Research on PC Component Quality Risk Evaluation Based on Intuitionistic Fuzzy Analytic Hierarchy Process

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Abstract: In order to further promote the development of prefabricated buildings, enrich the theoretical knowledge of the quality risk research of concrete prefabricated components, from the perspective of total quality management, the risk factors are divided into 5 aspects: personnel, equipment, system schemes, environment and raw material factors. With indicators and related descriptions, a set of risk evaluation indicator system is established. Based on the intuitionistic fuzzy analytic hierarchy process, the index weights of various risk factors are calculated, and a comprehensive quality risk evaluation model is established. The effectiveness of the model is proved by an example analysis, and the corresponding quality control points are summarized, with a view to the quality management provides a reference.

1. Introduction
The construction of traditional cast-in-place buildings has caused tremendous damage to the environment and resources. Due to its industrialized characteristics, prefabricated buildings have greatly improved their production efficiency and greatly reduced their impact on the environment and resources[1], and their development will surely become the future. The quality of parts and components is the key to affecting the quality safety, structural durability, and economical applicability of prefabricated buildings[2]. There have always been unsound management mechanisms and equipment in the manufacture of precast concrete components. The technology is immature, the production cost is high, and the industrial chain is not perfect. Therefore, it is necessary to conduct a risk assessment study on the quality of the precast concrete components, identify key risk factors, and provide a basis for the enterprise to formulate scientific quality management measures.

At present, domestic and foreign scholars have also carried out related research. From the perspective of standardization and generalization, Zhou Qiang et al, analyzed and researched the mold design and production of prefabricated building components to improve the quality of precast components[3]. Wu Shuigen et al, people divided the construction of component parts into three parts: pre-construction, under-construction, and post-construction, and established a quality risk evaluation model for the construction stage of assembled building parts[4]. Shi Jinhua et al, systematically analyzed the production process of prefabricated components, and the key control points have been studied and improved[5]. Fan Yi, Huang Xing and others have studied the design and construction technology of PC components formwork of new prefabricated buildings, which are relevant to improve the modernization, industrialization and industrialization level of prefabricated buildings[6]. From the
perspective of transportation, Zhu Hai et al, systematically introduced the technical measures of non-destructive transportation vibration reduction shelving equipment for large components, and engineering examples proved that the deformation and tremor effect of components can be significantly reduced and the damage rate of components[7]. Tian Dong and others introduced BIM technology into the system design of prefabricated concrete members, and discussed how to solve the production of prefabricated members. Industry information collaboration is difficult, the design cycle is long, the quality difference is large, and the construction cost is high[8]. Zhang Xia summarizes the quality control points of the prefabricated component design stage, manufacturing stage and on-site assembly stage, from quality inspection, quality behavior and engineering Entity supervision has given suggestions in three aspects[9]. In addition, in terms of standards, the state has issued GBJ321-90"Precast Concrete Component Quality Inspection and Evaluation Standards", DGTJ08-2252-2018 "Assembly of Integral Concrete Building Inspection "Technical standards"and other standard specifications give control points for the quality and performance of concrete members.

Comprehensive research by scholars at home and abroad can be found: the risk factors that affect the quality of prefabricated components exist in all stages of manufacturing, and most of the current evaluation systems have incomplete index factors, some indicators are not representative, and the risk evaluation method is not systematic, risk evaluation results are not objective, and the corresponding quality management measures are not practical. Based on this, this article establishes a systematic and comprehensive risk assessment index system from the perspective of total quality management, and uses intuitionistic fuzzy AHP to carry out risk comprehensive evaluation research, combined with risk evaluation results.

2. Quality risk of precast concrete components and establishment of evaluation index system

2.1. The meaning of quality risk
Quality risk is the uncertainty of the product throughout its life cycle, in other words, the possibility of quality problems and the possible harm. The identification and evaluation of quality risk is the core of enterprise quality management. Formulating reasonable quality management measures can effectively reduce the possibility of quality risks and improve product quality.

The quality risk of precast concrete components refers to the destruction of their quality during the life-cycle management of components, which affects their performance and affects the uncertainty of the quality of prefabricated buildings.

