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Research paper

AHP METHOD FOR RISK ASSESSMENT OF THEATRE PROJECTS

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Abstract

The construction industry experiences many issues, including high interest rates for project loans, difficulties from carbon dioxide emissions and global warming. Since the number of theatre projects is rising, risk management of theatre-style buildings has become important. This research investigates how to successfully manage risk using the Analytic Hierarchy Process, which is applied as an example on a large theatre project. This method converts subjective evaluations into indicators and combines qualitative and quantitative techniques to reduce uncertainty effectively. A risk assessment framework that ranks each risk factor and determines its importance and weight is developed. Finally, the weight and the contribution of these factors are estimated to propose the corresponding monitoring and control measures and to provide a decision-making basis for risk management of theatre projects. It is concluded that the empirical analysis of this study can help project managers to better understand risks in theatre project construction, as well as to take the corresponding measures for risk management and control. The most important risks in theatre projects are: economic risk, the delivery of stage equipment, the electricity supply to the theatre and concrete encapsulation backfill. For risk groups, the most important risk groups are: economic risk, occupational accidents and stage equipment.

Key words: *Risk Assessment, Risk Breakdown Structure, AHP method, Theatre projects.*

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1. INTRODUCTION

This study uses the Analytical Hierarchy Process (AHP) to analyse the importance of risks in theatre projects, focusing on factors such as artistry, operations, safety, government importance, and social impact [1]. AHP is a quantitative decision-making method that can decompose complex problems into multiple levels and compare and analyse them at each level to find the best solution. This method helps the project management team identify and evaluate project risks more systematically and comprehensively through hierarchical thinking [2]. In theatre projects, artistic and operational factors are the key to the success of the project, while safety is the guarantee for the smooth progress of the project. Government importance and social impact relate to the social value and public acceptance of the project. Through an AHP assessment of these factors, project managers can better understand the relative importance of each factor and their impact on the overall success of the project [3]. The advantage of AHP is its ability to deal with uncertainty and ambiguity, which are common in many decision-making processes. For example, when evaluating the artistic value of theatre design, different stakeholders may have different perspectives, and AHP allows these different perspectives to be integrated and quantified through mathematical models, resulting in a more objective and comprehensive basis for decision-making [4].

2. LITERATURE REVIEW

Risk evaluation in construction projects helps identify potential threats to people, the environment, or materials [5], addressing challenges like rising interest rates, inflation, and COVID-19 [6]. Effective risk management enhances project efficiency, minimises losses, and improves organisational resilience [7]. Risk tracking offers benefits like timely identification, cost reduction, project success, and safety assurance [8]. The integrated risk management procedure [8] is presented in Figure 1.

Figure 1. Integrated risk management

China's building projects often prioritise speed over long-term benefits, leading to a lack of risk management [9]. This lack of awareness is prevalent in the property industry, where engineering projects often face funding and financial constraints [10]. Developers aim to minimise risk and losses while minimising risk management expenses [11]. Companies are reluctant to invest in risk management due to the construction sector's insufficient consideration. The project's life cycle includes planning, design, construction, operation, and maintenance stages, each requiring risk assessment at each stage [12].

Theatre projects are prone to various risks, including design, building, economic, and legal hazards, which can arise from various causes, as illustrated in Table 1. The first column in Table 1 presents the group to which risks are associated, the second column is related to the name of risks and the third column is the source of risk from the reference.

This paper evaluates the AHP method for analysing the weight importance of project factors, aiming to improve expert judgment precision and diversity. Fuzzy models are effective for complex systems; nevertheless, they can be subjective and incorrect [13]. Monte Carlo simulation helps assess sustainability risks, but is resource-intensive and parameter-sensitive [14]. Machine learning automates prediction but can be affected by sample bias and information quality [15]. Current risk assessment methods for building projects lack consistency and accuracy [16].

