

## Article

# Critical Factors Influencing the Sustainable Construction Capability in Prefabrication of Chinese Construction Enterprises

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**Abstract:** Compared with the conventional cast-in-situ method, prefabricated construction (PC) is a sustainable construction method. In China, the sustainable performance qualities of PC—such as its improved quality, lower cost and shorter turnaround—have barely been achieved. This is likely attributable to the weak sustainable construction capability of construction enterprises in undertaking PC projects. This study observed that there is relatively scant research on critical influencing factors relating to this capability, after investigating the most recent literature about PC development obstacles. Without a clear understanding of this knowledge, construction enterprises are unlikely to formulate effective measures to enhance their sustainable construction capability to tackle efficiency, cost, risk, and broader performance issues in PC. Therefore, this study identified 27 factors from the literature and interviews, ranked these factors using the Entropy method and the fuzzy analytic hierarchy process (FAHP), examined the top five critical factors, and discussed the problem-solving measures. This study drew the conclusion that construction enterprises should focus on PC business scope expansion, project delivery quality improvement, and technology investment and innovation, as well as the return on investments in technology. It is also suggested that incentivised strategies be formulated by the Chinese government in order to improve industry practitioners' capability of implementing sustainable PC projects. This will eventually expedite the industry's transformation towards leaner, more efficient and sustainable practice.

**Keywords:** prefabricated construction; sustainable construction capability; construction enterprise; Entropy method; fuzzy analytic hierarchy process (FAHP)

## 1. Introduction

Prefabricated construction (PC) is a sustainable and productive construction mode, which allows cast-in-situ processes to take place in a controlled environment such as a factory [1,2]. Compared with traditional cast-in-situ construction, PC has some potential advantages for sustainable performance, such as faster construction, the improved quality of architecture and workforce safety, reduced construction waste and greenhouse gas (GHG) emissions, and so on [3–6]. Nowadays, while it has become widespread in many developed countries, such as the United Kingdom (U.K.), Singapore and Japan, PC is also gradually being applied by some developing countries, such as China and Malaysia, as a sustainable alternative to conventional cast-in-situ construction [7,8].

Thanks to the new-type urbanisation strategy, the Chinese PC market share has gradually increased over the last decade [9]. Such an increase is also owing to the extensive policies and measures that have

been formulated by governments at different levels to promote the application of PC [10]. For instance, the proportion of prefabricated buildings to new buildings has to increase to 30% in large cities until 2025 [11]; in addition to that, certain cities, such as Tianjin, are expected to deliver public buildings completely using PC workmanship.

Despite the tremendous development opportunity of PC in China, the use of PC techniques is still limited due to various barriers, such as its high initial cost, its poor quality, the lack of skilled labor, and technology standards. Extensive research has been conducted to address these challenges from the perspectives of project management, technical innovation, business modelling and performance evaluation [1]. However, the stakeholders' sustainable construction capability of implementing PC, a key factor affecting the successful delivery of PC projects, has been overlooked frequently [12]. The sustainable construction capability oriented to PC is the capacity of stakeholders to sustainably utilise, extend or adjust their resources (including technology, investment, and management), and to obtain the improved sustainable performance of PC projects [13,14]. It is necessary for stakeholders to have a clear understanding about the factors influencing their sustainable construction capability in PC projects [12]. It is critical for stakeholders to get to know how to stipulate and undertake effective measures for the improvement of their capability. Therefore, these factors should be identified.

PC stakeholders include, but are not limited to, designers, developers, general contractors, manufacturers, suppliers, governments, and the public [15,16]. In this study, general contractors, also known as construction enterprises, are one of the main stakeholder types, given their responsibility for project performance in areas such as quality, cost and duration [17]. In China, construction enterprises' sustainable construction capability is more influential to the sustainable performance and successful delivery of PC projects due to their low level of capability in developing PC technologies. Furthermore, compared with traditional construction, the improvement of construction enterprises' sustainable capability is more challenging due to the complexity of PC processes. In order to improve such a capability, construction enterprises should take into account many factors, such as technology innovation, workforce upskilling, workmanship and management adjustment, lifecycle sustainability, equipment and utilities. Thus, this study aims to develop construction enterprises' understanding and help them better leverage the positive aspects of these influencing factors when implementing PC projects. This study also aims to recommend effective strategies to boost the uptake of PC across the entire construction industry.

## 2. Literature Review

PC has overwhelming advantages over traditional construction, such as its shortened delivery time, and its improved project quality, safety and overall sustainability [8,18,19]. However, the challenges and constraints of implementing PC, including its high initial cost, lack of skilled workers, and inadequate technical and managerial experience, should not be overlooked in practice [20–23]. Researchers have made significant effort to solve these issues from different angles. As stated in Table 1, these articles can be organised into six major research themes and twenty-four research areas. It is recommended that stakeholders should make use of these findings in order to improve their PC performance in terms of PC quality, efficiency, economy, and sustainability [1,24].

**Table 1.** Previous research focusing on PC.

Research Theme	Research Areas	References
Prefabrication industry	1. Effectiveness of adoption, e.g., benefits, defects	[22,25]
	2. Critical factors for application, e.g., success, barriers, drivers	[21,26]
	3. Policies and incentives, e.g., promotion, subsidy	[27,28]
	4. Standards and guidance, e.g., design, production, assembly	[29,30]
Stakeholders and application	1. Stakeholders perspective, e.g., developer, client	[21,31]
	2. Multi-stakeholder relationship, e.g., synergy, interaction	[32,33]
	3. PC application in various areas, e.g., developed, developing areas	[9,31]
	4. PC application in various projects, e.g., private, public projects	[34,35]

Table 1. Cont.

Research Theme	Research Areas	References
Prefabrication product	1. PC components, e.g., stairs, modular components	[7,36]
	2. PC materials, e.g., thermal, pre-stressed concrete	[37,38]
	3. PC structures, e.g., framework, shear wall	[39,40]
	4. PC connections, e.g., dry connection	[41,42]
Performance evaluation	1. Sustainability, e.g., environment, resource, and energy	[20,43]
	2. Economy and society, e.g., cost-benefit, investment risk	[4,22]
	3. Operation, e.g., safety, quality, productivity	[44,45]
Managerial	1. Project management, e.g., plan, procurement, risk	[46,47]
	2. Supply chain management, e.g., collaboration	[48]
	3. Production operation management, e.g., scheduling, layout, logistics	[49,50]
	4. Lean construction management, e.g., standardization, improvement	[49,51]
Technical	1. Information technologies, e.g., BIM, IoT (Internet of Things)	[52,53]
	2. Design technologies, e.g., automatic reengineering	[36,54]
	3. Production technologies, e.g., automatic production line, inventory	[55,56]
	4. Assembly technologies, e.g., automatic facilities	[57,58]
	5. Decision-making technologies, e.g., algorithm, simulation	[59,60]

According to the literature review, the process of identifying the critical factors affecting PC can be mainly divided into two steps; namely, identifying a list of factors and ranking the factors based on their importance level. Each step includes different methods as well (Table 2). First, the primary factors were identified through the literature review (LR) and interview (IR) methods [61]. Second, the critical factors were further determined based on the questionnaire survey and mean value techniques [61]. Thanks to its simplicity in application, the mean value technique, in combination with questionnaires, tends to be the most widely used method [61,62]. Meanwhile, in order to improve the effectiveness, more innovative ranking approaches have been developed as an alternative to the mean score method. For instance, social network analysis (SNA) was applied to identify and analyse critical factors for schedule risk from the perspective of stakeholders, based on the initial factors determined by the literature review and interview [63].

