "j"
9	"i" is absolute morel importance to "j"

Note: 2, 4, 6 and 8 are intermediate values.

(3) Consistency assurance: Saaty defined a consistency index (CI), which is computed for each matrix size from relevant values [26]. The consistency ratio (CR) is defined as the ratio between the CI of a given matrix and the CI of a same-size reference matrix containing random values.

To check for consistency, A' matrix is calculated where A' is the normalized matrix of A:

$$A' = \begin{bmatrix} a'_{11} & a'_{12} & \cdots & a'_{1n} \\ a'_{21} & a'_{22} & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a'_{n1} & a'_{n2} & \cdots & a'_{nn} \end{bmatrix} \quad (3)$$

where, $a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$, i, j = 1, 2, 3, … , n

Then, we have to compute the Eigen value and Eigen vector.

$$W = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix}, \text{ and } W_i = \frac{\sum_{i=1}^{n} a'_{ij}}{n} \text{ and } W' = AW = \begin{bmatrix} W'_1 \\ W'_2 \\ \vdots \\ W'_n \end{bmatrix} \quad (4)$$

$$\lambda_{max} = \frac{1}{n}\left(\frac{W'_1}{W_1} + \frac{W'_2}{W_2} + \cdots + \frac{W'_n}{W_n}\right) \quad (5)$$

where W is the Eigen vector, W_i is Eigen value of the given matrix and λ_{max} is the largest Eigenvalue value of the pair-wise comparison matrix.

According to Saaty, it is safe to assume that the largest Eigenvalue is greater than or equal to n ($\lambda_{max} \geq n$). The closer λ_{max} is to n, the more consistent A is.

The consistency ratio (CR) is calculated by AHP as:

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$$\text{Consistency index(CI)} = \frac{\lambda_{max} - n}{n-1} \quad (6)$$

$$\text{Consistency ratio(CR)} = \frac{\text{CI}}{Random\ index(RI)} \quad (7)$$

where RI is the random consistency index related to the dimension of matrix, listed in Table 5.

Table 5. Random consistency index RI.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

If CR ≤ 0.10, the level of inconsistency is considered acceptable. Otherwise, the comparison matrix needs to be reconstructed.

(4) Calculate the weighting of each indicator. The weighting vector formed from the judgment matrix is obtained by repeating the 3 earlier processes mentioned above.

4.2. Calculation Results of the Indicator Weight

4.2.1. Determining the Evaluation Indicator Set

The evaluation indicator set of the target layer A is: $A = \{A1, A2, A3, A4, A5\}$ (Figure 3).

$A1 = \{A11, A12, A13, A14, A15, A16, A17\}$, $A2 = \{A21, A22, A23, A24, A25\}$,

$A3 = \{A31, A32, A33\}$, $A4 = \{A41, A42, A43\}$, $A5 = \{A51, A52, A53, A54\}$

4.2.2. Determining the Weight Set

Eleven experts were invited to participate in the review of this project, they provided scores on the basis of the comparison between two indicators. These scores represented the relative importance of the various indicators. The judgment matrix and the weight of each indicator are obtained using Equations (1)–(7). The results are shown in Tables 6-11.

Table 6. The judgment matrix and weight based on A.

A	A1	A2	A3	A4	A5	λ_{max}	Weight	$\text{CI} = (\lambda_{max} - n)/(n-1)$
A1	1	1/5	1/4	1/3	1/5	5.224	0.47	CI=0.056<0.1
A2	5	1	3	4	1/2		0.08	Uniform convergence
A3	4	1/3	1	3	1/2		0.13	
A4	3	1/4	1/3	1	1/4		0.26	
A5	5	2	2	4	1		0.06	

Table 7. The judgment matrix and weight based on A1.