2.2. Quality risk assessment index system of precast concrete members
A reasonable quality risk evaluation index system is the basis for evaluating quality risks and formulating quality management programs. From the meaning of the quality risk of precast concrete components, the risk evaluation index system should cover the entire life cycle of precast components, and quality management can be clear. Therefore, from the perspective of total quality management, this article adds the influencing factors of the system to the method elements. Refer to the existing research literature on the influencing factors of the quality of prefabricated components[4-12]. The opinions of relevant experts adhere to the principles of scientificity, systemicness, comprehensiveness, representativeness, and applicability, and finally divide the risk factor indicators into five aspects: personnel factor, equipment factor, system plan factor, environmental factor, and raw material factor, totaling 23 secondary indicators, the relevant indicators are shown in Table 1 below.

| Table 1. Quality risk evaluation index system |
|-----------------------------------------------|
| First-level indicators | Second-level indicators |
| Personnel factor A | Degree of professionalization of production personnel[9]A1 |
| | Production staff work experience A2 |
| | Designer Professional Level A3 |
| | Tester professional level A4 |

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3. Selection of risk assessment methods
The applicability of the risk assessment method will directly determine the rationality of the risk assessment results. In addition, the quality risk assessment results should also meet the requirements of objectivity, science, and practicality. By consulting relevant literature, common risks are found evaluation methods include expert scoring, questionnaire survey, analytic hierarchy process, Monte Carlo simulation method, fuzzy comprehensive evaluation method, intuitionistic fuzzy analytic hierarchy process, and LEC safety evaluation method. The advantages and disadvantages of different methods are shown in Table 2 below:

| Risk assessment method           | Advantages                                                                 | Disadvantages                                                                 |
|---------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Expert scoring                  | Convenient, simple and quick to get evaluation results                    | Strong subjectivity, easy to ignore the actual situation                     |
| Questionnaire                   | Large sample, wide coverage, flexible time, and easy data processing by computer | High requirements on the quality of the questionnaire and the professional quality of the respondents |
| AHP                             | Combining qualitative and quantitative, strong systematic and logical level | Less quantitative components, more qualitative components, unable to solve ambiguity and hesitation |
| Monte Carlo simulation          | It can simulate the approximate solution of the actual application scenario, and the results are intuitively presented in the form of a probability map | Can only get results, lack of analysis process, difficult to formulate risk control measures |
| Fuzzy comprehensive evaluation | Can solve some fuzzy and difficult to quantify problems                    | High requirements for the independence of evaluation indicators               |

Table 2. Advantages and disadvantages of common risk assessment methods
Intuitionistic Fuzzy AHP

Can eliminate uncertainty and ambiguity in judgment, objective and scientific evaluation results, strong logic

Large workload and complicated calculation process

LEC Safety Evaluation Method

Intuitive and simple, easy to operate

Strong subjectivity and certain limitations

Through the comparative analysis of the above risk evaluation methods, it can be found that the intuitionistic fuzzy analytic hierarchy process can eliminate the uncertainty and ambiguity in the judgment, the evaluation results are objective and scientific, and the logic is strong. The fuzzy comprehensive evaluation method can quantify the evaluation results and solve the difficulty of quantification. The combination of the two methods can meet the basic requirements of quality risk assessment. Therefore, this article will use the intuitionistic fuzzy analytic hierarchy process to determine the weight of the risk factors of concrete prefabricated components, and use the fuzzy comprehensive evaluation method to carry out fuzzy comprehensive calculation to obtain the risk evaluation results. In addition, the advantages of using intuitionistic fuzzy AHP-fuzzy comprehensive evaluation method are: (1) It can accurately describe the information contained in the non-subordination degree, subordination degree and hesitation degree of risk factors, to ensure that in a fuzzy environment the evaluation of the quality risk factors of precast concrete components is more comprehensive and is no longer affected by uncertain information; (2) The relationship between various indicators can be well considered, and some fuzzy and difficult to quantify indicators are quantified, and more maneuverability. (3) Intuitionistic fuzzy set theory is an extension of fuzzy theory, the use of intuitionistic fuzzy set theory can take into account the degree of hesitation in evaluation, and has greater practicability and flexibility.

