Study on Construction Risks of Prefabricated Assembly of Urban Bridge Substructures

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Abstract. In order to effectively identify, control and avoid the construction risk of prefabricated assembling of urban bridge substructures, this paper establishes a construction risk evaluation system for prefabricated assembling bridges by constructing an AHP-fuzzy comprehensive evaluation model. Firstly, through literature analysis, case studies and expert interviews, 61 specific risk sources are identified from four aspects, namely, environmental factors, materials and equipment, personnel factors, and organisational management; secondly, combining the hierarchical analysis method and the fuzzy comprehensive evaluation method, a construction risk evaluation system is set up; finally, through the analysis and calculation of engineering examples, the feasibility and validity of the method are demonstrated and a certain degree of risk control is provided for the precast assembling of substructures of urban bridges. assembling, and provides certain suggestions for risk control of urban bridge substructure prefabrication.

Keywords: Bridge Substructure; Construction Risk; AHP-fuzzy Comprehensive Evaluation; Risk Control.

1 Introduction

With China's economic and social development and the improvement of science and technology level, the city has become an important gathering point for human production and social activities all over the world, and urban roads and bridges, as the skeleton of the city, directly affect the efficiency of the circulation of passenger flow and logistics. The traditional bridge construction mode, with its long construction period, large traffic impact area and serious noise and dust pollution, is no longer suitable for the sustainable development of modern cities. Prefabricated assembling technology is increasingly favoured for its main features of factory production, mechanised installation and green construction. At the same time, new technology implies new risks, and effective identification, control and avoidance of construction risks of prefabricated assembled structures are of great theoretical and practical significance for bridge construction in modern cities. Each part of a bridge can usually be divided into several components such as superstructure (bridge span structure), bearing, substructure (cover

G. Zhao et al. (eds.), *Proceedings of the 2023 5th International Conference on Civil Architecture and Urban Engineering (ICCAUE 2023)*, Atlantis Highlights in Engineering 25,
https://doi.org/10.2991/978-94-6463-372-6_26

girder, pier, etc.), and ancillary structure (bridge deck system). The prefabrication and assembling technology of superstructure is relatively mature, and the bearing and ancillary structures are not the main factors restricting the development of bridges because of their small volume and simple structure. However, the prefabricated assembling technology of substructure has not been developed on a large scale due to the constraints of the development level of node connection technology and the performance of connection materials. From a comprehensive point of view, the construction of prefabricated assembling substructure is still faced with the problems of insufficient experience in construction, high safety risk, and difficulty in ensuring the reliability of node connection. Therefore, the research objective of this paper is to focus on the construction risk of prefabricated assembly of urban bridge substructure, and evaluate the construction risk, propose risk control measures to reduce the occurrence of risk, and provide theoretical guidance for the construction risk control of similar projects.

In the research carried out for bridge construction risk. Aiming at the shortcomings of the existing high-speed railway bridge construction risk assessment model, such as strong subjectivity, cumbersome links and the need for a large number of samples, LIU Y et al. proposed a high-speed railway bridge safety risk assessment model based on the hierarchical analysis method (AHP method) + BP neural network, and the results show that the model can comprehensively assess the impacts of the main risk factors on the construction of high-speed railway bridges, and the predicted risk levels are consistent with the results of the expert review. The results show that the model can more comprehensively assess the impact of the main risk factors on the construction of high-speed railway bridges, and the predicted risk level is consistent with the expert assessment results[1]. Aiming at the problem of dynamic risk assessment of large bridge construction, SHI Z adopts the structure-risk decomposition identification method to complete the preliminary identification of risk elements, introduces the decision-making and laboratory methods to identify the dynamic assessment of risk elements and constructs the risk element transfer network, and finally combines the Bayesian network and Ge NIe software to carry out Bayesian probability calculation on the risk element transfer network and combines the backward reasoning and sensitivity analysis to obtain the key risk elements and the main risk chain. The key risk elements and main risk chains were obtained by combining backward inference and sensitivity analysis. This method is used to carry out the dynamic risk assessment of the whole construction process of Wufengshan Yangtze River Bridge[2]. JIANG Z creatively proposed a new type of risk assessment method based on two-dimensional cloud model, which is used to evaluate the risk level by combining two indicators of risk probability and risk loss level [3]. Based on accident causes and system safety theory, LI Y systematically analysed the risks of various railway tunnel and bridge constructions and summarized them into five categories: risks in construction organization, risks in manpower materials and equipment, risks in construction environment, risks in construction technology, and special risks [4].WU J adopts WBS-RBS method to comprehensively identify the safety risks that may occur during the whole construction process, compiles a list of safety risks in the construction of large-span steel box girder cable-stayed bridges, and adopts LEC method, index system method, risk matrix method and other methods to semi-quantitatively evaluate the safety risks during the construction period of the bridge.