A1	A11	A12	A13	A14	A15	A16	A17	λ_{max}	Weight	$\text{CI} = (\lambda_{max} - n)/(n-1)$
A11	1	2	1/4	1/3	1/5	3	1/5	7.264	0.18	CI=0.044<0.1
A12	1/2	1	1/5	1/4	1/6	2	1/6		0.26	Uniform convergence
A13	4	5	1	3	1/2	5	1/3		0.06	
A14	3	4	1/3	1	1/3	4	1/4		0.10	
A15	5	6	2	3	1	6	1/2		0.04	
A16	1/3	1/2	1/5	1/4	1/6	1	1/7		0.33	
A17	5	6	3	4	2	7	1		0.03	

Table 8. The judgment matrix and weight based onA2.

A2	A21	A22	A23	A24	A25	λ_{max}	Weight	$\text{CI} = (\lambda_{max} - n)/(n-1)$
A21	1	1/5	1/3	1/3	1/3	5.104	0.45	CI=0.026<0.1
A22	5	1	3	3	2		0.07	Uniform convergence
A23	3	1/3	1	2	1/2		0.16	
A24	3	1/3	1/2	1	1/2		0.21	
A25	4	1/2	2	2	1		0.11	

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Table 9. The judgment matrix and weight based on A3.

A3	A31	A32	A33	λ_{max}	Weight	$CI = (\lambda_{max} - n)/(n-1)$
A31	1	3	4	3.036	0.13	CI=0.018<0.1
A32	1/3	1	2		0.32	Uniform convergence
A33	1/4	1/2	1		0.55	

Table 10. The judgment matrix and weight based on A4.

A4	A41	A42	A43	λ_{max}	Weight	$CI = (\lambda_{max} - n)/(n-1)$
A41	1	7	3	3.062	0.09	CI=0.031<0.1
A42	1/7	1	1/4		0.70	Uniform convergence
A43	1/3	4	1		0.21	

Table 11. The judgment matrix and weight based on A5

A5	A51	A52	A53	A54	λ_{max}	Weight	$CI = (\lambda_{max} - n)/(n-1)$
A51	1	1/2	4	1/3	4.075	0.20	CI=0.025<0.1
A52	2	1	5	1/2		0.12	Uniform convergence
A53	1/4	1/5	1	1/6		0.60	
A54	3	2	6	1		0.08	

4.3. Evaluation Criteria of Index System

In order to conduct a scientific and rational evaluation of the construction industrialization development level, it is imperative to establish the evaluation criteria [29]. Standard evaluation criteria are chosen on a scientific basis, which must be reasonable and easy to operate [30]. In this paper, the evaluation criteria of the RCI development level were set according to 4 categories: (i) Quantitative index with comparison to the national average in 2015, such as A21, A22, A23, A24, A51 and A54; (ii) Quantitative index with comparison to the proportion of the national total in 2015, such as A25, A33, A41, A42 and A43; (iii) Quantitative index regarding some specific data for application proportions, which will be evaluated by experts in a qualitative manner due to this data being difficult to acquire, such as A11, A12, A13, A14, A15, A16, A17 and A32; (iv) Quantitative index evaluated by experts in qualitative manner, such as A31, A52 and A53. The development level of RCI is divided into five evaluation grades on a five-point scale: 5 = excellent, 4 = good, 3 = medium, 2 = fair, 1 = poor. According to the above categories for criteria, the evaluation criteria of the RCI development level for each indicator are shown in Tables 12–16.

Table 12. Evaluation criteria of index system in the technical dimension (A1).

Index	Evaluation criteria	Score	Rule explained
A11, A12 A13, A15 A16, A17	Proportion more than 20% Proportion between 15%–20% Proportion between 10%–15% Proportion between 5%–10% Proportion lower than 5%	5 4 3 2 1	National programmer for construction industry modernization [31]
A14	Proportion more than 60% Proportion between 40%–60% Proportion between 20%–40% Proportion between 10%–20% Proportion lower than 10%	5 4 3 2 1	Compared with data of “Green building action plan of Jiangsu province” [32]

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Table 13. Evaluation criteria of index system in the economic dimension (A2).