4. Establishment of risk evaluation model

4.1. Calculate the index weight

(1) Establish an intuitionistic fuzzy complementary judgment matrix

In the intuitionistic fuzzy analytic hierarchy process, the judgment matrix of risk factors based on the comparison of risk factors with each other:

$$R = (a_{ij})_{n \times n}, a_{ij} = (\mu_{ij}, \nu_{ij}), (i = 1, 2, \cdots, n, j = 1, 2, \cdots, n)$$

The matrix R satisfies the following properties:

1) $\mu_{ii} = 0.5, i = 1, 2, \cdots, n$

2) If $a_{ij} = (\mu_{ij}, \nu_{ij}), a_{ji} = (\mu_{ji}, \nu_{ji}), i, j = 1, 2, \cdots, n$, it must be $\mu_{ij} + \mu_{ji} = 1$

According to the risk assessment scale table in Table 3, to quantitatively describe the importance of risk factors.

| Evaluation level | Intuitionistic fuzzy number |
|------------------|-----------------------------|
| Factor i is extremely important than factor j | (0.90, 0.10, 0.00) |
| Factor i is much more important than factor j | (0.80, 0.15, 0.05) |
| Factor i is significantly more important than factor j | (0.70, 0.20, 0.10) |
| Factor i is slightly more important than factor j | (0.60, 0.25, 0.15) |
| Factor i is as important as factor j | (0.50, 0.30, 0.20) |
| Factor j is slightly more important than factor i | (0.40, 0.45, 0.15) |
| Factor j is significantly more important than factor i | (0.30, 0.60, 0.10) |
| Factor j is much more important than factor i | (0.20, 0.75, 0.05) |
| Factor j is more important than factor i | (0.10, 0.90, 0.00) |
If $k$ evaluation experts make decisions to obtain $k$ intuitionistic fuzzy judgment matrices $R_k = (a^{i}_{jk})_{n \times m}$, an integrated intuitionistic fuzzy judgment matrix $R = (a_{ij})_{nm}$ is obtained according to the following formula (1), where $w_k$ represents the weight of each expert.

$$R = \begin{cases} \mu_{ij} = \sum_{p=1}^{k} w_p \mu_{ij}^{(p)} \\ v_{ij} = \sum_{p=1}^{k} w_p v_{ij}^{(p)} \\ \mu_{ii} = v_{ii} = 0.5 \end{cases}$$  \hspace{1cm} (1)$$

(2) Consistency test

The consistency test is performed on the intuitionistic fuzzy judgment matrix, and the distance measure of the intuitionistic fuzzy information is used $d(\overline{R}, R)$. The calculation formula is as follows:

$$d(\overline{R}, R) = \frac{1}{2(n-1)(n-2)} \sum_{i=1}^{n} \sum_{j=1}^{n} \left( |\overline{\mu}_{ij} - \mu_{ij}| + |\overline{v}_{ij} - v_{ij}| + |\overline{\pi}_{ij} - \pi_{ij}| \right)$$ \hspace{1cm} (2)$$

Where $R$ is the integrated intuitionistic fuzzy judgment matrix, and $\overline{R}$ is the product-type consistent fuzzy judgment matrix $\overline{R} = (\overline{a}_{ij})_{nm}$ calculated by $R$ through the following formulas (3) and (4).

$$\overline{\mu}_{ij} = \frac{\textstyle j^{-i-j} \prod_{r=j+1}^{i-1} \mu_{rr} \mu_{ij}} {\textstyle \sqrt{\prod_{r=j+1}^{i-1} \mu_{rr} \mu_{ij} + \prod_{r=j+1}^{i-1} (1-\mu_{rr})(1-\mu_{ij})} }$$ \hspace{1cm} (3)$$

$$\overline{v}_{ij} = \frac{\textstyle j^{-i-j} \prod_{r=j+1}^{i-1} v_{rr} v_{ij}} {\textstyle \sqrt{\prod_{r=j+1}^{i-1} v_{rr} v_{ij} + \prod_{r=j+1}^{i-1} (1-v_{rr})(1-v_{ij})} }$$ \hspace{1cm} (4)$$

When $j = i + 1$, let $\overline{a}_{ij} = a_{ij}$; when $j < i + 1$, let $\overline{a}_{ij} = (\overline{\mu}_{ij}, \overline{v}_{ij})$.