According to the established risk assessment system, the safety risks during the construction period of Wuhu Yangtze River Highway No.2 Bridge are identified, analysed, evaluated and controlled in a comprehensive and systematic way, which has played a better role in guiding the safety management of the whole bridge construction[5].AHN et al. analysed the risk factors in bridge construction and used multiple regression analysis to develop a risk-loss estimation model to carry out bridge risk-loss analysis[6]. Saputra et al. (2020) determine the precast bridge engineering Work Breakdown Structure (WBS) in identifying the risks present in the construction process of each component[7]. From the existing studies, it can be found that the analysis methods based on numerical calculations are becoming more mature, but there are fewer studies on the construction risk in areas that are at high seismic intensity and low level of precast assembly technology.

This study considers the characteristics and difficulties of applying prefabricated assembling technology to the construction of bridge substructures in areas with high seismic intensity and low level of prefabricated assembly technology, and applies the fuzzy comprehensive evaluation method integrating risk management theory to the risk analysis of prefabricated assembling construction of urban bridge substructures, to achieve the comprehensiveness and reliability of the risk source identification, and to assess the quantitative grade of the overall risk analysis of the project. The validity and feasibility of the method is verified through the actual case engineering project of Xinjiang Urumqi East Approach Elevated Bridge Project, and risk prevention and control measures are proposed according to the risk source level to ensure construction safety.

2 Construction risk assessment determination methodology

In order to accurately and reliably assess and analyse the risk of prefabricated assembling construction of urban bridge substructures, this study adopts questionnaire survey, expert interview, hierarchical analysis method and fuzzy comprehensive evaluation method to construct a risk assessment determination system and control method applicable to prefabricated assembling construction of urban bridge substructures, and the specific theories are introduced as follows.

2.1 Risk source identification

The prefabricated splicing of urban bridge substructure mainly includes the connection between pile foundation and bearing platform (abutment), the connection between bearing platform (foundation) and pier column, the connection between pier column and cover girder, and the segmental splicing of column and cover girder itself, and other technologies. However, in the process of prefabricated splicing construction, the various construction stages are technically complicated and there are more risks, so the identification of risk sources is crucial.

Based on the stages of prefabrication and assembling risk occurrence of urban bridge substructure, the risk assessment of construction is carried out from six stages of prefabrication, storage, transportation, lifting, installation and maintenance, mainly targeting four risk sources of environment, materials and equipment, personnel, and organisation and management as the first-level indicators.

2.2 Determination of risk indicator weights

In the overall evaluation of risk, risk is determined by two important aspects, the probability of the occurrence of a risk event and the severity of the possible consequences of the risk event. The severity index of the consequences of the occurrence of a risk can be regarded as the weight of the risk in the evaluation of the risk, and the greater the weight, the more serious the consequences of the risk once it occurs, and vice versa indicates that the consequences are less serious. Although the hierarchical analysis method has strong subjectivity, but through the use of increasing the number of survey samples, reasonable selection of experts and other means can reduce the degree of subjectivity discrete, to obtain a more reliable survey results. The specific AHP calculation and analysis are as follows:

(1) Establishment of hierarchical analysis model

Hierarchical analysis model from top to bottom usually includes the target layer, guideline layer, indicator layer, programme layer and so on. The target layer is the ultimate risk assessment goal to be achieved; the criterion layer is the standard for judging the result of the target; the indicator layer is the various sub-risk factors affecting the target, and the programme layer is the specific risk factors. Layering from top to bottom requires the establishment of inter-comparative hierarchical factors to form a hierarchical analysis model.