Table 1. The risk factors in theatre projects

Groups	Risk factors	Reference
Economic	Tight funding supply, Inflation Increase in prices of raw materials and equipment	[9,12,16,17]
Legal	Imperfect laws cause challenges in construction	[16,17]
Social	Acceptance of the project in the local community	[3,16]
Soil	Groundwater causes soil	[2,9,16,18]
Weather	Unfavourable weather, fire, earthquake and other natural causes	[9,16,19]
Environment	Noise	[12,16]
	Construction wastewater	[9,12,16]
	Solid waste	[9,20]
	Dust and waste gas	[9,12,16]
Design phase	Design changes	[12,19,16]
	Delay in the design process	[9]
	Design errors	[16,19]
Earthworks	Breakdown of excavation equipment	[9,16]
	Layout utilities	[12]
	Pipe cushion pouring	[21]
	Installation of pipes	[22]
	Transportation of soil	[23]
Occupational accidents	Concrete encapsulation backfills	[24,25]
	Fall from height	[24,25]
	Electric shock accident	[24,25]
	Crushing and injuring people	[24,25]
	Backfill in soil excavation	[24,25]
Stage equipment	Delay in the delivery of stage equipment	[16,19,26]
	Breakdown of stage equipment	[26]
Concrete works	Poor quality of concrete	[9,16]
	Poor quality of steel bars	[9,16]
Electricity	Construction power access	[27]
HVAC system	Breakdown of HVAC	[28]
Personal management risks	Lack of experience with the project	[9,16]
	Unreasonable work arrangement	[9]
	Lack of strict technical management	[9,16]

3. METHODOLOGY

This study utilises quantitative and qualitative methods to analyse theatrical risk projection levels and priority risks, utilising AHP for comprehensive, accurate, and specific results. The research design is provided in a three-phase method: creating a Risk Breakdown Structure (RBS), designing a questionnaire for AHP and distributing it to the specialists in the construction industry for collecting data, and implementing the AHP method for the calculation of factor weights.

A questionnaire was created to assess key risks in the construction industry, focusing on education, work experience, background, projects, and hazards, using non-probability sampling and Questionnaire Star distribution. The procedure for the AHP method is as following:

The hierarchy of traits was created using empirical data and research, starting with research objectives and progressing to criteria and alternatives. Data collection began with pairwise comparisons to assess trait importance. This involved constructing contrast matrices, determining element significance, and calculating consistency ratios at each level [ref]. The procedure for AHP calculations is:

(1) Establish a judgment matrix as given in equation (1) [29]:

$$C = \begin{bmatrix} c_{11} & \cdots & c_{1n} \\ \cdots & \cdots & \cdots \\ c_{n1} & \cdots & c_{nn} \end{bmatrix} \quad (1)$$

The comparative importance of c_i and c_j is represented as element c_{ij} in the matrix. If the element is more significant, then the value of $c_{ij} > 1$; otherwise, it is insignificant. In case two risk factors are equally important, then $c_{ij} = 1$.

(2) Judgements of the importance of matrix elements are provided in Table 2.

Table 2. The relative importance ratio standard [29]

Scaling	Meaning
1	Comparing two factors, they have the same importance
3	Comparing two factors, the former factor is slightly more important than the second factor
5	Comparing two factors, the former factor is obviously more important than the second factor
7	Comparing two factors, the former factor is more important than the latter factor
9	Comparing two factors, the former factor is extremely important than the second factor
The reciprocal of the above	The two factors are compared in turn; they are the reciprocals of the original comparison value.

(3) Calculate the weight vector of each indicator:

- Normalise the matrix using the following equation (2):

$$\overline{a_{ij}} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (2)$$

where, a_{ij} is the element in the i -th row and j-th column of the judgment matrix A, and $\bar{a}_{ij}$ is the data in the i-th row and j-th column of the normalisation matrix.

- Add the elements in the matrix using the equation:

$$\overline{w_i} = \sum_{i=1}^{n} \overline{a_{ij}} \quad (3)$$

- Implement the normalization process using the equation (4):

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{n} \overline{w_{ij}}} \quad (4)$$

where w_i is the weight of the i-th element

- Calculate the maximum eigenvalue of the judgment matrix as follows:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i} \quad (5)$$

Where, n – the order of the matrix, A is the judgment matrix

(4) Consistency tests on vectors and eigenvalues are conducted to ensure a reasonable judgment matrix with explanatory value, using CI as the consistency index, and it is provided in Table 3:

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

Table 3. Random Consistency Index

N	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41

Consistency ratio is the ratio between the consistency index and the random consistency index, CR = CI/RI. The RI is obtained through the n value from Table 3. If the CR < 0.1, the detection meets the requirements.

(5) Absolutely weights:

- The absolute weight of risk factors is calculated as follows:

$$Absolute\ weight\ (risk) = Risk\ group\ weight\ x\ Risk\ factor\ Weight \quad (7)$$

4. RESULTS

In total, 110 experts in theatre projects participated in the questionnaire survey. Their educational background, working experience and job position are given in Table 4. The majority of them, around 54.5%, have graduated with a Bachelor's degree. It is estimated that 65.4% of respondents have working experience between 5 and 15 years. They are mainly working in job positions as a designer, in total 31.81% of them, followed by a civil engineer, around 25.4%.