If $d(\overline{R}, R) < \tau$ (where $\tau$ is the consistency test threshold, generally 0.1), then pass the consistency test. Otherwise fail, you need to modify the fuzzy judgment matrix $R = (a_{ij})_{nm}$, set the correction coefficient $\sigma$ using the following formula (5), (6) iteration, where $\sigma = [0,1]$.

$$\overline{\mu}_{ij} = (\mu_{ij})^{-\sigma} \left( \overline{\mu}_{ij} \right)^{\sigma}$$ \hspace{1cm} (5)$$

$$\overline{v}_{ij} = (v_{ij})^{-\sigma} \left( \overline{v}_{ij} \right)^{\sigma}$$ \hspace{1cm} (6)$$

For the modified intuitionistic fuzzy judgment matrix $\tilde{R} = (\tilde{a}_{ij})_{nm}$, the formula $d(\overline{R}, \tilde{R})$ is used to continue calculating the distance measure until $d(\overline{R}, \tilde{R}) < 0.1$, and the obtained result passes the consistency test.

(3) Determine the index weight

1) Determination of the weight of the first-level indicators
According to the calculated intuitionistic fuzzy judgment matrix that satisfies the consistency test is \( \tilde{R} = (\tilde{a}_{ij})_{nm} \), the intuitionistic fuzzy number is calculated using the following formula:

\[
\begin{align*}
(\mathbf{w}^T) &= \begin{bmatrix} w_1^{(l)} & w_2^{(l)} & \cdots & w_n^{(l)} \end{bmatrix} = \\
&= \left[ \sum_{j=1}^{n} \frac{a_{ij}^{(l)}}{\sum_{j=1}^{n} a_{ij}^{(l)}} \frac{a_{ij}^{(l)}}{\sum_{j=1}^{n} a_{ij}^{(l)}} \cdots \frac{a_{ij}^{(l)}}{\sum_{j=1}^{n} a_{ij}^{(l)}} \right] = \\
&= \left[ \begin{array}{cccc}
\frac{\sum_{j=1}^{n} \mu_{ij}^{(l)}}{\sum_{j=1}^{n} \sum_{i=1}^{n} \mu_{ij}^{(l)}} & \frac{\sum_{j=1}^{n} \nu_{ij}^{(l)}}{\sum_{j=1}^{n} \sum_{i=1}^{n} \nu_{ij}^{(l)}} \\
\frac{\sum_{j=1}^{n} \mu_{ij}^{(l)}}{\sum_{j=1}^{n} \sum_{i=1}^{n} \mu_{ij}^{(l)}} & \frac{\sum_{j=1}^{n} \nu_{ij}^{(l)}}{\sum_{j=1}^{n} \sum_{i=1}^{n} \nu_{ij}^{(l)}} \\
\end{array} \right]
\end{align*}
\] (7)

According to the intuitionistic fuzzy number obtained by formula (7), using formula (8), the first-level index weight is equal to:

\[
H(\lambda_i) = \frac{1 - v_i}{1 + \pi_j}, i = 1, 2, \ldots, n
\] (8)

Normalized to:

\[
\sigma_i = \frac{H(\lambda_i)}{\sum_{j=1}^{m} H(\lambda_j)}, i = 1, 2, \ldots, n
\] (9)

2) Determination of the weight of the secondary indicators

The calculation method of the same level index layer, the weight of the second level index under different categories is \( \sigma = (\sigma_j)_{(r,s)} \) \( (i, j = 1, 2, \ldots, m) \), and then the comprehensive weight according to formula (10) is:

\[
\sigma^{(2)} = (\sigma^{(1)})^T \sigma = (\sigma_1, \sigma_2, \ldots, \sigma_m)
\] (10)

4.2. Determining the fuzzy comprehensive judgment matrix

The quality risk levels of precast concrete components are classified into low risk (level I), lower risk (level II), moderate risk (level III), higher risk (level IV) and high risk (level V). The risk is calculated using a percentage system, and the corresponding scores at each level are [100, 90, 80, 60, 40, 0]. Each factor is obtained through a questionnaire survey the evaluation vector of the risk level of the indicator. Obtain the fuzzy evaluation matrix \( R_i (i = A, B, C, D, E) \) of the second-level indicators under each category.