(2) Construct risk source judgement matrix

Based on the hierarchical analysis model, invite experts with rich engineering experience and on-site technical management personnel to determine the relative importance of the method of two-by-two comparison, all-round assessment of construction risk sources, for each layer of factors need to construct a judgement matrix. For example, a layer of n factors $H = (H_1, H_2, ..., H_n)$, to compare the degree of their impact on the previous layer, each time to take the two factors H_i and H_j, with h_{ij} that the index H_i and the index of the comparison of the results of the H_j, which can be constructed to judge the matrix, see the following formula:

$$H = (h_{ij})_{n\times n} = \begin{pmatrix} h_{11} & h_{12} & \cdots & h_{1n} \\ h_{21} & h_{22} & \cdots & h_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ h_{n1} & h_{n2} & \cdots & h_{nn} \end{pmatrix} \quad (1)$$

Values 1-9 and their reciprocals were used to assign values to the importance of the risk sources as a scale of judgement, and the meanings represented by the values are shown in Table 1.

Table 1. 1-9 Scale assignment

Scale	Exegesis	Note
1	Comparison of two factors of equal importance	Comparison of row factor i with column factor j yields h_{ij}
3	Comparison of two factors, one slightly more important than the other	
5	Comparison of two factors, one significantly more important than the other	
7	Comparison of two factors, one more strongly important than the other	Comparison of row factor j with column factor i yields h_{ji}
9	Comparison of two factors, one more extremely important than the other	
2,4,6, 8	Importance is the median of neighbouring judgements	$h_{ij}=\frac{1}{h_{ji}}$

(3) Calculation of risk source weight values

The relative size of the risk sources is measured by the weight values, which have a significant impact on the overall project risk assessment results. Based on the risk source judgement matrix H obtained above, the specific calculation steps for the weight value of each risk source are as follows.

First, determine the product of factors Mi for each row of the judgement matrix, and calculate the nth root of Mi, see the following formula:

$$M_i=\prod_{j=1}^{n}h_{ij}, i=1,2,3,\cdots,n \tag{2}$$

$$m_i=\sqrt[n]{M_i} \tag{3}$$

Then, the weight vector W=[w1,w2,...,wn]T is normalised as shown in the following equation:

$$w_i=\frac{m_i}{\sum_{i=1}^{n}m_i} \tag{4}$$

Finally, the maximum characteristic root of the judgement matrix is calculated, see the following equation:

$$\lambda_{\max}=\frac{1}{n}\sum_{i=1}^{n}\frac{HW}{W} \tag{5}$$

H is the judgement matrix; *n* is the order of the judgement matrix, w_i is the relative weight value of the ith criterion layer; *W* is the risk source weight vector.

(4) Judgement matrix consistency test

Experts and on-site technical management personnel scores constitute a risk source judgement matrix, as each expert gives a judgement matrix with subjectivity, the judgement results may be inconsistent, when inconsistency exceeds the allowable range, the judgement results are not considered credible, therefore, the judgement matrix needs to be consistency test, to ensure that prefabricated assembled construction of urban bridge substructures of the risk of the source of the weight value of the scientific and accurate, the specific test steps are as follows.

Firstly, the general consistency index CI of the judgement matrix is determined with the formula[8-9]:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{6}$$

Then, to measure the size of the CI, the stochastic consistency index RI was introduced to measure [10], see Table 2.