Index	Scoring criteria	Score	Rule explained
A21	more than 340,000 Yuan per person	5	The national average is 324026 [33]
	between 330,000–340,000 Yuan/person	4	
	between 320,000–330,000 Yuan/person	3	
	between 290,000–320,000 Yuan/person	2	
	lower than 290,000 Yuan per person	1	
A22	more than 70,000 Yuan per person	5	The national average is 52,000 Yuan / person [33]
	between 60,000–70,000 Yuan/person	4	
	between 50,000–60,000 Yuan/person	3	
	between 40,000–50,000 Yuan/person	2	
	lower than 40,000 Yuan/person	1	
A23	Price index below 90	5	The national average is 100.0 [33]
	Price index between 90–95	4	
	Price index between 95–100	3	
	Price index between 100–105	2	
	Price index more than 105	1	
A24	Proportion more than 7.5%	5	The national average is 6.86% [33]
	Proportion between 7.0%–7.5%	4	
	Proportion between 6.5%–7.0%	3	
	Proportion between 6.0%–6.5%	2	
	Proportion lower than 6.0%	1	
A25	Proportion more than 15%	5	The national total is 37.972 trillion Yuan [33]
	Proportion between 7%–15%	4	
	Proportion between 4%–7%	3	
	Proportion between 2%–4%	2	
	Proportion below 2%	1	

Table 14. Evaluation criteria of index system in the sustainable dimension (A3).

Index	Scoring criteria	Score	Rule explained
A31	A large number of projects	5	Expert decision
	Between 3–5	4	
	Several projects	3	
	Between 1–2	2	
	No project	1	
A32	Ratio reaches 65% or more	5	Compared with data of "The twelfth Five-Year Plan of energy efficiency in buildings of Jiangsu province" [34]
	Ratio between 55%–65%	4	
	Ratio between 45%–55%	3	
	Ratio between 30%–45%	2	
	Ratio below 30%	1	
A33	Proportion more than 15%	5	The national total is 3636 [35]
	Proportion between 7%–15%	4	
	Proportion between 4%–7%	3	
	Proportion between 2%–4%	2	
	Proportion below 2%	1	

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Table 15. Evaluation criteria of index system in the enterprise development dimension (A4)

Index	Scoring criteria	Score	Rule explained
A41	Proportion more than 15%	5	The national total is 80,911 [33]
	Proportion between 7%–15%	4	
	Proportion between 4%–7%	3	
	Proportion between 2%–4%	2	
	Proportion below 2%	1	
A42	Number reaches 7 or more	5	The national total is 70 [36]
	Number between 5–6	4	
	Number between 3–4	3	
	Number between 2	2	
	Number 1 or on	1	
A43	Proportion more than 15%	5	The national total is 18.43 trillion Yuan [33]
	Proportion between 7%–15%	4	
	Proportion between 4%–7%	3	
	Proportion between 2%–4%	2	
	Proportion below 2%	1	

Table 16. Evaluation criteria of index system in the development base dimension (A5).

Index	Scoring criteria	Score	Rule explained
A51	Ratio reaches 65% or more	5	The national average is 56.1% [33]
	Ratio between 60%–65%	4	
	Ratio between 55%–60%	3	
	Ratio between 55%–50%	2	
	Ratio below 50%	1	
A52	High degree of market competition	5	Expert decision
	Between 3–5	4	
	Common degree of market competition	3	
		2	
	Between 1–3	1	
	Poor degree of market competition		
A53	High degree acceptance	5	Expert decision
	Between 3–5	4	
	Common degree acceptance	3	
	Between 1–3	2	
	Poor degree acceptance	1	
A54	More than 40 m^2	5	The national average is 33 m^2 [33]
	Between 37–40 m^2	4	
	Between 33–37 m^2	3	
	Between 30–33 m^2	2	
	Lower than 30 m^2	1	