4.3. Calculate the comprehensive evaluation vector

According to formula \( Y_i = Q_i \cdot R_i (i = A, B, C, D, E) \), the corresponding secondary index evaluation vector can be calculated, where \( Q_i \) is the secondary index weight vector. The comprehensive evaluation vector is \( Y = U (Y_A, Y_B, Y_C, Y_D, Y_E)^T \), and \( U \) is the primary index weight vector.

4.4. Get the calculation result

In order to facilitate the quantification of the evaluation level, the median value \( (95, 85, 70, 50, 20)^T \) of each risk level score is combined with the comprehensive evaluation vector \( Y \), and the comprehensive evaluation score \( Z \) is calculated using formula (11).

\[
Z = Y (95, 85, 70, 50, 20)^T
\] (11)
5. Example analysis
This article selects prefabricated concrete members produced by a large-scale prefabricated building integration group in Beijing for quality risk evaluation and research. The business includes prefabricated building design, engineering construction and PC manufacturing and manufacturing as three types of prefabricated buildings in China. The pioneers and leaders of the industry, relying on their own development and design capabilities, continue to innovate, and always stand at the forefront of assembly-building production technology. With integrated design, construction and strong PC production capacity, the company can complete nearly 2 million square prefabricated building construction work. The company's business includes component design, production, testing, transportation and construction, covering the entire life of concrete prefabricated components, the company's selection of the quality risk assessment of concrete precast components is representative.

5.1. Determination of weights of quality risk assessment indicators for precast concrete members
Through field visits to the company and questionnaire surveys of relevant experts, based on the technical characteristics and difficulties of the precast concrete components, combined with the importance scale in Table 3, the fuzzy numbers of relative importance between the first-level indicators can be obtained, and accordingly. The five experts are college scholars, senior production employees, enterprise managers, professional designers and government managers, and a pairwise comparison judgment matrix for the factors affecting the quality and safety risks of precast concrete components. The weight vector of each expert is

\[ w_k = (0.2, 0.2, 0.2, 0.2, 0.2) \], \( k \) is the number of experts interviewed, \( k = 1, 2, \ldots, 5 \). The fuzzy judgment matrix \( R_k \) \( (k = 1, 2, \ldots, 5) \) is as follows:

\[
R_1 = \begin{bmatrix}
(0.50, 0.30) & (0.70, 0.20) & (0.30, 0.60) & (0.80, 0.15) & (0.90, 0.10) \\
(0.30, 0.60) & (0.50, 0.30) & (0.30, 0.60) & (0.80, 0.15) & (0.80, 0.15) \\
(0.70, 0.20) & (0.70, 0.20) & (0.50, 0.30) & (0.90, 0.10) & (0.90, 0.10) \\
(0.20, 0.75) & (0.20, 0.75) & (0.10, 0.90) & (0.50, 0.30) & (0.30, 0.60) \\
(0.10, 0.90) & (0.20, 0.75) & (0.10, 0.90) & (0.70, 0.20) & (0.50, 0.30) \\
\end{bmatrix}
\]

\[
R_2 = \begin{bmatrix}
(0.70, 0.20) & (0.70, 0.20) & (0.50, 0.30) & (0.90, 0.10) & (0.70, 0.20) \\
(0.40, 0.45) & (0.20, 0.75) & (0.10, 0.90) & (0.50, 0.30) & (0.30, 0.60) \\
(0.10, 0.90) & (0.30, 0.60) & (0.30, 0.60) & (0.70, 0.20) & (0.50, 0.30) \\
(0.50, 0.30) & (0.80, 0.15) & (0.30, 0.60) & (0.70, 0.20) & (0.80, 0.15) \\
(0.20, 0.75) & (0.50, 0.30) & (0.30, 0.60) & (0.80, 0.15) & (0.70, 0.20) \\
\end{bmatrix}
\]