Table 2. Stochastic consistency metrics for 1st to 9th order judgement matrices

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RI	0	0	0.58	0.89	1.12	0.24	1.32	1.41	1.49

Finally, the consistency coefficient CR is calculated. The consistency coefficient is the ratio of the general consistency index to the random consistency index, which is calculated by the iterative method, and the result can determine whether the scoring of each expert meets the consistency or not, and when CR < 0.1, it indicates that the consistency of the judgement matrix passes [11], and the formula is:

$$CR = \frac{CI}{RI} \tag{7}$$

2.3 Classification of risks

According to the definition of the concept of risk in the "Guidelines for Safety Risk Assessment of Highway Bridge and Tunnel Construction (Trial)", risk is the combination of the likelihood and severity of the occurrence of a particular accident, i.e., the risk in a general sense has the duality of probability and consequence, and the size of the risk value is expressed by the product of probability of occurrence of the risky event, P, and consequence of the event, C [12]. That is: R (risk value) = P (probability of risk occurrence) × C (risk occurrence consequence index), in this paper, the likelihood of risk occurrence is divided into 5 levels: unlikely, less likely, possible, more likely, very likely; the loss that may be caused by the occurrence of the risk is divided into 5 levels: minor loss, general loss, major loss, serious loss, destructive loss. This paper proposes to divide the risk level into five levels according to the probability of the occurrence of risky accidents and the impact consequences caused by the risky accidents, from low to high, low risk level, lower risk level, medium risk level, higher risk level, and very high risk level, as shown in Table 3.

Table 3. Risk rating criteria

probability of occurrence / Consequence level	unlikely	less likely	likely	more likely	extremely likely
Minor losses	low risk	low risk	Lower risk	Lower risk	Medium risk
General losses	low risk	Lower risk	Lower risk	Medium risk	Medium risk
Larger loss	Lower risk	Lower risk	Medium risk	Higher risk	Higher risk
Heavy losses	Medium risk	Medium risk	Higher risk	Higher risk	Extremely high risk
Devastating losses	Medium risk	Higher risk	Higher risk	Extremely high risk	Extremely high risk

2.4 Determination of the risk affiliation matrix

Risk affiliation matrix reflects the likelihood of each level of risk occurrence, according to the likelihood of risk occurrence grading, the establishment of the evaluation set V = {v1,v2,v3,v4,v5} = {unlikely, less likely, likely, more likely, extremely likely} = {1,2,3,4,5}, and then invited experts in related fields to the likelihood of the occurrence of each source of risk to score, calculating the proportion of the number of experts of the same level of likelihood of the occurrence of the same source of risk to establish the fuzzy relationship matrix R, see the following formula:

$$R = [R_1, R_2, \cdots, R_n] = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{8}$$

2.5 Risk rating

Combining the risk weight values and the risk fuzzy relationship matrix, the combined operation of the two can determine the risk source to the overall risk level affiliation B, see the following formula:

$$B = W \bullet R \tag{9}$$

Based on the size of each element in the calculation result B as a judgement standard, the risk level corresponding to the largest element in B is selected as the overall risk level of the project in accordance with the principle of maximum affiliation.

3 Engineering applications and analyses

3.1 Overview of the project

Urumqi City, Xinjiang Uygur Autonomous Region, East Approach Elevated main line design speed 80km/h, ramp design speed 40km/h, is an important part of the airport hub rapid distribution system, will become the east side of the main access to the airport hub after completion. The project starts from Anning Drainage Road in the west, and extends eastward along the existing Dongrong Street to the east extension of the main road in the north of the city, the total length of the road is 12.9km, among which the length of the elevated is about 12.7km. the standard bridge width of the main line is 24.5m, and the width of the ramp bridge is 8.0m. the columns and the cover beams of the lower structure of the project adopt the prefabrication of the factory, and the on-site lifting way of the construction, and the weight is controlled within 260t, combining with the lifting capacity of the equipments, the transport conditions, and the road access conditions. The weight is controlled within 260t.

In order to analyse and control the risk of prefabrication and assembling construction of urban bridge substructure, the risk assessment model and method proposed in this study are applied to this project, and the specific calculation and analysis process is as follows.

