doi.org/10.62683/SINARG2025.213

Research paper

RISK ASSESSMENT OF GREEN BUILDING PROJECTS WITH GREY CLUSTER METHOD

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Abstract

With the rise of green building projects in the construction industry, questions of risks in project implementation have become increasingly prominent. The green building industry showcases new design concepts, material applications, innovations in green technologies, energy efficiency and carbon dioxide emission reduction. This study adopts the grey cluster assessment method for risk evaluation to improve the risk management ability of green building projects. Through the theory and method of grey mathematics, the subjective assessment of risk factors is transformed into grey quantitative indicators, and the uncertainty in the evaluation process is effectively dealt with by combining qualitative and quantitative research methods. The green building risk assessment index system is established, the relative importance of each risk factor is judged by experts, and the contribution of each factor to the overall risk is calculated. Finally, the analysis identifies the key risk factors that need to be focused on mitigation and control, and puts forward the corresponding risk countermeasures, which provide scientific decision support for the risk management of green building projects. The key risk factors in green building projects in China are: construction accidents, design errors, inaccurate GB investment estimation, absence of site-specific design considerations, designs with poor constructability and the quality problems of GB materials. While the least critical risks in GB projects are the deterioration of GB materials during the operation and maintenance period, unclear responsibility sharing for future upgrades, absence of regular maintenance of equipment and innovative equipment for assembling GB products.

Keywords: *Green Building projects, Sustainable development, Risk assessment, Grey cluster method, China*

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1. INTRODUCTION

In the 21st century, green building (GB) as a new trend in the construction industry has become an important aspect to promote sustainable development [1]. The construction sector in China has made progress in low-carbon, healthy and high-quality development. The GB industry is promoting new design concepts, energy efficiency, material applications, and technology integration [2]. With the global aim of energy conservation, emission reduction, environmentally friendly materials, and a healthy life, as well as the improvement of policy support, technological progress and public awareness, the GB industry has entered a period of rapid development, and the demand for GB projects will continue to rise [3]. The global investment opportunities in GB projects are expected to reach $24.7 trillion by 2030, with the main potential in Asia [4]. Due to the novel technologies and materials, complexity, uncertainty and innovations involved in GB projects, risks can increase significantly in the implementation phase of a project. As a result, it can lead to project failure, overbudget or delay [5]. For example, 32.3% of GB projects were delayed in Singapore, compared to 15.9% of traditional building projects that experienced time overrun [6]. From this study, it is concluded that GB projects are more prone to delays compared to traditional construction projects. The average delay of GB projects in Singapore was 4.8% of the planned schedule. Due to their uniqueness, their development is challenged by various risk factors, and the success rate is doubtful. The ensuing economic losses and social impacts are profound and hinder the development of the GB industry. According to the analysis of several reasons for the failure of GB projects, one of the key reasons for the failure is the lack of a comprehensive risk assessment and management approach [7]. The current studies show that spending a part of the budget on decision-making for risk management will increase the rate of project successful delivery [8]. To avoid the failure of GB projects, risk assessment and management capabilities must be enhanced to establish risk mitigation, response and control strategies in advance and prevent them from occurring.

The aims of this paper are: (1) to identify the key risk factors through in-depth analysis and assessment of the risks of GB projects in China; (2) to establish a systematic rating framework by constructing a comprehensive evaluation index system including main stages, key links, and related indicators; and (3) to calculate the grey clustering coefficient of each indicator and to reflect the risk contribution of each evaluation index. This study applies the grey cluster evaluation method to conduct an in-depth analysis of the risks in GB projects, aiming to identify and quantify the specific impact of potential risk factors on the implementation of GB projects, so as to provide scientific assessment tools and decision support for project management teams. Grey clustering method is a process of aggregating objects to be evaluated into several categories based on the grey relational matrix and the whitening power function of grey numbers [9]. The coefficients for risk factors can be determined by expert evaluation and actual data, and by performing a comprehensive grey clustering assessment. Based on the assessment results and risk classification, risk management and response measures are proposed to reduce the negative impact on the project. The risk assessment of GB projects is particularly complex because it involves multiple dimensions such as environmental sustainability, economic benefits, social acceptance, policy support and technical feasibility. The importance of risk assessment in GB projects is being taken seriously gradually by the industry.