5. Case Study

5.1. Study Area

Jiangsu province is composed of 13 prefecture-level cities located in the east of China, with an overall area of 10.72 × 10^4 km^2 and a population of 79.76 million in 2015 [37]. Jiangsu is one of China's most developed regions, primarily due to the high urbanization and industrialization of the cities in the south of the Yangtze River. The gross domestic production (GDP) of Jiangsu was about 7.609 trillion in 2016, ranking it second out of all Chinese provinces [33]. The per capita GDP of Jiangsu was ranked first out of all Chinese provinces. Jiangsu's total output of construction industry is 2.479 trillion Yuan in 2015, which ranked first out of all Chinese provinces [33]. As a result, Jiangsu is a strong province in the economic and construction industry fields.

5.2. Data Collection

According to the evaluation index system and evaluation criteria above, we gathered the required data of Jiangsu in 2015 (Table 17) and designed the expert scoring method for experts using a five-point scale. Sixteen experts from universities, the administration of housing and construction in addition to construction enterprises provided an answer from 1 to 5, representing their individual view of the RCI development level in Jiangsu.

Table 17. The relative data of quantitative evaluation index.

Index	Data	Source
A21	297,437/Yuan/Year	Statistical Yearbook of Jiangsu [37]
A22	88,500	National Bureau of Statistics of China [33]
A23	91.7	Statistical Yearbook of Jiangsu [37]
A24	6%	National economy and social development statistical bulletin of Jiangsu [38]
A25	2.757 trillion Yuan	Statistical Yearbook of Jiangsu [37]
A33	562	Ministry of Housing and Urban-Rural Construction of China [35]
A41	9146	Statistical Yearbook of Jiangsu [37]
A42	8	List of national housing industrialization base [36]
A43	2.077 trillion Yuan	Statistical Yearbook of Jiangsu [37]
A51	66.5%	National economy and social development statistical bulletin of Jiangsu [38]
A54	45.22 m^2	Statistical Yearbook of Jiangsu [37]

5.3. Calculation Results of Evaluation Score

We calculated the score for each indicator of Jiangsu in 2015, with the steps being as follows: Mean of indicator score $\overline{SC_{ij}}$ is calculated according to Equation (8), followed by calculating the dimension score SC_i according to Equation (9), before finally calculating the target evaluation score SC according to Equation (10). The results are shown in Table 18.

$$\overline{SC_{ij}} = \frac{1}{n}\sum_{k=1}^{n} S_{ij} \quad (8)$$

$$SC_i = \sum \overline{SC_{ij}} \times W_{ij} \quad (9)$$

$$SC = \sum SC_i \times W_i \quad (10)$$

Where n is the number of experts, SC_{ij} represents the score of A_{ij} as the expert k evaluation, W_{ij} represents the weight of A_{ij}, W_i represents the weight of A_i.

Table 18. Calculated results of Jiangsu construction industrialization development level.

Evaluation target (A)	Dimension (A_i)	Index (A_{ij})	$\overline{SC_{ij}}$	W_{ij}	SC_i	W_i	SC
	A1	A11	3.7	0.18	3.39	0.47	
		A12	3.2	0.26			
		A13	3.8	0.06			
		A14	2.7	0.10			
		A15	3.4	0.04			
		A16	3.5	0.33			
		A17	3.4	0.03			
	A2	A21	2	0.45	2.75	0.08	
		A22	5	0.07			
		A23	4	0.16			
Regional construction industrialization development level		A24	2	0.21			3.81
		A25	4	0.11			
	A3	A31	3.3	0.13	4.30	0.13	
		A32	3.5	0.32			
		A33	5	0.55			
	A4	A41	4	0.09	4.70	0.26	
		A42	5	0.70			
		A43	4	0.21			
	A5	A51	5	0.20	3.58	0.06	
		A52	4.2	0.12			
		A53	2.8	0.60			
		A54	5	0.08			

6. Conclusions

Most prior studies on construction industrialization concentrated on the technical system, energy analysis and information technology, with fewer studies aiming to evaluate the development level of construction industrialization. To address this knowledge gap, we proposed a method for evaluating the level of regional construction industrialization. The findings of this study are as follows.