Table 4. Respondent's background

Educational Background		Working experience		Job Position	
College degree	28	Less than 5 years	6	Project Manager	23
Bachelor degree	60	5 – 10 years	36	Civil Engineer	28
Master degree	21	10 – 15 years	36	Designer	35
PhD degree	1	15 – 20 years	23	Safety Director	24
		More than 20 years	9	Other	

The results of the weight of importance for each risk according to the AHP method are provided in Table 5. Further, the results for each group are considered. Since groups are divided into external and internal risks. The AHP method is estimated for these two groups separately. The results are provided in Tables 6 – 7.

Overall, the most important risk factor is economic risk. Economic risk includes tight funding supply, inflation, an increase in prices of raw materials, equipment and labour. For the successful completion of the theatre project, it is important to provide a sufficient budget that will cover all expenses. In the second place, it is the delay in the delivery of stage equipment. The theatre equipment can be very expensive, and some equipment is rare, and it can be designed only for special purposes. So, the purchase of theatre equipment should be done in a timely manner, giving the supplier enough time to ship the product. The other important risks are the electricity supply to the theatre and concrete encapsulation backfill, which belongs to a group of occupational accidents.

Table 5. The results for risk factors based on the AHP method

Groups	Risk factors	Weights
Economic	Tight funding supply, Inflation Increase in prices of raw materials and equipment	0.292
Legal	Imperfect laws cause challenges in construction	0.035
Social	Acceptance of the project in the local community	0.043
Soil	Groundwater causes soil	0.035
Weather	Unfavourable weather, fire, earthquake and other natural causes	0.036
Environment	Noise	0.020
	Construction wastewater	0.014
	Solid waste	0.020
	Dust and waste gas	0.005
Design phase	Design changes	0.008
	Delay in the design process	0.012
	Design errors	0.005
Earthworks	Breakdown of excavation equipment	0.002
	Layout utilities	0.002
	Pipe cushion pouring	0.002
	Installation of pipes	0.005
	Transportation of soil	0.002
Occupational accidents	Concrete encapsulation backfills	0.054
	Fall from height	0.039
	Electric shock accident	0.021
	Crushing and injuring people	0.017
	Backfill in soil excavation	0.007
Stage equipment	Delay in the delivery of stage equipment	0.070
	Breakdown of stage equipment	0.035
Concrete works	Poor quality of concrete	0.040
	Poor quality of steel bars	0.040
Electricity	Construction power access	0.062
HVAC system	Breakdown of HVAC	0.044
Personal Management Risks	Lack of experience with the project	0.004
	Unreasonable work arrangement	0.010
	Lack of strict technical management	0.015

When different groups are considered, among the external risks, the most significant is economic risk, followed by environmental risk. In case of the internal risks on projects, the most important risk groups are occupational accidents that can occur on the construction site and stage equipment, including delays in the delivery of equipment and the breakdown of equipment.

Table 6. The results for risk groups that belong to external risks

Groups	Weights
Economic	0.584
Legal	0.070
Social	0.085
Soil	0.070
Weather	0.074
Environment	0.117

Table 7. The results for risk groups that belong to internal risks

Groups	Weights
Design phase	0.050
Earthworks	0.030
Occupational accidents	0.276
Stage equipment	0.210
Concrete works	0.161
Electricity	0.125
HVAC system	0.089
Personal Management Risks	0.058

5. CONCLUSIONS

This paper uses the AHP method to determine the most important risks and groups of risks in theatre projects. Studies show that the AHP method is very useful and gives clear results when there is a need for decision-making. Also, the AHP can be applied as an addition to other methods for risk assessment. For example, the AHP can be used for determining the weight importance of risk, and the other method is for determining the risk values. According to the results, the most important risks in theatre projects are economic risk related to providing budget, inflation and changes in the cost of equipment, material and labour. In addition to economic risk factors, other important risk factors are: the delivery of stage equipment, the electricity supply to the theatre and concrete encapsulation backfill. When groups of risks are considered, the most important risk groups are: economic risk, occupational accidents and stage equipment.