3.2 Risk identification of bridge substructure prefabrication and assembly construction

According to the primary and secondary indicators for identifying risk sources established in the previous section, combined with the characteristics of this project, the summary list of risk factors in the construction of the substructure of the project is as follows, containing a total of 4 primary indicators, 17 secondary indicators and 61 specific risk factors.

Table 4. Urban substructure construction risk indicator system

Level 1 indicators	Level 2 indicators	Risk factors
environmental factor	environment	Severe weather, climate
		Geological conditions and groundwater distribution
		Earthquakes and Accidental Foundation Shaking
	Social security environment	Complaints from neighbouring residents about disruption to construction
		Malicious damage and theft of construction materials and equipment
		Lack of policy support or social resistance
	Construction environment	Demolition not completed, construction fencing not completed
		"Three passes and one levelling" on site
		Lighting, lighting conditions
		Temperature and humidity conditions
	Site Space Layout	Effects of high-risk objects and surrounding obstacles
		Availability of adequate working surfaces
		Rationalisation of the layout of the construction area
Materials and equipment	Material Preparation	General raw material preparation
		UHPC material readiness

Level 1 indicators	Level 2 indicators	Risk factors
		Preparation of production and living materials
	Quality of components	Failure of prefabricated components to meet quality standards
		UHPC material performance failure
	equipment preparation	Status of transport and lifting equipment
		Condition of mixing and filling equipment
		Status of equipment for the production of prefabricated plant components
		Status of equipment for positioning and deflection of components on site
		Measurement equipment situation
	Repair and maintenance of equipment	Regular inspection and testing of construction equipment
		Maintenance of construction equipment
		Whether the measuring equipment is calibrated
Personnel factors	Persons other than the builder	Quality of design drawings and efficiency of changes
		Supervisor's conscientious and responsible attitude
		Coordination of problem-solving by the builder
	Staffing	Safety officers, technicians, experimenters, surveyors equipped
		Information on drivers and operators of machinery
		Situation of labourers on site
		Logistics staffing
	working skill	Prefabrication plant worker experience and proficiency
		Experience and proficiency of lifting and transport personnel
		Experience and proficiency of laboratory and measurement personnel
		Managerial experience
		Level of education of construction personnel, execution
	operating state	Responsibility of on-site construction operators
		Conscientiousness of managers
		Intensity of work and rest of personnel
		Physical fitness of personnel
Organisational management	security management	Hazard identification and review of construction plans
		Safety management training delivery and implementation
		Safety Management System and Emergency Response Plan
	construction organisation	Supply of production materials
		Arrangement of construction machine shifts
		Management and labour arrangements
		Scientific implementation of the construction programme
	Coordination of communication	Communication and co-operation with construction, design and supervision parties
		Coordination with other management
		Communication and coordination with labourers and subcontractors
	Funding for construction	Availability of funds for construction
		Rising prices of people, materials and machinery
		Extension of construction period for additional interest payments on borrowings
		Payment of compensation for accidents during construction
	Construction period requirements	Inadequate construction procedures did not start in time
		Failure to commence work in a timely manner
		The builder asked for early completion
		Supervisory authority penalties, issuance of stop-work orders
		Force majeure factors requiring a shorter construction period

3.3 Use of hierarchical analysis to determine the weighting of risk factors

In order to determine the weight of each risk factor in the risk evaluation model of the Urumqi East Approach Elevated Project, the expert survey method is used to invite the experts in the industry to score the importance of the risk factors based on the project experience of the importance of the two comparisons, and the scoring results of the experts are summarised and analysed using the hierarchical analysis method, and finally the importance of the risk factors is derived from the weight of the risk factors.

3.3.1 Constructing judgement matrices. In this case, the following risk judgement matrix was constructed by researching 41 personnel involved in the Urumqi East Approach Elevated Project and experts in the industry, and asking them to rate each indicator according to the importance scale.