2. LITERATURE REVIEW

In recent years, there has been growing research interest in the risks associated with GB projects, and discussion around the topic has increased. To reduce the risks existing in GB projects, more reasonable planning and management of projects should be carried out after sufficient risk identification. Zhenxiang Shi et al. have adjusted and modified the project management methods in the whole project lifecycle based on traditional construction projects [10]. To summarise the method suitable for GB project management, the intersection of different disciplines should be considered comprehensively in the early establishment of a project team. Many developed countries have successively issued GB standards and evaluation systems suitable for their respective national conditions, such as LEED developed by the United States Green Building Council [11], BREEAM developed by the British Building Research Centre [12], and CASBEE established by the Japanese Ministry of Environmental Protection [13]. Some countries have developed their national GB standards and assessment systems to promote the development of GB and to deepen the understanding of the role of green. The project lifecycle includes four stages: planning phase, design, construction, and operation and maintenance [14]. The list of risk factors in green building projects is provided in Table 1.

Table 1. The risk factors in GB projects

Groups	Risk factors	Reference
Decision making and planning	R_{11}: Inexperienced green building consultants	[15, 16]
	R_{12}: Incomplete green building law and regulations	[16,17,18]
	R_{13}: Misaligned green building project objectives	[5]
	R_{14}: Inaccurate green building investment estimation	[5,16,19]
Design phase	R_{21}: Poor quality of GB design schemes	[16, 20]
	R_{22}: GB design innovations	[5,16]
	R_{23}: Designs with poor constructability	[19,21]
	R_{24}: Absence of site-specific design considerations	[5,22]
	R_{25}: Design changes	[5,16,19]
	R_{26}: Design errors	[16,21]
Construction phase	R_{31}: Lack of GB construction experience personnel	[5,16,17]
	R_{32}: Innovative equipment for assembling GB products	[17,19]
	R_{33}: Lack of products meeting GB requirements	[16,18]
	R_{34}: Changes in the price of labour	[5,19]
	R_{35}: The quality problems of GB materials	[5,16,19]
	R_{36}: Changes in the prices of GB materials	[5,16,19]
	R_{37}: Construction accidents	[5,16,19]
	R_{38}: Delays in material and equipment delivery	[16,19]
	R_{39}: Influence of weather on GB materials	[16,23]
	$R_{3,10}$: Lack of suppliers for GB materials	[5,24]
	$R_{3,11}$: Force Majeure	[16,24]
Operation and maintenance phase	R_{41}: Lack of experienced property management	[5,16,25]
	R_{42}: Absence of regular maintenance of equipment	[26]
	R_{43}: Unclear responsibility sharing for future upgrades	[27]
	R_{44}: Deterioration of GB materials	[27]
	R_{45}: Lack of maintenance of GB materials	[5,27]

3. METHODOLOGY

The specific steps of the proposed methodology for risk evaluation in GB projects are highlighted in Figure 1. To conduct a reasonable and effective evaluation of GB risks, the first step is to identify all risks that are associated with GB projects. The risk identification process is carried out through a literature review. The selected risks in GB projects are outlined in Table 1. Once the risks are identified, the second step is to establish the risk assessment levels. In this case, the risk factors are divided into groups according to which project lifecycle phase they belong to. The groups represent a higher level of risk. In the hierarchy, the highest level is GB projects. The third is to design a questionnaire. Based on the list of risks identified in the literature review, a questionnaire was created for this study. The questionnaire was structured into two sections: the first section is the background of respondents, including their working experience and education; the second part is to evaluate risk factors. This study uses non-probabilistic sampling methods, including purposeful sampling and snowball sampling, which can identify the key risks in the construction industry. The questionnaire was distributed to construction practitioners, especially those who specialise in GB projects (purposeful sampling). Each expert will answer a questionnaire. They will use a *Questionnaire Star* to answer questions. When data is collected, a grey clustering evaluation method is applied to calculate grey weights for coefficients. By professional judgments in the risk evaluation index system, the evaluation level of each risk in GB projects is calculated.