\[
R_3 = \begin{bmatrix}
(0.70, 0.20) & (0.70, 0.20) & (0.50, 0.30) & (0.70, 0.20) & (0.70, 0.20) \\
(0.30, 0.60) & (0.20, 0.75) & (0.30, 0.60) & (0.50, 0.30) & (0.40, 0.45) \\
(0.20, 0.75) & (0.30, 0.60) & (0.30, 0.60) & (0.60, 0.25) & (0.50, 0.30) \\
(0.50, 0.30) & (0.80, 0.15) & (0.40, 0.45) & (0.80, 0.15) & (0.80, 0.15) \\
(0.20, 0.75) & (0.50, 0.30) & (0.20, 0.75) & (0.70, 0.20) & (0.70, 0.20) \\
\end{bmatrix}
\]

\[
R_4 = \begin{bmatrix}
(0.60, 0.25) & (0.80, 0.15) & (0.50, 0.30) & (0.90, 0.10) & (0.80, 0.15) \\
(0.20, 0.75) & (0.30, 0.60) & (0.10, 0.90) & (0.50, 0.30) & (0.40, 0.45) \\
(0.20, 0.75) & (0.30, 0.60) & (0.20, 0.75) & (0.60, 0.25) & (0.50, 0.30) \\
\end{bmatrix}
\]
According to formula (1), the integrated fuzzy judgment matrix can be obtained as:

\[
R = \begin{bmatrix}
(0.50, 0.30) & (0.70, 0.20) & (0.40, 0.45) & (0.60, 0.25) & (0.90, 0.10) \\
(0.30, 0.60) & (0.50, 0.30) & (0.30, 0.60) & (0.80, 0.15) & (0.70, 0.20) \\
(0.60, 0.25) & (0.70, 0.20) & (0.50, 0.30) & (0.80, 0.15) & (0.80, 0.15) \\
(0.40, 0.45) & (0.20, 0.75) & (0.20, 0.75) & (0.50, 0.30) & (0.40, 0.45) \\
(0.10, 0.90) & (0.30, 0.60) & (0.20, 0.75) & (0.60, 0.25) & (0.50, 0.30)
\end{bmatrix}
\]

According to formulas (3) and (4), the product judgment matrix for judging consistency can be obtained as:

\[
\tilde{R} = \begin{bmatrix}
(0.50, 0.30) & (0.74, 0.18) & (0.53, 0.27) & (0.84, 0.08) & (0.72, 0.13) \\
(0.18, 0.74) & (0.50, 0.50) & (0.28, 0.63) & (0.67, 0.20) & (0.62, 0.20) \\
(0.27, 0.53) & (0.63, 0.28) & (0.50, 0.50) & (0.84, 0.13) & (0.25, 0.13) \\
(0.08, 0.84) & (0.20, 0.63) & (0.13, 0.84) & (0.50, 0.50) & (0.36, 0.51) \\
(0.13, 0.72) & (0.20, 0.62) & (0.13, 0.25) & (0.51, 0.36) & (0.50, 0.50)
\end{bmatrix}
\]

Calculate the distance measure according to formula (2). The result \(d(\tilde{R}, \tilde{R}) = 0.22 > 0.1\) indicates that the consistency test has not been passed. The fuzzy number in the judgment matrix \(R\) is corrected using formulas (3) and (4), and the correction parameter \(\sigma = 0.9\) is taken to obtain the corrected intuitive fuzzy judgment. The matrix is:

\[
\tilde{R} = \begin{bmatrix}
(0.500, 0.500) & (0.740, 0.180) & (0.510, 0.293) & (0.829, 0.088) & (0.737, 0.129) \\
(0.187, 0.733) & (0.500, 0.500) & (0.280, 0.630) & (0.682, 0.196) & (0.631, 0.199) \\
(0.304, 0.495) & (0.640, 0.270) & (0.500, 0.500) & (0.840, 0.130) & (0.297, 0.133) \\
(0.093, 0.822) & (0.202, 0.640) & (0.133, 0.837) & (0.500, 0.500) & (0.360, 0.510) \\
(0.131, 0.734) & (0.207, 0.620) & (0.137, 0.290) & (0.523, 0.346) & (0.500, 0.500)
\end{bmatrix}
\]