(1) Judgement matrix under environmental factors:

$$H_1 = \begin{pmatrix} 1.0000 & 1.1517 & 0.4541 & 0.3889 \\ 0.8683 & 1.0000 & 0.4684 & 0.3919 \\ 2.2023 & 2.1350 & 1.0000 & 1.0341 \\ 2.5714 & 2.5517 & 0.9670 & 1.0000 \end{pmatrix}$$

(2) Judgement matrix under material and equipment factors:

$$H_2 = \begin{pmatrix} 1.0000 & 1.2067 & 0.8946 & 1.0249 \\ 0.8287 & 1.0000 & 0.8113 & 0.7641 \\ 1.1178 & 1.2325 & 1.0000 & 0.8387 \\ 0.9757 & 1.3087 & 1.1923 & 1.0000 \end{pmatrix}$$

(3) Judgement matrix under the personnel factor:

$$H_3 = \begin{pmatrix} 1.0000 & 0.4008 & 0.3088 & 0.3533 \\ 2.4952 & 1.0000 & 0.5159 & 0.5765 \\ 3.2383 & 1.9384 & 1.0000 & 1.0237 \\ 2.8302 & 1.7347 & 0.9769 & 1.0000 \end{pmatrix}$$

(4) Judgement matrix under organisational management factors:

$$H_4 = \begin{pmatrix} 1.0000 & 1.3856 & 1.5075 & 1.6516 & 1.9947 \\ 0.7217 & 1.0000 & 1.2346 & 0.9815 & 1.0181 \\ 0.6633 & 0.8100 & 1.0000 & 0.7943 & 0.8543 \\ 0.6055 & 1.0188 & 1.2590 & 1.0000 & 1.0098 \\ 0.5013 & 0.9822 & 1.1705 & 0.9903 & 1.0000 \end{pmatrix}$$

(5) Judgement matrix at the guideline level of the first level indicator:

$$H_0 = \begin{pmatrix} 1.0000 & 0.5281 & 0.3956 & 0.3264 \\ 1.8936 & 1.0000 & 0.5076 & 0.4206 \\ 2.5278 & 1.9700 & 1.0000 & 0.5025 \\ 3.0639 & 2.3777 & 1.9902 & 1.0000 \end{pmatrix}$$

According to Eq. 6 and Eq. 7, after the judgement matrix consistency test, the consistency test results are all good.

3.3.2. Results of weighting calculations. The weights were calculated according to Eq. 2-Eq. 4 and the results are shown in Table 5 below:

Table 5. Summary of weighting results

Ordinal number	Risk factors	normative layer				Total weight
		Environments U_1	Materials and equipment U_2	Staffing U_3	Organisational management U_4	
		0.1129	0.1761	0.2785	0.4325	
1	Environment U_{11}	0.1534				0.0173
2	Social security environment U_{12}	0.1444				0.0163
3	Construction environment U_{13}	0.3395				0.0383
4	Site Space Layout U_{14}	0.3627				0.0410
5	Material Preparation U_{21}		0.2553			0.0450
6	Quality of components U_{22}		0.2101			0.0370
7	Equipment preparation U_{23}		0.2581			0.0454
8	Repair and maintenance of equipment U_{24}		0.2765			0.0487
9	Persons other than the builder U_{31}			0.1029		0.0287
10	Staffing U_{32}			0.2090		0.0582
11	Working skill U_{33}			0.3566		0.0993
12	Operating state U_{34}			0.3315		0.0923
13	Security management U_{41}				0.2888	0.1249
14	Construction organisation U_{42}				0.1906	0.0824
15	Coordination of communication U_{43}				0.1599	0.0692
16	Funding for construction U_{44}				0.1858	0.0804
17	Construction period requirements U_{45}				0.1749	0.0756

3.4 Risk assessment using a fuzzy integrated evaluation approach

In order to determine the likelihood of the risk of Urumqi East Approach Elevated Project, the questionnaire method is used to invite experts in the industry and project personnel to judge the likelihood of the occurrence of risk factors based on project experience, which is classified as "unlikely, less likely, possible, possible, more likely, very likely", and finally, according to the results of the questionnaire survey, the degree of affiliation of the indicators of each level is obtained.