First, we determined the indicators of the RCI development level through literature analysis, policy research, small-scale expert interviews and questionnaire survey analysis. Based on the questionnaire survey data gathered and analyzed, twenty-two indicators were identified as important components of the RCI development level. These methods were used to ensure that the final index system was comprehensive and reliable. After calculating and analyzing the questionnaire survey data, we found that the total effects of the dimension layers on RCI development level range from 3.742 to 4.383. The results indicate that the core dimension for RCI development level is the technical dimension. After re-ranking according to questionnaire survey, six indicators of the technical dimension were found to be in the top ten (Figure 4). The ratio of new buildings assemblage (A16, 4.685), application of standardized products (A12, 4.628), number of the national industrial bases (A42, 4.587), application of modular design (A11, 4.540) and support rate of the masses (A53, 4.469) were identified as the most important indicators of RCI development level, which were among the top five in the index system. In addition, we found that the economic dimension of the RCI development level ranges from 3.157 to 4.376, ranking this dimension fourth out of the five dimensions. The results indicate that the level of economic development is not a key factor of influencing the performance of construction industrialization, which is not quite the same as in other industries.

Secondly, a hierarchy-type structure was proposed based on the final index system, with AHP being conducted to calculate the weighting of each indicator. Identifying these indicators and their

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respective weighting would be very useful for assessment of RCI development level as well as management from the perspective of the government regulators.

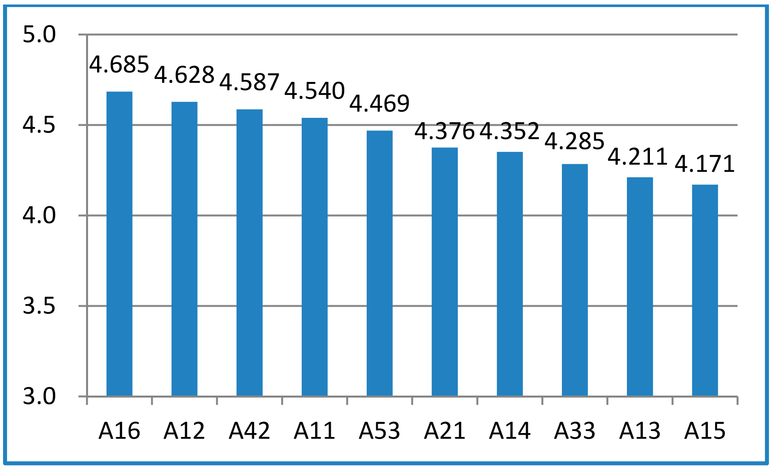

Figure 4. The top ten ranked indicators through questionnaire survey analysis.

Finally, the index system and evaluation method for the development level of RCI are proposed in this study, which were tested using a case study. We calculated the score for the development level of Jiangsu construction industrialization in 2015. The results showed that the degree score of the development level is 3.81, which is a relatively high value. Scores of the five dimensions are shown in Figure 5. We discovered that out of the five dimensions, the enterprise development dimension achieved the top score while economic dimension received the lowest score. The construction enterprise developmental level of Jiangsu is the leading level in China and will provide foundation and drive for construction industrialization. Although this province is the leader in China with regards to total output of its construction industry, Jiangsu is confronting an era of slower economic growth.