Table 2. Methods of identifying the factors affecting PC.

Theme	Method for Primary Factors	Method for Critical Factors	Source
Major barriers to off-site construction	LR & in-depth IR		[21]
Constraints on PC promotion	LR & semi-structured IR		[23]
Critical factors affecting IBS * quality	LR & semi-structured IR	Mean score based on questionnaire	[64]
Critical success factors for project management	LR & in-depth IR		[65]
Factors affecting PC capital cost	LR & semi-structured IR		[44]
Critical success factors for PC optimum	LR & IR & brainstorming	Mean score based on expert survey	[66]
Challenges to industrialised building	LR & in-depth IR	Fuzzy set theory based on questionnaire	[10]
Risk management factors for PC	LR & IR	SNA	[63]
Project delivery delay factors for PC	LR & IR	DEMATEL-ANP * based on expert survey	[67]

\* Note: DEMATEL–ANP stands for decision-making trial and evaluation laboratory with analytic network process; IBS stands for Industrialised Building System.

However, these ranking approaches are mostly based on the factors' subjective values derived from the survey, which may overlook the objectivity of the factors. The objective value is a direct reflection of the factors' importance relating to the sustainable construction capability oriented to PC for construction enterprises, especially during the initial development phase. For instance, the market scale of the construction enterprise was generally small during the initial development stage of the Chinese PC industry, which can be important to the reflection of their sustainable capability.

In fact, methods for the importance evaluation that integrate the objective and subjective weights have been developed. These methods include, but are not limited to, analytic hierarchy process integrated with Entropy (AHP-Entropy) [68], fuzzy AHP-Entropy (FAHP-Entropy), and so on [69]. For example, the AHP-Entropy method was adopted in order to evaluate the capability of the construction industrialisation of construction firms [70]. The FAHP-Entropy approach was used to construct an evaluation index system of energy-saving building design, and to identify the critical indexes to optimise the design [69]. On this basis, an integrated quantitative FAHP-Entropy approach that takes into account both the subjective and objective values was used to identify the critical factors of this study. The objective value of factors was further evaluated by different categories of values in this study in order to assure the accuracy and comprehensiveness of the values. The categories include numeric values (NV), interval values (IV) (such as [1,4] and [5,10]), and linguistic values (LV) (such as good and poor) [71].

### 3. Research Method

In this study, the research process involves two stages; namely, the identification of the primary factors using the literature review and the in-depth interview, and the identification of the critical factors using the Entropy-AHP approach.

#### 3.1. Preliminary Factors

This study further conducted a literature review and interviews in order to identify the factors relating to the sustainable construction capability of construction enterprises that implement PC. A systematic literature review was first undertaken in order to identify a list of preliminary factors. This study searched journal articles in Scopus through the keywords of prefabricated construction, off-site construction, precast construction, and the like. Then, in-depth interviews with ten experts were conducted in order to validate the initial factors' rationality and comprehensiveness.

These experts included one government official, two developers, five contractors and two consultants. They all had more than five years of PC experience. They were presented with the aforementioned preliminary factors, and were asked to formulate a number of valid factors at the end of the day. They also determined each factor's objective (O) or subjective type. The objective type could be represented with a precise NV (PNV) or an IV. The subjective type can be represented with an intuitive fuzzy number (IFN) or an LV.

As illustrated in Table 3, twenty-seven factors were identified as the preliminary factors relating to the sustainable construction capability. They were grouped into seven categories, and were coded with  $C_i$  ( $i = 1, 2, \dots, 27$ ) and  $B_c$  ( $c = 1, 2, \dots, 7$ ).

**Table 3.** Identified preliminary factors for PC.

Aspects	Factors	Type	Value Type	Source
Technology aspect (B <sub>1</sub> )	C <sub>1</sub> Applicability of BIM technology	S	IFN	[3,72,73]
	C <sub>2</sub> Applicability of efficiency management technology	S	IFN	[66,74,75]
	C <sub>3</sub> Applicability of quality control technology	S	IFN	[64,67]
	C <sub>4</sub> Applicability of cost management technology	S	IFN	[22,44,76]
	C <sub>5</sub> High prefabricated rate	O	PNV	[77,78]
Management aspect (B <sub>2</sub> )	C <sub>6</sub> Level of supply chain management	S	LV	[79–81]
	C <sub>7</sub> Level of lean construction	S	LV	[51,59,82]
	C <sub>8</sub> Level of resource management	S	LV	[50,83,84]
	C <sub>9</sub> Ability to plan management	S	IFN	[63,66,83,85]
Labor aspect (B <sub>3</sub> )	C <sub>10</sub> Proportion of skilled workers	O	IV	[23,24]
	C <sub>11</sub> Professional level of skilled workers	S	LV	[22,23,67]
	C <sub>12</sub> Number of improvement proposals by one person	O	IV	[59,82,83]

Table 3. Cont.

Aspects	Factors	Type	Value Type	Source
R&D aspect (B <sub>4</sub> )	C <sub>13</sub> Number of research publications per year article	O	PNV	[76,86,87]
	C <sub>14</sub> Number of external collaborated institutions	O	PNV	[8,86]
	C <sub>15</sub> Number of standard and system innovation	O	PNV	[22,64,87]
	C <sub>16</sub> Level of information platform innovation	S	LV	[3,72,73]
Market aspect (B <sub>5</sub> )	C <sub>17</sub> Number of prefabricated construction areas per year	O	PNV	[4,24,63]
	C <sub>18</sub> Number of prefabricated projects per year	O	PNV	[8,24]
	C <sub>19</sub> Number of prefabricated construction factories	O	PNV	[88]
	C <sub>20</sub> Number of prefabricated components categories	O	PNV	[22,66,89]
Environmental aspect (B <sub>6</sub> )	C <sub>21</sub> Proportion of sustainable materials in all materials	O	IV	[87,90]
	C <sub>22</sub> Level of material utilization	S	LV	[1,66,91]
	C <sub>23</sub> Ability to protect environment	S	IFN	[90–92]
	C <sub>24</sub> Level of social recognition	S	LV	[23,24,77]
Economic aspect (B <sub>7</sub> )	C <sub>25</sub> Annual output value of prefabricated projects	O	PNV	[4,44,76]
	C <sub>26</sub> Total assets value	O	PNV	[4,22,87]
	C <sub>27</sub> Annual profit value of prefabricated projects	O	PNV	[24,44,76]

### 3.2. The Ranking Model of Preliminary Factors

This study further ranked the twenty-seven preliminary factors using the FAHP-Entropy method, in order to identify the critical factors. This method determined each factor's importance degree through the calculation of its integrated weight, which combined the subjective and objective weights [93]. FAHP was used to calculate the subjective weight, based on experts' opinions on the factors' relative importance [60]. Entropy was used to calculate the objective weight, based on the factors' practical value [94].

As illustrated in Figure 1, the data collection and calculation processes consisted of four steps: data collection from the experts (coded by  $D_e$ ) and construction enterprises (coded by  $G_i$ ); the calculation of the subjective weights (coded by  $\theta_i$ ), based on FAHP; the calculation of the objective weights (coded by  $\omega_i$ ), based on Entropy; and the calculation of the integrated weights (coded by  $W_i$ ), before the preliminary factors were ranked down.