REFERENCES

[1] Naji Mehdi Amine, Mousrij Ahmed, Cillo Valentina, and Chierici Roberto: **Measuring the maintenance performance through fuzzy logic and analytical hierarchy process**, *International Journal of Managerial and Financial Accounting*, Vol. 11, No. 3-4, 290-319, 2019, doi:10.46254/af03.20220192

[2] Dey, Prasanta Kumar: **Analytic hierarchy process helps evaluate project in Indian oil pipelines industry**. *International Journal of Operations & Production Management*, Vol. 24, No. 6, 588-604, 2004, https://doi.org/10.1108/01443570410538122

[3] Aucamp Ilse, and Woodborne Stephan: **Can social impact assessment improve social well-being in a future where social inequality is rife?**. *Impact Assessment and Project Appraisal*, Vol. 38, No. 2, 132-135, 2020, https://doi.org/10.1080/14615517.2019.1676068

[4] Mohammed Ahmed, Harris Irina, Soroka Anthony, Naim Mohammed, and Ramjaun Tim: **Evaluating Green and Resilient Supplier Performance: AHP-Fuzzy Topsis Decision-Making Approach**, In *ICORES*, 209-216, 2018

[5] Bernsmed Karin, Bour Guillaume, Lundgren Martin, and Bergström Erik: **An evaluation of practitioners' perceptions of a security risk assessment methodology in air traffic management projects**. *Journal of Air Transport Management*, Vol. 102, 102223, 2022, https://doi.org/10.1016/j.jairtraman.2022.102223

[6] Mahmoudi Amin, Javed Saad Ahmed, and Mardani Abbas: **Gresilient supplier selection through fuzzy ordinal priority approach: decision-making in post-COVID era**. *Operations management research*, Vol. 15, No. 1, 208-232, 2022, https://doi.org/10.1007/s12063-021-00178-z

[7] Waqar Ahsan, Othman Idris, Shafiq Nasir, Deifalla Ahmed, Ragab Adham E., and Khan Muhammad: **Impediments in BIM implementation for the risk management of tall buildings**. *Results in Engineering*, Vol. 20, 101401, 2023, https://doi.org/10.1016/j.rineng.2023.101401

[8] Kardes Ilke, Ozturk Ayse, Cavusgil S. Tamer, and Cavusgil Erin: **Managing global megaprojects: Complexity and risk management**. *International business review*, Vol. 22, No. 6, 905-917, 2013, https://doi.org/10.1016/j.ibusrev.2013.01.003

[9] Tang Wenzhe, Qiang Maoshan, Duffield Colin F., Young David M., and Lu Youmei: **Risk management in the Chinese construction industry**. *Journal of Construction Engineering and Management*, Vol. 133, No. 12, 944-956, 2007, https://doi.org/10.1061/(ASCE)0733-9364(2007)133:12(944)

[10] Cox Jr Louis Anthony: **Introduction to Engineering Risk Analysis**. *Risk Analysis of Complex and Uncertain Systems*, Boston, MA: Springer US, 35-72, 2009.

[11] Abioye Sofiat O., Oyedele Lukumon O., Akanbi Lukman, Ajayi Anuoliwapo, Delgado Juan Manuel D., Bilal Muhhamad, Akinade O. Olugbenga and Ahmed Ashraf: **Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges**. *Journal of Building Engineering*, Vol. 44, 103299, 2021, https://doi.org/10.1016/j.jobe.2021.103299

[12] Zou Patrick X.W., Zhang Guoming, and Wang Jiayuan: **Understanding the key risks in construction projects in China**. *International journal of Project Management*, Vol. 25, No. 6, 601-614, 2007, https://doi.org/10.1016/j.ijproman.2007.03.001

[13] Du Qifa, Sun Zhaobin, and Duan Zhiyun: **The performance evaluation model of troops logistics construction based on the fuzzy comprehensive evaluation method**. *IFAC Proceedings Volumes*, Vol. 46, No. 24, 224-228, 2013, https://doi.org/10.3182/20130911-3-BR-3021.00045

[14] Ildarabadi Pouria, and Alamatian Javad: **Proposing a new function for evaluation of the financial risk of construction projects using Monte Carlo method: Application on Iranian construction industry**. *Journal of Building Engineering*, Vol. 43, 103143, 2021, https://doi.org/10.1016/j.jobe.2021.103143

[15] Kristiansen Thomas Birk: **Erroneous data and drug industry bias can impair machine learning algorithms**. *Bmj*, Vol. 367,2019, https://doi.org/10.1136/bmj.l6042

[16] Andrić Jelena M., Wang Jiayuan, Zou Patrick X., Zhang Jingrong, Zhong Ruoyu: **Fuzzy logic–based method for risk assessment of Belt and Road infrastructure projects**, *Journal of Construction Engineering and Management*, Vol. *145, No.* 12, 04019082, 2019, https://doi.org/10.1061/(ASCE)CO.1943-7862.0001721