Use formula (2) to recalculate the distance measure \(d(\tilde{R}, \tilde{R}) = 0.0339 < 0.1\) to meet the consistency requirements and can be used to calculate the first-level index weights.

The obtained modified intuitionistic fuzzy judgment matrix \(\tilde{R}\) using formulas (7) and (8) to calculate the index weight results is: \((0.561, 0.499, 0.530, 0.439, 0.471)\).

Using formula (9) to normalize the obtained index weights, the result is: \((0.224, 0.199, 0.213, 0.176, 0.188)\).

Similarly, the results of the remaining secondary index weights and comprehensive weights are shown in Table 4 below:

| First-level indicator | weight value | Second-level indicator weight value | Comprehensive weight value |
|-----------------------|--------------|------------------------------------|---------------------------|
| Personnel factor A    | 0.224        | A_1 0.298                          | 0.067                     |
|                       |              | A_2 0.255                          | 0.057                     |
|                       |              | A_3 0.233                          | 0.052                     |
5.2. Determination of fuzzy comprehensive judgment matrix

A total of 10 valid expert questionnaires composed of professional testing institutions, peer production personnel, university scholars, enterprise managers, and testing agency personnel were selected for this evaluation score. The fuzzy evaluation matrix is composed as follows:

The corresponding evaluation vector can be calculated according to formula $Y_i = Q_i R_i (i = A, B, C, D, E)$. Taking personnel qualification factors as an example:
Similarly, the risk factor evaluation vectors under the remaining first-level indicators are:
\[ Y_{B} = (0.734, 0.140, 0.126, 0.0) \]
\[ Y_{C} = (0.724, 0.187, 0.068, 0.019, 0) \]
\[ Y_{D} = (0.697, 0.235, 0.046, 0.021, 0) \]
\[ Y_{E} = (0.886, 0.038, 0.038, 0.038, 0) \]

Calculate the comprehensive evaluation vector consisting of:
\[ Y = (0.224, 0.199, 0.213, 0.176, 0.188) \]
\[ (Y_{A}, Y_{B}, Y_{C}, Y_{D}, Y_{E})^{T} \]
\[ = (0.785, 0.121, 0.045, 0.049, 0) \]
\[ (0.734, 0.140, 0.126, 0.0) \]
\[ (0.724, 0.187, 0.068, 0.019, 0) \]
\[ (0.697, 0.235, 0.046, 0.021, 0) \]
\[ (0.886, 0.038, 0.038, 0.038, 0) \]

5.3. Comprehensive evaluation score
According to the formula (11), the risk assessment scores of the precast concrete members are:
\[ Z = (0.766, 0.143, 0.065, 0.026, 0) \]
\[ \begin{pmatrix} 95 \\ 85 \\ 70 \\ 50 \\ 20 \end{pmatrix} = 90.775 \]

5.4. Evaluation results
By comparing the risk level scale, it can be seen that 90.775 is between [100, 90), indicating that the quality risk level of the concrete prefabricated components produced by the component factory is level I low risk. According to the actual sampling method, 100 components are selected. According to the inspection, only two pieces have the problems of reserved steel bar displacement and reserved hole deviation, and the quality pass rate reaches 98%. This is basically consistent with the results obtained by the quality risk evaluation in this article, so it shows that the evaluation model is reasonable and feasible. By comparing one, it can be seen that the weight of each level indicator is that personnel factors and system plan factors are the main risk categories that affect the quality of components. This is related to China's current learning stage of prefabricated building development, and the corresponding quality management system and technology are not mature. By analyzing the weights of all secondary indicators, we can see that the professionalism of the production personnel, the quality of the production equipment, the traceability of the enterprise's product quality, the integrity of the enterprise's product quality standard system, and the quality of raw materials are the risk factors that component manufacturers should focus on preventing and controlling.