3.4.1 Establishment of the affiliation matrix. A total of 118 valid questionnaires were returned and their calculations were sought by processing the questionnaire data as follows:

(1) Affiliation matrix under environmental factors:

$$R_1=\begin{bmatrix} 0.0847 & 0.1949 & 0.2684 & 0.2938 & 0.1582 \\ 0.1328 & 0.3842 & 0.3051 & 0.1215 & 0.0565 \\ 0.1271 & 0.2938 & 0.3701 & 0.1554 & 0.0508 \\ 0.0452 & 0.2740 & 0.3672 & 0.2203 & 0.0932 \end{bmatrix}$$

(2) Affiliation matrix under material equipment:

$$R_2=\begin{bmatrix} 0.1949 & 0.2938 & 0.3023 & 0.1412 & 0.0678 \\ 0.0960 & 0.3023 & 0.3362 & 0.1921 & 0.0734 \\ 0.1165 & 0.2825 & 0.3305 & 0.2345 & 0.0480 \\ 0.1158 & 0.2881 & 0.3898 & 0.1667 & 0.0395 \end{bmatrix}$$

(3) Affiliation matrix under the personnel factor:

$$R_3=\begin{bmatrix} 0.0621 & 0.2655 & 0.4520 & 0.1808 & 0.0395 \\ 0.1017 & 0.3432 & 0.4004 & 0.1271 & 0.0275 \\ 0.0746 & 0.2983 & 0.3898 & 0.1864 & 0.0508 \\ 0.0911 & 0.3178 & 0.4047 & 0.1462 & 0.0403 \end{bmatrix}$$

(4) Affiliation matrix under organisational management:

$$R_4=\begin{bmatrix} 0.0819 & 0.3023 & 0.3785 & 0.1723 & 0.0650 \\ 0.0742 & 0.3453 & 0.4110 & 0.1271 & 0.0424 \\ 0.0791 & 0.2712 & 0.4209 & 0.1751 & 0.0537 \\ 0.0487 & 0.2479 & 0.4449 & 0.1992 & 0.0593 \\ 0.0458 & 0.2746 & 0.4068 & 0.1898 & 0.0831 \end{bmatrix}$$

3.4.2 Fuzzy integrated evaluation results. According to the results of weight calculation to construct the weight matrix W and affiliation matrix R for the integrated operation can be derived from the risk factor evaluation results B, B = W·R, the comprehensive evaluation results of the risk factors are as follows:

$$B_1 = W_1 \cdot R_1 = (0.1534, 0.1444, 0.3395, 0.3627) \bullet \begin{bmatrix} 0.0847 & 0.1949 & 0.2684 & 0.2938 & 0.1582 \\ 0.1328 & 0.3842 & 0.3051 & 0.1215 & 0.0565 \\ 0.1271 & 0.2938 & 0.3701 & 0.1554 & 0.0508 \\ 0.0452 & 0.2740 & 0.3672 & 0.2203 & 0.0932 \end{bmatrix}$$

$$= (0.0917, 0.2845, 0.3441, 0.1953, 0.0835)$$

The same reasoning can be used to find that:

$$B_2 = W_2 \cdot R_2 = (0.1320, 0.2911, 0.3409, 0.1830, 0.0560)$$

$$B_3 = W_3 \cdot R_3 = (0.0844, 0.3108, 0.4034, 0.1601, 0.0413)$$

$$B_4 = W_4 \cdot R_4 = (0.0675, 0.2906, 0.4088, 0.1722, 0.0610)$$

Availability:

$$R_0 = \begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{pmatrix} = \begin{bmatrix} 0.0917 & 0.2845 & 0.3441 & 0.1953 & 0.0835 \\ 0.1320 & 0.2911 & 0.3409 & 0.1830 & 0.0560 \\ 0.0844 & 0.3108 & 0.4034 & 0.1601 & 0.0413 \\ 0.0675 & 0.2906 & 0.4088 & 0.1722 & 0.0610 \end{bmatrix}$$

Overall project evaluation result B_0:

$$B_0 = W_0 \cdot R_0 = (0.0863, 0.2956, 0.3880, 0.1733, 0.0572)$$

According to the principle of maximum affiliation, the maximum value in this evaluation vector is 0.3880, which corresponds to the risk level: medium risk, from which it is judged that the engineering risk of the project is medium.