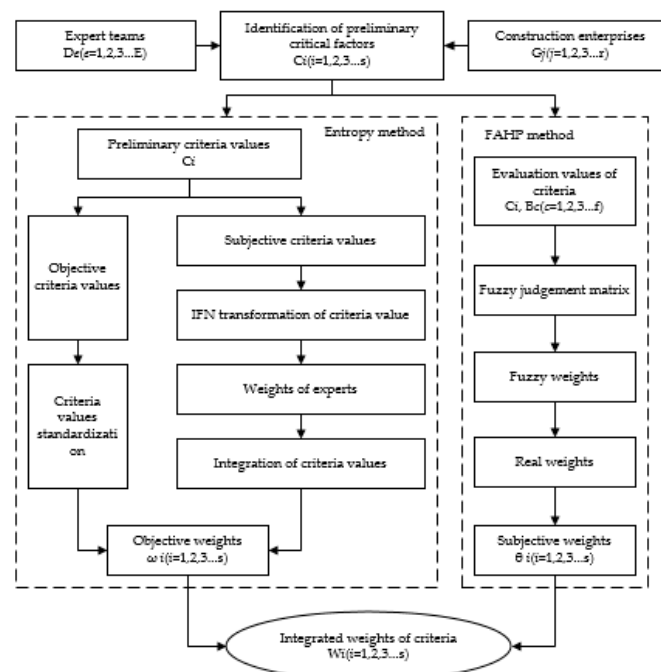


Figure 1. Integrated weights calculation process.

### Step 1: Data collection.

In order to rank the twenty-seven preliminary factors using FAHP-Entropy, this study first needed to select some construction enterprises as the study cases. Then, the data for the calculation of the subjective and objective factors' weights using FAHP and Entropy were respectively collected.

Four Chinese construction enterprises undertaking PC projects were selected as the study cases. They were four main contractors, namely, ZJ (denoted as  $G_1$ ), YD (denoted as  $G_2$ ), BY (denoted as  $G_3$ ), and YZ (denoted as  $G_4$ ). The criteria for the selection of these enterprises mainly included the PC market scale and the start time. The four construction enterprises covered four different cases, including the big market scale with the early start time (ZJ), the big market scale with the late start time (YD), the small market scale with the early start time (BY), and the small market scale with the late start time (YZ). All four cases were considered in this study in order to achieve a balanced view and measure the importance of difference factors.

When calculating the subjective weights, an important process was to construct a fuzzy pairwise comparison matrix based on the relative importance scores among the factors collected from the aforementioned ten experts.

The relative importance involved the comparisons not only between the factors under one aspect, but also between aspects under the project goal (the sustainable construction capability oriented to PC for construction enterprise). In order to simplify the calculation, these experts were further organised into four stakeholder types, which are the government (coded by  $D_1$ ), the developer (coded by  $D_2$ ), the contractor (coded by  $D_3$ ), and the consultant (coded by  $D_4$ ).

The four expert teams, respectively, presented the relative importance scores using the triangular fuzzy number (TFN) [75]. TFN was represented by  $(l, m, u)$  in this study, where  $l$ ,  $m$  and  $u$  denote the smallest, most and bigger possible values, respectively. Generally, the expert teams determined the  $m$  value using a 1 to 9 scale [60,95]. They further evaluated the fuzzy degree of the determination of  $m$ , including not fuzzy, fuzzy and very fuzzy, which were used to calculate the  $l$  and  $u$  values [96]. The relative importance scores for the aspects ( $B \rightarrow B$ ) were taken as an example to illustrate the processes (see Appendix A).

This study used the questionnaire technique to collect the expert evaluation of the fuzzy degree. The questionnaire covered all of the factors and aspects, which were delivered to the four expert teams via email. Then, the relative importance was aggregated through the geometric mean method (GMM); thus, the final fuzzy pairwise comparison matrices were calculated [75].

In the calculation of the objective weights using Entropy, the values of the factors were collected for the four construction enterprises. As illustrated in Table 3, the types of factors relating to the sustainable construction capability oriented to PC for construction enterprises included objective and subjective factors. The values of the objective factors were determined from the construction enterprise practical data. This study utilised the survey of construction enterprise and a website-based search to collect these data. In terms of subjective factors, their values came from the aforementioned expert team evaluation. This study conducted a questionnaire to collect these values. Each team, respectively, evaluated the IFN or LV. The linguistic value included nine aspects—namely, extremely poor (EP), very poor (VP), poor (P), a little poor (LP), common (C), a little good (LG), good (G), very good (VG), and extremely good (EG)—and should be further converted into IFN using the Entropy calculation process [97,98]. Appendix B shows the value of the subjective factors collected from the four expert teams. Therefore, the collected data provided the basis for the calculation of the subjective and objective weights of all of the preliminary factors.

### Step 2: The calculation of the objective weight using the Entropy method.

The Entropy method is commonly used to calculate objective weights relying on practical factors' values, as illustrated in step 1. Entropy is the reflection that the more various values of a factor for different construction enterprises, the larger the weight of the factor [68]. The calculation processes and equations using Entropy are described as follows.



$\omega = (\omega_1, \omega_2, \dots, \omega_i, \dots, \omega_s)$  is the factors' objective weight. Specially,  $\omega_i$  is the objective weight of the  $i$ -th criterion, and  $\omega_i \geq 0, i = 1, 2, \dots, s, \sum_{i=1}^s \omega_i = 1$ .

$x_{ij}$  represents the  $i$ -th factor value of the  $j$ -th enterprise. The mean value  $\bar{x}_{ij}$  of  $x_{ij}$  can be calculated using the following equation:

$$\bar{x}_{ij} = (x_{i1} \oplus x_{i2} \oplus \dots \oplus x_{ir}) / r = \begin{cases} \frac{1}{r} \sum_{j=1}^r x_{ij} & x_{ij} \in M_1 \\ \left[ \frac{1}{r} \sum_{j=1}^r (x_{ij})^L, \frac{1}{r} \sum_{j=1}^r (x_{ij})^U \right] & x_{ij} \in M_2 \\ \left( \prod_{j=1}^r (\mu_{ij})^{\frac{1}{r}}, 1 - \prod_{j=1}^r (1 - \gamma_{ij})^{\frac{1}{r}}, \prod_{j=1}^r (1 - \gamma_{ij})^{\frac{1}{r}} - \prod_{j=1}^r (\mu_{ij})^{\frac{1}{r}} \right) & x_{ij} \in M_3 \end{cases} \quad (1)$$

$M_1$  is the set of precise values, which are the normalised values of the raw precise data.  $M_2$  is the set of interval values, which are the normalised values of the raw interval data.  $M_3$  is the set of IFNs, including the converted IFNs from the LVs [99]. Due to the fact that the subjective factors' values for the evaluation object are evaluated by different expert teams, the values need to be integrated into one comprehensive value based on the weighting of the experts. The Entropy value  $\sigma_i$  of the  $i$ -th factor can be calculated using the following equation:

$$\sigma_i = -1 / \ln(r) \sum_{j=1}^r \left( \frac{d(x_{ij}, \bar{x}_{ij})}{\sum_{j=1}^r d(x_{ij}, \bar{x}_{ij})} \ln \left( \frac{d(x_{ij}, \bar{x}_{ij})}{\sum_{j=1}^r d(x_{ij}, \bar{x}_{ij})} \right) \right) \quad (2)$$

Here,  $d$  is the distance between  $x_{ij}$  and  $\bar{x}_{ij}$ , which can be calculated by referring to [99]. Ultimately, the  $\omega_i$  can be calculated using the following equation:

$$\omega_i = \frac{1 - \sigma_i}{\sum_{i=1}^s (1 - \sigma_i)} \quad (3)$$

Step 3: The calculation of the subjective weight using FAHP.