6. Conclusion
(1) There are many risk factors affecting the quality of concrete prefabricated components. From the
perspective of total quality management, this paper identifies the comprehensive and representative risk factors that cover the entire life cycle of component manufacturing. Establish a corresponding quality risk evaluation index system.

(2) By sorting out common risk assessment methods, this paper establishes a risk assessment model based on intuitionistic fuzzy analytic hierarchy process, and proves the effectiveness of the model through example analysis, which provides a new idea for the selection of quality risk assessment models.

(3) Through an example analysis of a typical prefabricated building integrated enterprise in Beijing, it is found that the personnel and system program factors under the first-level indicators should be the key aspects of prevention and control, and the key risk factors under the second-level indicators include the professionalism of production personnel, the quality of production equipment, the traceability of enterprise product quality, the integrity of enterprise product quality standard system and the quality of raw materials, etc.

(4) To improve the quality of concrete prefabricated components, enterprises can proceed from establishing a systematic quality management system, adopt strengthening training and incentives for enterprise employees, timely detect and update production equipment, formulate and improve quality standards and regulations, and improve quality management measures such as the ability to improve product quality traceability and the introduction of an information management model based on the internet of things.

References

[1] Guo Zhanglin, Liang Tingting. On the development of prefabricated buildings [J]. Value Engineering, 2017, 36 (02): 233-235.
[2] Li Hongxia. Research on design and on-site construction of prefabricated building components [J]. Engineering Construction and Design, 2020 (04): 173-174.
[3] Zhou Qiang, Ma Jinhua, Zhang Degang, Zhu Mintao, Li Lingyu. Research on standardization and generalization of PC component molds [J]. Concrete and Cement Products, 2020 (03): 82-85.
[4] Wu Shuigen, Bai Jianwei. Quality evaluation of prefabricated building structure parts construction [J]. Building Construction, 2013, 35 (2): 116-117.
[5] Shi Jinhua. Deepening design and production process of prefabricated structural members [D]. Nanjing: Southeast University, 2014.
[6] Fan Yu, Huang Xin, Huang Jizhan. Design and construction technology of new prefabricated building PC component template [J]. Construction Technology, 2018, 47 (04): 44-46.
[7] Zhu Hai, Liao Xiandong, Chen Xinxi, Li Hao. Non-destructive transportation measures for large prefabricated components [J]. Construction Technology, 2018, 47 (10): 16-19.
[8] Tian Dong, Li Xinwei, Ma Tao. Design analysis and research of assembly concrete building component system based on BIM [J]. Building Structure, 2016, 46 (17): 58-62.
[9] Zhang Xia. Research on quality control and supervision of fabricated concrete structures [J]. Construction Technology, 2016, 45 (17): 137-140.
[10] He Shoukui, Fu Hongyuan. Economic interpretation of engineering quality risk and risk prevention [J]. Journal of Chongqing University of Architecture, 2006 (06): 106-110.
[11] Chen Shengli. Research on the risk assessment method of construction management of engineering projects [J]. Shanxi Architecture, 2012, 38 (02): 254-256.
[12] Qi Renguang, Zou Jun, Xu Ang, Liang Hao, Fan Peihong. Research on the risk influencing factors of prefabricated bay windows in fabricated concrete buildings [J]. Concrete and Cement Products, 2019 (07): 75-79.
[13] Zhuang Xueli. Research on construction quality management of prefabricated concrete houses [D]. Beijing Jiaotong University, 2018.
[14] Zhang Qiang. Research and practice of construction technology and quality control of small concrete prefabricated components [J]. Low Carbon World, 2020, 10 (01): 175-176.
[15] Ma Yumang. Discussion on steam curing process of precast concrete components [J]. Green and Environmental Protection Building Materials, 2017 (05): 4-6.
[16] Wang Guangyan, Pang Hongmei. Manufacturing technology of prefabricated reinforced concrete prefabricated components [J]. Urban Housing, 2017, 24 (04): 59-62.