3.5 Risk classification

In the normalised vector, the risk occurrence consequence level value of 0.225 is used as the central judging value of the intermediate level, and 0.09 is used as the judging interval of the level, and with the results of the weight calculation in Table 4 and the results of the single-factor and multi-factor evaluations, and based on the principle of the maximum degree of affiliation, the results of the risk level of the first-level indicators and second-level indicators can be obtained as follows in Table 6 and Table 7 below:

Table 6. Risk level for tier 1 indicators

	Low risk	Lower risk	Medium risk	Higher risk	Extremely high risk
Environments		√			
Materials and equipment		√			
Staffing				√	
Organisational management				√	

Table 7. Risk level for tier 2 indicators

Risk level Level 2 indicators		Low risk	Lower risk	Medium risk	Higher risk	Extremely high risk
environmental factor	environment			√		
	Social security environment		√			
	Construction environment				√	
	Site Space Layout				√	
Materials and equipment	Material Preparation			√		
	Quality of components			√		
	equipment preparation			√		
	Repair and maintenance of equipment				√	
Personnel factors	Persons other than the builder		√			
	Staffing			√		
	working skill				√	
	operating state				√	
Organisational management	security management				√	
	construction organisation			√		
	Coordination of communication		√			
	Funding for construction			√		
	Construction period requirements		√			
total		0	4	7	6	0

4 Conclusion

Bridge substructure prefabrication assembly technology belongs to the relatively new bridge construction technology, this paper for prefabricated structure facing construction experience, construction risk is higher, based on AHP-fuzzy comprehensive evaluation model using mathematical methods on the city bridge substructure prefabrication assembly construction risk quantitative analysis and research, and Urumqi East approach elevated project as an example of a specific analysis of the application of the project, can help the construction personnel to better identify the risk, so as to take measures to control and avoid the risk in advance, can better provide reference for similar projects. It can help the construction personnel to better recognize the risk, so as to take measures in advance to control and avoid the risk, and can better provide reference for similar projects. This paper concludes as follows:

(1) The project is in the "lower" risk level of four indicators, namely, social security environment, personnel outside the construction party, communication and coordination, construction period. For lower risk, it means that the probability of risk occurrence is relatively low, and the loss caused by the risk occurrence is relatively small, so this kind of risk can be accepted and tolerated.

(2) There are 7 indicators that the project is in "medium" risk level, which are natural environment, material preparation, component quality, machine preparation, construction staffing, construction organization, construction funds. For medium risk, it means that the probability of risk occurrence is moderate, and the risk occurrence will cause certain loss, for this kind of risk, general control measures should be taken to rectify and control the loss or reduce the probability of risk occurrence.

(3) There are 6 indicators in the "higher" risk level, which are construction work environment, site space layout, machinery repair and maintenance, work skills, work condition and safety management. For the higher risk, it means that the probability of its risk is greater, once the risk risk, the loss caused by the risk is also relatively large, for such risks should be focused on, and immediately rectify, to prevent the risk from occurring.

This paper takes an urban elevated bridge project in Urumqi City, Xinjiang as an example, and introduces how to establish a risk evaluation model for prefabricated assembling construction of urban substructures under high intensity region, and for the medium and high risk sources identified in this project, it should flexibly use various means to minimize the construction risk from the aspects of risk avoidance, risk control, risk transfer, risk retention, etc., which is of certain guiding significance for the construction of the project.

Acknowledgments

First, we express our gratitude to Ziqiang Bu. His insightful advice and helpful comments inspired us to improve our thinking and raised the caliber of our work. We would also like to thank Guangtai Zhang and Qiaojun Guo. Their helpful advice and kind support motivated us to complete this research.

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