FAHP is used widely to calculate subjective weights based on experts' opinions [100]. The calculation processes of FAHP is mainly comprised of four steps [75]: (1) the construction of pairwise comparison matrices through the integration of  $p$  experts' evaluation of each factor using the GMM method; (2) the determination of the fuzzy weights; (3) the conversion of the fuzzy weights into real weights with defuzzification; (4) the determination of the final weights through normalization.

The specific calculation processes of FAHP are generally illustrated as follows, with the example of one factor. The value  $f$  represents the number of holistic aspects ( $B_c$ ).  $n$  is the number of factors ( $C_i$ ) corresponding to a certain aspect, where  $n = 1, 2, 3, \dots, s$ .

First, the fuzzy judgment matrix  $A_c^*$  can be constructed as follows:

$$A_c^* = \begin{bmatrix} (1, 1, 1) & a_{12}^* & \dots & a_{1n}^* \\ a_{21}^* & (1, 1, 1) & \dots & a_{2n}^* \\ \dots & \dots & \dots & \dots \\ a_{n1}^* & a_{n2}^* & \dots & (1, 1, 1) \end{bmatrix} \quad (4)$$

In this matrix,  $a_{ij}^*$  is the mean value of the  $C_i$  factor's relative importance scores corresponding to the  $c$  aspect from all of the experts, where  $i, j = 1, 2, 3, \dots, n$  and  $c = 1, 2, 3, \dots, f$ . The  $a_{ij}^t$  is the score for the  $C_i$  factor corresponding to the  $c$  aspect from  $t$ -th experts, where  $t = 1, 2, 3, \dots, P$ . Moreover,  $a_{ij}^*$  can be calculated using the following equation:

$$a_{ij}^* = \frac{1}{P} (a_{ij}^1 + a_{ij}^2 + \dots + a_{ij}^P) \quad (5)$$

$$a_{ij}^* = \frac{1}{P}(a_{ij}^1 + a_{ij}^2 + \dots + a_{ij}^P) \quad (6)$$

The original fuzzy weight ( $C_i^c$ ) of the  $i$ -th factor corresponding to the  $c$ -th aspect can then be calculated:

$$C_i^c = \sum_{j=1}^n a_{ij} / \left( \sum_{i=1}^n \sum_{j=1}^n a_{ij} \right) \quad (7)$$

Based on this, the fuzzy weights ( $C^c$ ) of all of the factors corresponding to the aspect can be calculated. Moreover, the fuzzy weights ( $S$ ) of all of the aspects corresponding to the goal (the sustainable construction capability) can be calculated.

Then,  $C^c$  and  $S$  should undergo defuzzification, following [75].  $C^c$  is thus transformed into the actual weights  $d(C^i)$ , and  $S$  is transformed to  $d(S^i)$ . Furthermore,  $d(C^i)$  and  $d(S^i)$  should be normalized through the min–max equation [75], which can be defined in terms of  $D(C^i)$  and  $D(S^i)$ . Finally, the actual weights of all of the factors corresponding to the goal can be calculated as follows:

$$\theta = (\theta_1, \theta_2, \theta_3, \dots, \theta_s) = D(C^i) \otimes D(S^i) \quad (8)$$

Step 4: The calculation of the integrated weights.

The integrated weights can be calculated by combining objective and subjective weights. The equation used to calculate the integrated weights is [99]:

$$W_i = \eta \theta_i + (1 - \eta) \omega_i \quad (9)$$

In this equation,  $\eta$  was the risk preference factor, which indicates risk neutrality in the experts' evaluation. Generally,  $\eta$  was taken to be 0.5.

#### 4. Factors' Weights and Ranking Analysis

##### 4.1. Factors' Weight Results Using the FAHP-Entropy Method

The factors' integrated weights can be further calculated based on the aforementioned processes. The specific results are illustrated below.

Step 1: Data preprocessing.

The factors' precise and interval values should be normalised in order to eliminate their dimensional impact, and this could be done using the extremum method [99]. The factors' LVs should be transformed into IFNs.

Step 2: The calculation of the factors' objective weights using the Entropy approach.

In calculating factors' objective weight processes using Entropy, two key parameters including  $\bar{x}_i$  and  $\sigma_i$  were first calculated using Equations (1) and (2).  $\bar{x}_i$  and  $\sigma_i$  represented the factors' comprehensive value and Entropy value, respectively. Based on the  $\bar{x}_i$  and  $\sigma_i$  values, the factors' objective weight  $\omega_i$  was determined using the Equation (3). The calculation results of  $\bar{x}_i$ ,  $\sigma_i$  and  $\omega_i$  were specifically illustrated in Table 4.

Step 3: The calculation of the factors' subjective weights using the FAHP method.

In calculating the factors' subjective weight processes using FAHP, the seven aspects' fuzzy weights  $S$  and factors' weights were respectively calculated based on Equations (4)–(6). Then, the fuzzy weights of  $S$  and  $C$  were respectively converted into real weights coded by  $D(S)$  and  $D(C)$  through the undertaking of defuzzification and normalisation. For example,  $S$  for each aspect can be



represented by  $S^1 = (0.125, 0.190, 0.297)$ ,  $S^2 = (0.092, 0.147, 0.231)$ ,  $S^3 = (0.067, 0.104, 0.166)$ ,  $S^4 = (0.087, 0.133, 0.204)$ ,  $S^5 = (0.118, 0.175, 0.258)$ ,  $S^6 = (0.083, 0.128, 0.197)$  and  $S^7 = (0.083, 0.121, 0.177)$ , which were further converted into  $D(S) = (0.210, 0.210, 0.068, 0.122, 0.188, 0.113, 0.090)$ .

Based on  $D(S)$  and  $D(C)$ , the final weights  $\theta$  were calculated using Equation (7). More specifically, the  $D(S)$ ,  $D(C)$  and  $\theta$  values are illustrated in Table 5.