[17] Skorupka Dariusz: **Identification and initial risk assessment of construction projects in Poland**, *Journal of Management in Engineering*, Vol. 24, No. 3, 120-127,2008, https://doi.org/10.1061/(ASCE)0742-597x(2008)24:3(120)

[18] Xiang Zijing, Wu Shijin, Zhu Lizhong, Yang Kun, and Lin Daohui: **Pollution characteristics and source apportionment of heavy metal(loid)s in soil and groundwater of a retired industrial park**, *Journal of Environmental Sciences*, Vol. 143, 23-34, 2024, https://doi.org/10.1016/j.jes.2023.07.015

[19] Xie Linlin, Wu Sisi, Chen Yajiao, Chang Ruidong, and Chen Xiaoyan, **A case-based reasoning approach for solving schedule delay problems in prefabricated construction projects**, *Automation in Construction*, Vol. 154, 105028, 2023, https://doi.org/10.1016/j.autcon.2023.105028

[20] Vinti Giovanni, Bauza Valerie, Clasen Thomas, Tudor Terry, Zurbrügg Christian, and Vaccari Mentore: **Health risks of solid waste management practices in rural Ghana: A semi-quantitative approach toward a solid waste safety plan.** *Environmental Research*, Vol. 216, 114728, 2023, https://doi.org/10.1016/j.envres.2022.114728

[21] Liu Feng, Feng Wanhui, Xiong Zhe, Li Lijuan, Yang Yibo, Lin Hai, and Shen Yangjin: **Impact performance of new prestressed high-performance concrete pipe piles manufactured with an environmentally friendly technique**. *Journal of Cleaner Production*, Vol. 231, 683-697, 2019, https://doi.org/10.1016/j.jclepro.2019.05.241

[22] Carretero-Ayuso Manuel J., Moreno-Cansado Alberto, and García-Sanz-Calcedo Justo: **Occurrence of faults in water installations of residential buildings: An analysis based on user complaints**. *Journal of Building Engineering*, Vol. 27, 100958, 2020, https://doi.org/10.1016/j.jobe.2019.100958

[23] Pongtuluran Ravael Eldad, Machfudiyanto Rossy Armyn, and Suraji Akhmad: **Hazard and Risk Identification in Earthworks for Road Tunnel Construction: A Case Study of the First Road Tunnel in Kalimantan Island, Indonesia**. *International Journal of Safety & Security Engineering*, Vol. 14 No. 6, 1949 – 1961, 2024, 10.18280/ijsse.140629

[24] Abukhashabah Emad, Summan Ahmed, and Balkhyour Mansour: **Occupational accidents and injuries in construction industry in Jeddah city**. *Saudi Journal of Biological Sciences*, Vol. 27, No. 8, 1993-1998, 2020, https://doi.org/10.1016/j.sjbs.2020.06.033

[25] Cabello Antonio Trillo, Martínez-Rojas Maria, Carrillo-Castrillo Jesus A., and Rubio-Romero Juan Carlos: **Occupational accident analysis according to professionals of different construction phases using association rules**. *Safety science*, Vol. 144, 105457, 2021, https://doi.org/10.1016/j.ssci.2021.105457

[26] Yang Yishu, Yu Chenglin, and Zhong Ray Y.: **Generalized linear model-based data analytic approach for construction equipment management**. *Advanced Engineering Informatics*, Vol. 55, 101884, 2023, https://doi.org/10.1016/j.aei.2023.101884

[27] Martins Ricardo C., Bernardino Joana, and Moreira Francisco: **A review of post-construction monitoring practices used in the evaluation of transmission**

power line impacts on birds and mitigation effectiveness, with proposals for guideline improvement. *Environmental Impact Assessment Review*, Vol. 100, 107068, 2023, https://doi.org/10.1016/j.eiar.2023.107068

[28] Mosaad Salah A. A., Issa Usama Hamed, and Hassan M. Salah: **Risks affecting the delivery of HVAC systems: Identifying and analysis**. *Journal of Building Engineering*, Vol. 16, 20-30, 2018, https://doi.org/10.1016/j.jobe.2017.12.004

[29] Zayed Tarek, Amer Mohamed, and Pan Jiayin: **Assessing risk and uncertainty inherent in Chinese highway projects using AHP**. *International Journal of Project Management*, Vol. 26, No. 4, 408-419, 2008, https://doi.org/10.1016/j.ijproman.2007.05.012