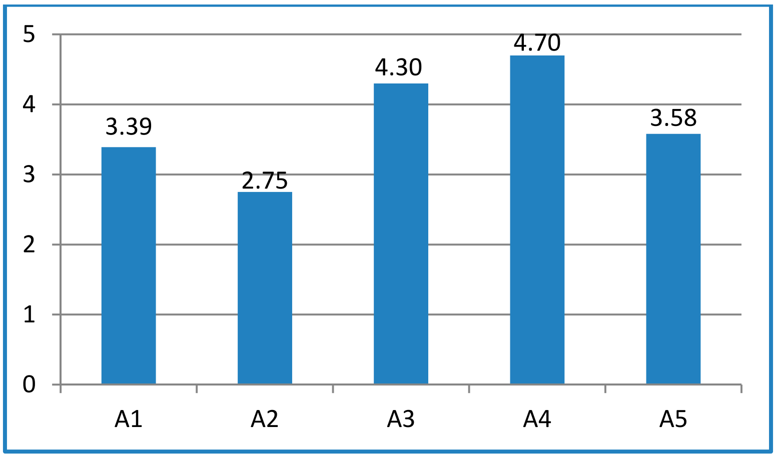

Figure 5. Scores on the five dimensions for the development level of Jiangsu.

Through analysis of all the indicator scores as shown in Figure 6, we discovered that indicator scores of the technical dimension were below the good level of 4.0. The government should introduce according mandatory and encouraging policies in increasing technology R&D and application level to guide construction industry to improve technology application level. In addition, we found that proportion of finished housing (A14, 2.7), labor productivity (A21, 2), the construction industry output value' share of GDP (A24, 2), support rate of the masses (A53, 2.8) were below the medium level of 3.0. Apart from slower economic growth, support rate of the masses is ranked as being fifth most important out of all the indicators (Figure 4) despite becoming third last in importance in all the indicator scores (Figure 6). The government should strengthen publicity and guidance of the industry as people lack up-to-date knowledge of technologies. Furthermore, this could potentially increase public support for construction industrialization.

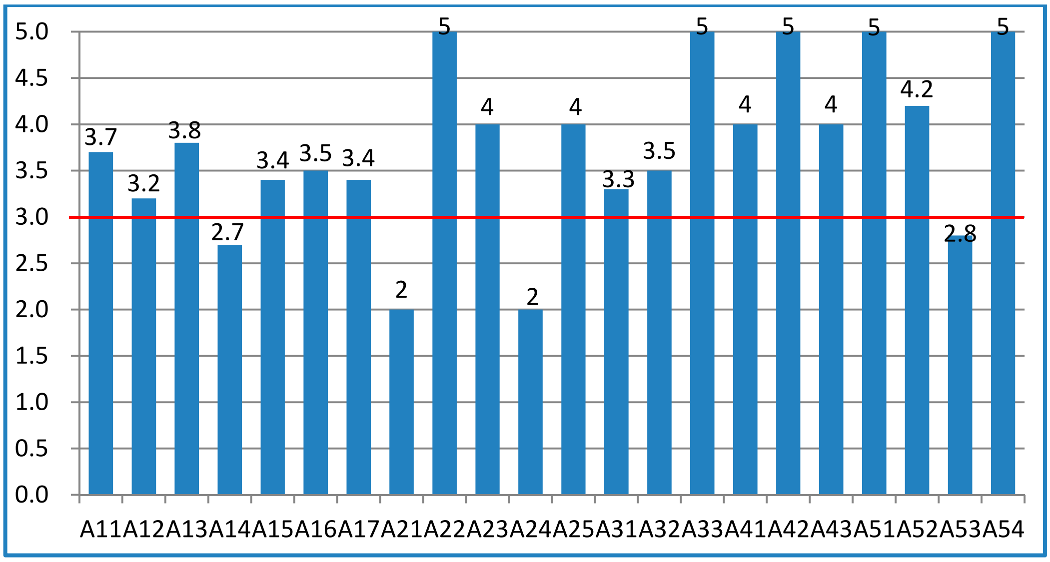

Figure 6. Indicator scores for the development level of Jiangsu.

Although this study obtained useful findings related to the development level of RCI, two limitations should be mentioned. First, it has been proposed that some quantitative indicators should be evaluated by experts in a qualitative manner, due to data for application proportions being difficult to acquire. Secondly, it is critical to extend and broaden the index system with the rapid development of construction industrialization, which we will pursue and perfect in the future research.

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