**Table 4.**  $\bar{x}_i$ ,  $\sigma_i$ , and  $\omega_i$  values.

Factor	$\bar{x}_i$	$\sigma_i$	$\omega_i$
C <sub>1</sub>	(0.359, 0.515, 0.126)	0.969	0.007
C <sub>2</sub>	(0.438, 0.462, 0.100)	0.840	0.038
C <sub>3</sub>	(0.568, 0.331, 0.102)	0.891	0.026
C <sub>4</sub>	(0.399, 0.497, 0.103)	0.767	0.055
C <sub>5</sub>	0.768	0.872	0.030
C <sub>6</sub>	(0.347, 0.554, 0.099)	0.842	0.037
C <sub>7</sub>	(0.305, 0.604, 0.091)	0.821	0.042
C <sub>8</sub>	(0.368, 0.532, 0.100)	0.843	0.037
C <sub>9</sub>	(0.347, 0.553, 0.100)	0.935	0.015
C <sub>10</sub>	(0.417, 0.625)	0.852	0.035
C <sub>11</sub>	(0.489, 0.405, 0.105)	0.925	0.018
C <sub>12</sub>	(0.125, 0.450)	0.888	0.026
C <sub>13</sub>	0.453	0.806	0.046
C <sub>14</sub>	0.660	0.805	0.046
C <sub>15</sub>	0.588	0.730	0.064
C <sub>16</sub>	(0.401, 0.506, 0.093)	0.865	0.032
C <sub>17</sub>	0.650	0.720	0.066
C <sub>18</sub>	0.618	0.797	0.048
C <sub>19</sub>	0.567	0.918	0.019
C <sub>20</sub>	0.750	0.970	0.007
C <sub>21</sub>	(0.406, 0.625)	0.917	0.020
C <sub>22</sub>	(0.408, 0.481, 0.112)	0.765	0.055
C <sub>23</sub>	(0.435, 0.393, 0.173)	0.912	0.021
C <sub>24</sub>	(0.717, 0.185, 0.098)	0.865	0.032
C <sub>25</sub>	0.586	0.735	0.062
C <sub>26</sub>	0.675	0.799	0.047
C <sub>27</sub>	0.625	0.716	0.067

**Table 5.**  $D(S)$ ,  $D(C)$ , and  $\theta$  values.

Aspect	$D(S)$	Factor	$D(C)$	$\theta$
B1	0.210	C <sub>1</sub>	0.216	0.045
		C <sub>2</sub>	0.216	0.045
		C <sub>3</sub>	0.491	0.103
		C <sub>4</sub>	0.077	0.016
		C <sub>5</sub>	0.000	0.000
B2	0.210	C <sub>6</sub>	0.250	0.053
		C <sub>7</sub>	0.250	0.053
		C <sub>8</sub>	0.209	0.044
		C <sub>9</sub>	0.291	0.061
B3	0.068	C <sub>10</sub>	0.374	0.026
		C <sub>11</sub>	0.374	0.026
		C <sub>12</sub>	0.251	0.017
B4	0.122	C <sub>13</sub>	0.225	0.027
		C <sub>14</sub>	0.225	0.027
		C <sub>15</sub>	0.456	0.055
		C <sub>16</sub>	0.095	0.012
B5	0.188	C <sub>17</sub>	0.341	0.064
		C <sub>18</sub>	0.341	0.064
		C <sub>19</sub>	0.249	0.047
		C <sub>20</sub>	0.068	0.013
B6	0.113	C <sub>21</sub>	0.297	0.033
		C <sub>22</sub>	0.297	0.033
		C <sub>23</sub>	0.169	0.019
		C <sub>24</sub>	0.238	0.027
B7	0.090	C <sub>25</sub>	0.386	0.035
		C <sub>26</sub>	0.386	0.035
		C <sub>27</sub>	0.229	0.021

Step 4: The calculation of the factors' integrated weights.

The factors' integrated weight  $W$  was calculated based on the objective weights  $\omega$  and subjective weights  $\theta$  using Equation (8). The  $W$  result was shown as follows:

$W = (W_1, W_2, W_3, \dots, W_{27}) = (0.026, 0.042, 0.064, 0.036, 0.015, 0.045, 0.047, 0.040, 0.038, 0.030, 0.022, 0.022, 0.037, 0.037, 0.060, 0.022, 0.065, 0.056, 0.033, 0.010, 0.027, 0.044, 0.020, 0.029, 0.049, 0.041, 0.044)$ .

#### 4.2. Ranking Analysis Results

As a result, the twenty-seven preliminary factors were ranked by the integrated weights  $W$ , as depicted in Table 6. The five critical factors are  $C_{17}$ ,  $C_3$ ,  $C_{15}$ ,  $C_{18}$  and  $C_{25}$ .  $C_{17}$ , the number of prefabricated construction areas per year, is ranked the first, with the highest integrated weight of 0.065. Hence,  $C_{17}$  is considered to be the most important factor impacting the sustainable construction capability oriented to PC for construction enterprises.

Table 6. Factor ranking results.

Code	Objective Weight $\omega$	Subjective Weight $\theta$	Integrated Weight $W$	Rank
$C_{17}$	0.066	0.064	0.065	1
$C_3$	0.026	0.103	0.064	2
$C_{15}$	0.064	0.055	0.060	3
$C_{18}$	0.048	0.064	0.056	4
$C_{25}$	0.062	0.035	0.049	5
$C_7$	0.042	0.053	0.047	6
$C_6$	0.037	0.053	0.045	7
$C_{22}$	0.055	0.033	0.044	8
$C_{27}$	0.067	0.021	0.044	9
$C_2$	0.038	0.045	0.042	10
$C_{26}$	0.047	0.035	0.041	11
$C_8$	0.037	0.044	0.040	12
$C_9$	0.015	0.061	0.038	13
$C_{13}$	0.046	0.027	0.037	14
$C_{14}$	0.046	0.027	0.037	15
$C_4$	0.055	0.016	0.036	16
$C_{19}$	0.019	0.047	0.033	17
$C_{10}$	0.035	0.026	0.030	18
$C_{24}$	0.032	0.027	0.029	19
$C_{21}$	0.020	0.033	0.027	20
$C_1$	0.007	0.045	0.026	21
$C_{11}$	0.018	0.026	0.022	22
$C_{12}$	0.026	0.017	0.022	23
$C_{16}$	0.032	0.012	0.022	24
$C_{23}$	0.021	0.019	0.020	25
$C_5$	0.030	0.000	0.015	26
$C_{20}$	0.007	0.013	0.010	27

$C_3$ , the applicability of the quality control technology, obtained the integrated weight of 0.064, which is just lower than  $C_{17}$ 's weight. The third-, fourth- and fifth-ranked factors are  $C_{15}$ ,  $C_{18}$  and  $C_{25}$ , which represent the number of standard and system innovations, the number of prefabricated projects per year, and the annual output value of the prefabricated projects, respectively.

Moreover, these five critical factors, e.g.,  $C_{17}$ ,  $C_3$ ,  $C_{15}$ ,  $C_{18}$  and  $C_{25}$ , are distributed in different aspects involving B1, B4, B5 and B7. The five critical factors are indicated with the green square, which is distinguished with other factors indicated with black dots, as illustrated in Figure 2. Figure 2 also demonstrates the correlation between B1 to B7 and  $C_1$  to  $C_{27}$ . For example,  $C_{17}$  and  $C_{18}$  belong to B5, which represents market-related aspects.

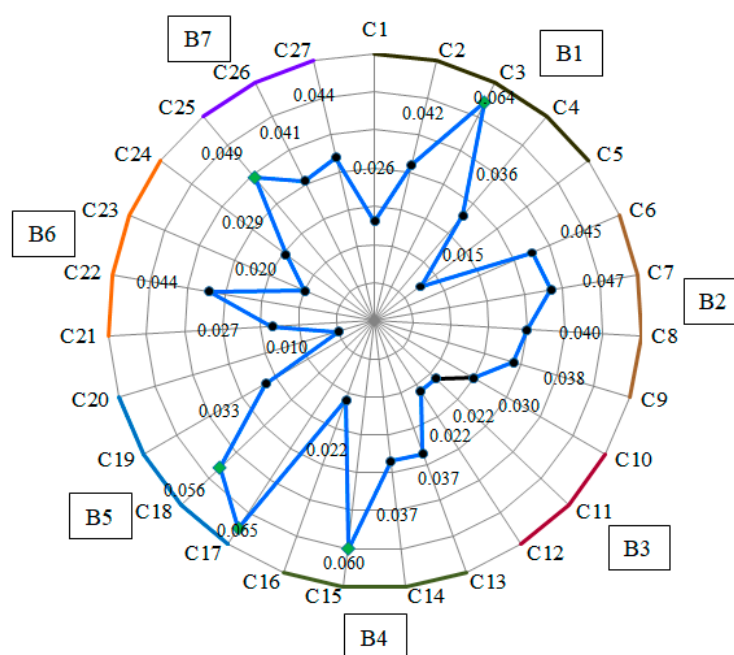


Figure 2. Radar chart of the weightings.

## 5. Discussion

The above five factors are the most important factors influencing the construction enterprises' sustainable construction capability. These five factors can be further divided into four clusters through aggregation with their corresponding aspects. These four clusters are market scale, quality control technology, standard and system innovation, and economic output value. Their important impacts are further analysed as follows.

### (1) Market scale.

C<sub>17</sub> (the number of prefabricated construction areas per year) and C<sub>18</sub> (the number of prefabricated projects per year) belong to B<sub>5</sub> [21,22]. The market scale aspect has been perceived as the most direct influencing aspect of the sustainable construction capability oriented to PC for construction enterprises [4]. Especially in the Chinese original PC development phase, the market scale is the main indicator reflecting the sustainable construction capability for construction enterprises. This is probably because construction enterprises need to depend on higher sustainable construction capability in order to help expand their PC market scale. In fact, the Chinese PC sector is less mature, with the proportion of PC market scale to the new construction market being only about 3%–5% [21,24], which is far lower than some developed countries such as Sweden (80%) and Japan (70%).

Moreover, PC projects cost more than traditional construction projects, and this is considered to be one of the main barriers for the developer for the expansion of the holistic PC market scale [21]. In this way, construction enterprises with higher sustainable construction capability can reduce PC costs and expand their PC market scale [77]. Thus, the PC market is always dominated by a few construction enterprises with higher capability.

The increment of the holistic PC market scale is critical in reaching the scale economy, which is likely to promote construction enterprises to expand the PC market. In fact, the Chinese policy-maker has issued a set of policies and incentive measures to expand the holistic PC market scale [11,101]. For example, the Ministry of Housing and Urban–Rural Development of the People's Republic of China (MOHURD) has stated that the proportion will reach 15% throughout China, and 20% in major areas—such as Beijing, Tianjin and Shanghai—by 2020 [102]; an incentivised measure issued by the Beijing government was to provide financial and building area incentives for non-nation-owned PC

projects. This may provide a good opportunity for more and more construction enterprises to enter the PC market and boost the share.

## (2) Quality control technology.

C<sub>3</sub>, the quality control technology, is a critical factor relating to the sustainable construction capability oriented to PC for construction enterprises. In fact, it is essential for construction enterprises to place quality in the primary position, and to take quality control very seriously. Assuring PC projects' higher quality is key to PC enterprises, which should rely on their sustainable construction capability.

The PC quality level is another key factor influencing PC development [64]. Excellent quality performance plays a vital role in obtaining significant progress in PC in some countries, e.g., Japan, Sweden, Singapore [64]. In fact, its high quality is considered to be one of the advantages of PC, which should attract the stakeholders' and policymakers' attention [77]. Furthermore, quality is also the main concern for the public to accept prefabricated buildings [103]. Therefore, policymakers should always emphasise quality assurance and control when promoting PC. For example, high quality has also been identified as the most critical requirement in the 2011–2015 Malaysian roadmap for PC.

In addition, quality control is always more difficult in PC projects than traditional projects. This is largely attributed to the more complicated construction processes in PC projects, such as production, transportation and assembly. Thus, this is a big challenge that construction enterprises have to face and resolve [64]. There have been frequent quality issues in some of the PC projects in China; for example, there have been connection problems of prefabricated components and main structures [103].

The Chinese policymaker emphasises PC quality, and has issued many laws, policies and mandatory standards, especially since 2016. For example, there is a government policy issued by MOHURD relating to the guidelines for the enhancement of construction quality by improving the system of quality control [104]. In addition, policymakers have also encouraged academic institutions such as universities and technical colleges to develop training courses about PC in order to cultivate more PC-oriented skilled workers. Nowadays, some universities have set up PC majors which offer enterprise-oriented professional education and upskilling. For example, Nanjing University built a PC industry training base in 2018 which provides classroom and laboratory subjects, in order to develop hands-on PC knowledge and hands-on skills. In line with government requirements and incentives, construction enterprises should continuously enhance their sustainable construction capability in order to improve quality control and reduce the quality risks in PC projects.

## (3) Standard and system innovation.

C<sub>15</sub>, the number of standard and system innovations, is a critical indicator of the R&D capability for construction enterprises. From the holistic perspective, PC standards and systems are more complex, due to the complicated construction processes in PC projects. Thus, it is difficult for construction enterprises to carry out innovations on PC standards and systems. Construction enterprises are generally weak in PC innovation capability [21,87]. Especially in the primary PC stage in China, construction enterprises are also confronted with the lack of national standards and limited R&D resources, resulting in more challenges for construction enterprise PC innovation. Thus, innovation capability can better reflect the sustainable construction capability oriented to PC for a construction enterprise. With the limited innovation capability for construction enterprises, the existing PC standard and system are often unmaturing, which has resulted in some issues, further impeding the Chinese PC development.

The issues are mainly due to three reasons. Firstly, the quality of PC products—such as stairs, walls and pillars—is not reliable [103]. For example, the connection between walls and floors with grounding sleeve technology is not always effective, therefore resulting in weak structural strength. Secondly, the PC application is mostly used in highly standardised, low-to-medium level buildings for public institutions, e.g., schools, hospitals and enterprises. However, PC applications in high-rise buildings and private commercial real estate are limited [34]. Thirdly, for the PC modular level

aspect, the levels can be categorised into four levels, namely component subassembly, non-volumetric preassembly, volumetric preassembly, and modular construction. The modular degree in China remains at the component subassembly level [20]. In contrast, some developed countries—such as North America, Australia and Japan—have widely adopted modular construction in their PC projects.

In fact, Chinese policymakers have considered PC innovation as one of the critical factors for the development of PC, and have made a great effort to develop PC standards and innovative PC systems [87]. Although the proportion of R&D investment in the building sector to the total GDP of the Chinese construction industry is only 0.4%–0.6% [21], the investment in innovative PC applications has increased a lot in recent years. Part of this investment has been used to support scientific research. For example, the guidance on PC technological systems for residential buildings was issued, which provided a technical system and reference for construction enterprises to extend the PC application range [105]. In addition, different schemes—such as financial subsidy, tax reduction and subject support—have been developed in order to incentivise construction enterprises to innovate PC workmanship. For example, the Tianjin government would reduce the tax for enterprises exploring innovative PC applications [66,76].

#### (4) Economic output value.

C<sub>25</sub>, the annual output value of prefabricated projects, is an economic aspect, which is also one of the major indicators of the construction enterprise's competitiveness and sustainable construction capability [23,44]. The output value directly impacts the investment in PC R&D, and the work extension. However, the output value of Chinese construction enterprises is generally low, thus not only limiting their sustainable construction capability increase but also reducing their motivation in developing the PC project [21].

The reason for the low output value is probably attributable to the high cost of implementing PC. The incremental cost in PC projects would be one to two times higher than traditional construction projects. In the initial stage of transforming from traditional construction to PC, construction enterprises need to invest in PC facilities, thus increasing the initial cost of a PC project. For example, a construction enterprise, YZ, invested approximately USD 14 million in building a PC factory, which covered the cost of the land, equipment, and buildings.

In addition, most construction enterprises lack PC experience, skilled workers, and resource management capability [106]. These issues would increase the cost of implementing PC. For example, the weak capability for construction enterprises in PC operation and supply chain management can result in more design changes and quality deficiency, bringing about resource waste and cost blowouts. Therefore, the sustainable construction capability oriented to PC can affect the output value positively. Construction enterprises should pay more attention to their internal improvement, in order to enhance their sustainable capability. The improvement plan may involve the development of lean construction, information management and automated construction methods [1].

## 6. Conclusions

Although PC has been regarded as a sustainable method to address various issues related to the construction sector—such as resource waste, environment pollution and quality deficiency—it is still in its infancy in China. To some extent, this is due to the limited sustainable performance in PC projects, and the solution relies on the improvement of the sustainable construction capability oriented to PC for construction enterprise.

This study explored the factors affecting the sustainable construction capability oriented to PC for construction enterprises, contributing to the existing literature around the improvement of the PC development. Twenty-seven factors relating to sustainable construction capability were identified and examined using qualitative methods including a literature review and in-depth interviews. These factors were further ranked through the FAHP-Entropy method. Five critical factors were selected to analyse the ways in which these factors affect construction enterprises' sustainable construction

capability, and what measures construction enterprise can take to improve these factors' performance and the overall sustainable construction level.

The results of this study indicate that the sustainable construction capability for Chinese construction enterprise is weak. Construction enterprises should pay more attention to the development of the sustainable construction capability related to market scale, quality control technology, standard and system innovation and economic output value. Furthermore, construction enterprises are encouraged to extend their production scale, increase investments on innovation, and adopt lean construction and digital technologies in order to improve their sustainable construction capability. The results provide a reference for Chinese governments at different levels to formulate appropriate policies.

Although this study contributes to the identification of the critical influencing factors relating to the sustainable construction capability using the comprehensive quantitative approach of FAHP-Entropy, it also has some limitations. One is that, since this study is based on the current PC development state in China, the critical influencing factors may vary from country to country. The other limitation refers to the lack of concrete measures to tackle the critical influencing factors, due to the limited number of construction enterprises and experts that were examined in our study.

In view of this, our future study will revolve around conducting more case studies to explore the impact of the critical factors on the sustainable construction capability, the formulation of concrete measures for more and more construction enterprises to improve their sustainable construction capability, the evaluation of more construction enterprises' sustainable construction capability maturity, and the determination of their capability levels.

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

## Appendix A

**Table A1.** Table of importance scores, taking aspects as an example in FAHP.

B→B	Expert Teams	Making Score Items	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	B <sub>5</sub>	B <sub>6</sub>	B <sub>7</sub>
B <sub>1</sub>	D <sub>1</sub>	m	(1,1,1)	1/4	1/3	1	3	3	1
		Fuzzy degree		Not fuzzy	Fuzzy	Fuzzy	Not fuzzy	Fuzzy	Fuzzy
	D <sub>2</sub>	m		3	3	1	4	3	3
		Fuzzy degree		Not fuzzy	Fuzzy	Not fuzzy	Fuzzy	Fuzzy	Fuzzy
	D <sub>3</sub>	m		5	2	2	1/3	4	1/3
		Fuzzy degree		Not fuzzy	Not fuzzy	Fuzzy	Not fuzzy	Fuzzy	Not fuzzy
	D <sub>4</sub>	m		3	4	5	1	4	4
		Fuzzy degree		Not fuzzy	Fuzzy	Not fuzzy	Not fuzzy	Fuzzy	Not fuzzy
B <sub>2</sub>	D <sub>1</sub>	m	1/B <sub>1</sub> →B <sub>2</sub>	(1,1,1)	3	2	4	3	4
		Fuzzy degree			Not fuzzy	Fuzzy	Not fuzzy	Fuzzy	Fuzzy
	D <sub>2</sub>	m			1/4	1/4	3	3	2
		Fuzzy degree			Not fuzzy	Fuzzy	Fuzzy	Fuzzy	Not fuzzy
	D <sub>3</sub>	m			2	1/5	1/4	1/2	1/4
		Fuzzy degree			Fuzzy	Fuzzy	Not fuzzy	Fuzzy	Not fuzzy
	D <sub>4</sub>	m			4	4	1/5	2	3
		Fuzzy degree			Fuzzy	Not fuzzy	Fuzzy	Fuzzy	Fuzzy
B <sub>3</sub>	D <sub>1</sub>	m	1/B <sub>1</sub> →B <sub>3</sub>	1/B <sub>2</sub> →B <sub>3</sub>	(1,1,1)	2	3	2	3
		Fuzzy degree				Very fuzzy	Not fuzzy	Fuzzy	Not fuzzy
	D <sub>2</sub>	m				1/3	1/4	4	2
		Fuzzy degree				Not fuzzy	Fuzzy	Fuzzy	Fuzzy



Table A1. Cont.

B→B	Expert Teams	Making Score Items	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	B <sub>5</sub>	B <sub>6</sub>	B <sub>7</sub>			
	D <sub>3</sub>	m				1/5	1/4	1	1/5			
		Fuzzy degree				Fuzzy	Not fuzzy	Fuzzy	Not fuzzy			
	D <sub>4</sub>	m				1/3	1/5	1/3	3			
		Fuzzy degree				Not fuzzy	Fuzzy	Fuzzy	Not fuzzy			
B <sub>4</sub>	D <sub>1</sub>	m				1/B <sub>1</sub> →B <sub>4</sub>	1/B <sub>2</sub> →B <sub>4</sub>	1/B <sub>3</sub> →B <sub>4</sub>	(1,1,1)	2	1/4	3
		Fuzzy degree								Not fuzzy	Fuzzy	Not fuzzy
	D <sub>2</sub>	m								3	1/4	3
		Fuzzy degree								Fuzzy	Not fuzzy	Fuzzy
	D <sub>3</sub>	m	1/2	4	1/3							
		Fuzzy degree	Fuzzy	Not fuzzy	Fuzzy							
	D <sub>4</sub>	m	1/5	1/4	1/4							
		Fuzzy degree	Not fuzzy	Fuzzy	Not fuzzy							
B <sub>5</sub>	D <sub>1</sub>	m	1/B <sub>1</sub> →B <sub>5</sub>	1/B <sub>2</sub> →B <sub>5</sub>	1/B <sub>3</sub> →B <sub>5</sub>	1/B <sub>4</sub> →B <sub>5</sub>	(1,1,1)	1/5	3			
		Fuzzy degree						Not fuzzy	Not fuzzy			
	D <sub>2</sub>	m						1/3	1/5			
		Fuzzy degree						Fuzzy	Not fuzzy			
	D <sub>3</sub>	m						5	3			
		Fuzzy degree						Fuzzy	Not fuzzy			
	D <sub>4</sub>	m						4	4			
		Fuzzy degree						Not fuzzy	Fuzzy			
B <sub>6</sub>	D <sub>1</sub>	m	1/B <sub>1</sub> →B <sub>6</sub>	1/B <sub>2</sub> →B <sub>6</sub>	1/B <sub>3</sub> →B <sub>6</sub>	1/B <sub>4</sub> →B <sub>6</sub>	1/B <sub>5</sub> →B <sub>6</sub>	(1,1,1)	4			
		Fuzzy degree							Fuzzy			
	D <sub>2</sub>	m							1/3			
		Fuzzy degree							Not fuzzy			
	D <sub>3</sub>	m							1/4			
		Fuzzy degree							Fuzzy			
	D <sub>4</sub>	m							5			
		Fuzzy degree							Not fuzzy			
B <sub>7</sub>	D <sub>1</sub>	m	1/B <sub>1</sub> →B <sub>7</sub>	1/B <sub>2</sub> →B <sub>7</sub>	1/B <sub>3</sub> →B <sub>7</sub>	1/B <sub>4</sub> →B <sub>7</sub>	1/B <sub>5</sub> →B <sub>7</sub>	1/B <sub>6</sub> →B <sub>7</sub>	(1,1,1)			
		Fuzzy degree										
	D <sub>2</sub>	m										
		Fuzzy degree										
	D <sub>3</sub>	m										
		Fuzzy degree										
	D <sub>4</sub>	m										
		Fuzzy degree										

## Appendix B

Table A2. The collected data of the subjective factors in Entropy.

Enterprises	Factors	Value Type	Minimum Value	Maximum Value	Expert Teams' Evaluated Value			
					D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
G <sub>1</sub>	C <sub>1</sub>	IFN	(0.01, 0.99)	(0.99, 0.01)	(0.45, 0.40)	(0.50, 0.45)	(0.55, 0.40)	(0.45, 0.40)
	C <sub>2</sub>	LV	EP	EG	P	LG	C	C
	C <sub>3</sub>	LV	EP	EG	C	C	LG	G
	C <sub>4</sub>	LV	EP	EG	LP	LP	C	C
	C <sub>6</sub>	LV	EP	EG	P	LP	C	LP
	C <sub>7</sub>	LV	EP	EG	LP	C	LP	P
	C <sub>8</sub>	LV	EP	EG	P	LP	C	C
	C <sub>9</sub>	IFN	(0.01,0.99)	(0.99,0.01)	(0.35,0.6)	(0.40,0.05)	(0.40,0.50)	(0.45,0.50)
	C <sub>11</sub>	LV	EP	EG	C	LG	LG	LG
	C <sub>16</sub>	LV	EP	EG	LP	C	C	LP
	C <sub>22</sub>	LV	EP	EG	LP	C	C	LP
	C <sub>23</sub>	IFN	(0.01,0.99)	(0.99,0.01)	(0.50, 0.30)	(0.50, 0.40)	(0.55,0.35)	(0.50, 0.25)
	C <sub>24</sub>	LV	EP	EG	LG	G	LG	G

Table A2. Cont.

Enterprises	Factors	Value Type	Minimum Value	Maximum Value	Expert Teams' Evaluated Value			
					D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
G <sub>2</sub>	C <sub>1</sub>	IFN	(0.01,0.99)	(0.99,0.01)	(0.55, 0.40)	(0.60,0.25)	(0.65,0.30)	(0.60,0.30)
	C <sub>2</sub>	LV	EP	EG	LP	C	G	C
	C <sub>3</sub>	LV	EP	EG	C	LG	G	LG
	C <sub>4</sub>	LV	EP	EG	LP	C	C	LP
	C <sub>6</sub>	LV	EP	EG	P	C	LG	LP
	C <sub>7</sub>	LV	EP	EG	VP	P	C	C
	C <sub>8</sub>	LV	EP	EG	P	C	LG	LP
	C <sub>9</sub>	IFN	(0.01, 0.99)	(0.99, 0.01)	(0.30, 0.65)	(0.45, 0.50)	(0.50, 0.45)	(0.55, 0.40)
	C <sub>11</sub>	LV	EP	EG	LP	C	G	LG
	C <sub>16</sub>	LV	EP	EG	LP	LG	G	LG
	C <sub>22</sub>	LV	EP	EG	P	LP	C	C
	C <sub>23</sub>	IFN	(0.01, 0.99)	(0.99, 0.01)	(0.3, 0.45)	(0.45, 0.45)	(0.50, 0.40)	(0.45, 0.35)
	C <sub>24</sub>	LV	EP	EG	G	G	G	LG
G <sub>3</sub>	C <sub>1</sub>	IFN	(0.01, 0.99)	(0.99, 0.01)	(0.60, 0.30)	(0.65, 0.20)	(0.65, 0.30)	(0.55, 0.40)
	C <sub>2</sub>	LV	EP	EG	C	C	LG	LG
	C <sub>3</sub>	LV	EP	EG	LG	C	LG	LG
	C <sub>4</sub>	LV	EP	EG	C	C	LG	C
	C <sub>6</sub>	LV	EP	EG	LP	LP	C	C
	C <sub>7</sub>	LV	EP	EG	P	P	C	LG
	C <sub>8</sub>	LV	EP	EG	LP	C	C	LG
	C <sub>9</sub>	IFN	(0.01, 0.99)	(0.99, 0.01)	(0.25, 0.60)	(0.55, 0.30)	(0.60, 0.30)	(0.50, 0.45)
	C <sub>11</sub>	LV	EP	EG	C	G	C	LG
	C <sub>16</sub>	LV	EP	EG	C	G	LG	LG
	C <sub>22</sub>	LV	EP	EG	C	C	LG	C
	C <sub>23</sub>	IFN	(0.01,0.99)	(0.99,0.01)	(0.40, 0.40)	(0.45, 0.40)	(0.50, 0.35)	(0.55, 0.30)
	C <sub>24</sub>	LV	EP	EG	G	G	VG	G
G <sub>4</sub>	C <sub>1</sub>	IFN	(0.01,0.99)	(0.99, 0.01)	(0.10, 0.85)	(0.10, 0.80)	(0.15, 0.75)	(0.05, 0.80)
	C <sub>2</sub>	LV	EP	EG	VP	P	C	LP
	C <sub>3</sub>	LV	EP	EG	C	LP	C	C
	C <sub>4</sub>	LV	EP	EG	P	LP	P	P
	C <sub>6</sub>	LV	EP	EG	VP	P	LP	P
	C <sub>7</sub>	LV	EP	EG	VP	VP	LP	P
	C <sub>8</sub>	LV	EP	EG	VP	LP	P	P
	C <sub>9</sub>	IFN	(0.01,0.99)	(0.99,0.01)	(0.15, 0.70)	(0.25, 0.60)	(0.30, 0.55)	(0.10, 0.85)
	C <sub>11</sub>	LV	EP	EG	P	LP	LP	P
	C <sub>16</sub>	LV	EP	EG	VP	VP	P	VP
	C <sub>22</sub>	LV	EP	EG	P	LP	LP	LP
	C <sub>23</sub>	IFN	(0.01, 0.99)	(0.99, 0.01)	(0.25, 0.70)	(0.40, 0.35)	(0.35, 0.40)	(0.45, 0.25)
	C <sub>24</sub>	LV	EP	EG	C	G	G	G

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