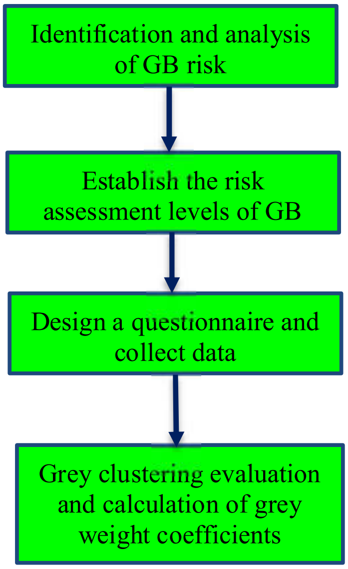

Figure 1. The proposed methodology for identifying the critical risk in GB projects

Grey clustering method is based on an observation index that can be grouped into several categories of definition methods. A clustering process is a collection of observed objects which belong to the same class. The evaluation indicator for clustering is a dynamic interval, referred to as a grey number, denoted by "⊗". The whitening weight function can indicate the degree of closeness of the evaluated object to the grey number within this dynamic interval. In the context of risk evaluation, it is assumed that there are m evaluation objects and n evaluation indicators, with s different grey classes. The clustering sample value of the i (*i = 1,* *2, ..., m*) evaluation object concerning j (*j = 1, 2, ..., n*) indicator is represented as D_{ij}. The matrix representation of the evaluation samples is as follows:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \cdots & \cdots & \cdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Grey class (s = 1, 2, ... w) represents the risk levels of the evaluation indicators. The risk levels in this paper are categorised as very low risk, low risk, medium risk, high risk, and very high risk, corresponding to the "first grey class", "second grey class", ... and "fifth grey class," respectively. The risk level sequence number for each grey class is s = 1, 2, ... 5.

Experts within the dynamic range of grey numbers have different levels of expectation for different values of X, which correspond to the numerical values of the grey variable X at different levels. The typical expressions and schematic diagrams of the whitening weight functions is shown in Figure 2 below：

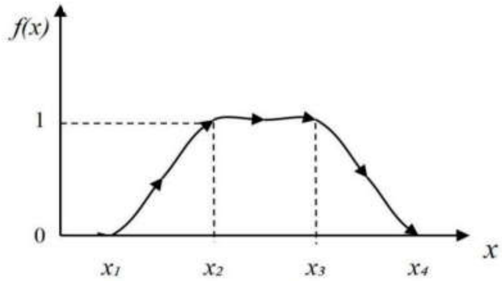

Figure 2. The example of the typical whitening weight function

where, *f* (*xij*) - the weight of the grey number *x*, which can be referred to as the whitening weight function of *x*.

$$f(x) = \begin{cases} 0, & x \notin [x_1, x_4] \\ \frac{x-x_1}{x_2-x_1}, & x \in [x_1, x_2] \\ 1, & x \in [x_2, x_3] \\ \frac{x_4-x}{x_4-x_3}, & x \in [x_3, x_4] \end{cases} \tag{2}$$

The risk level of the first grey category is denoted as "*very low risk*", and the assigned grey number $\otimes 1 \in [0, 1, 2]$, where numbers represent the threshold and the range of values is between 0 and 2. The whitening weight function is given in equation 3, and the graph for this function is illustrated in Figure 3 below:

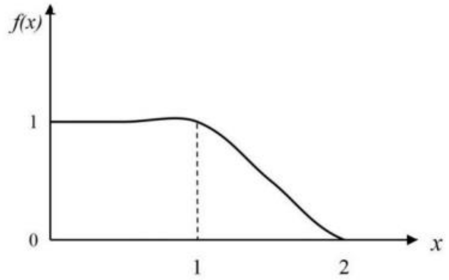

Figure 3. The whitening weight function for grey cluster number $\otimes 1$

$$f_1(x) = \begin{cases} 1, & x \in [0,1] \\ \frac{2-x}{2-1}, & x \in [1,2] \\ 0, & x \notin [0,2] \end{cases} \tag{3}$$

The risk level of the second grey category is denoted as "*low risk*", and the assigned grey number ⊗ 2 ∊ [0, 2, 4]. The whitening weight function is given in equation 4, and the graph for this function is illustrated in Figure 4 below:

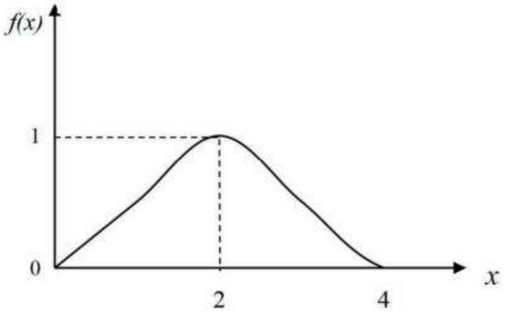

Figure 4. The whitening weight function for grey cluster number ⊗ 2

$$f_2(x) = \begin{cases} \frac{x}{2}, & x \in [0,2] \\ \frac{4-x}{2}, & x \in [2,4] \\ 0, & x \notin [0,4] \end{cases} \tag{4}$$

Similarly, the risk level of the third grey category is denoted as "*moderate risk*", and the assigned grey number ⊗ 3 ∊ [0, 3, 6]. The whitening weight function is given in equation 5, and the graph for this function is illustrated in Figure 5 below:

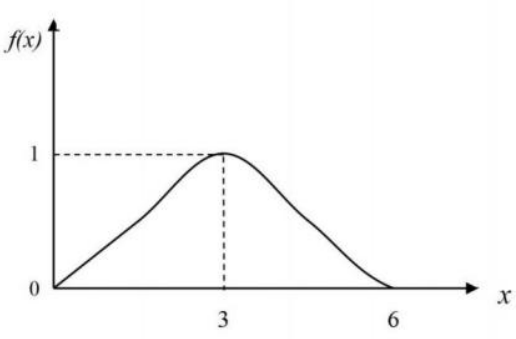

Figure 5. The whitening weight function for grey cluster number ⊗ 3

$$f_3(x) = \begin{cases} \frac{x}{3}, & x \in [0,3] \\ \frac{6-x}{3}, & x \in [3,6] \\ 0, & x \notin [0,6] \end{cases} \tag{5}$$

Similarly, the risk level of the fourth grey category is denoted as "*high risk*", and the assigned grey number ⊗ 4 ∊ [0, 4, 8]. The whitening weight function is given in equation 6, and the graph for this function is illustrated in Figure 6 below:

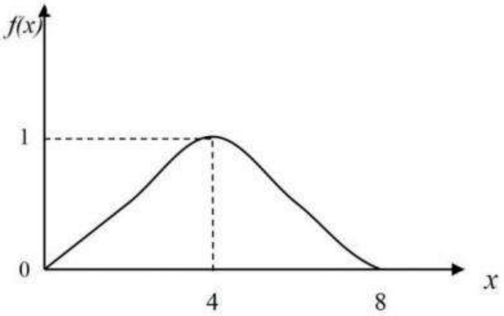

Figure 6. The whitening weight function for grey cluster number ⊗ 4

$$f_4(x) = \begin{cases} \frac{x}{4}, & x \in [0,4] \\ \frac{8-x}{4}, & x \in [4,8] \\ 0, & x \notin [0,8] \end{cases} \tag{6}$$

The risk level of the fifth grey category is denoted as “*very high risk*”, and the assigned grey number ⊗ 5 ∊ [0, 5, 10]. The whitening weight function is given in equation 7, and the graph for this function is illustrated in Figure 7 below:

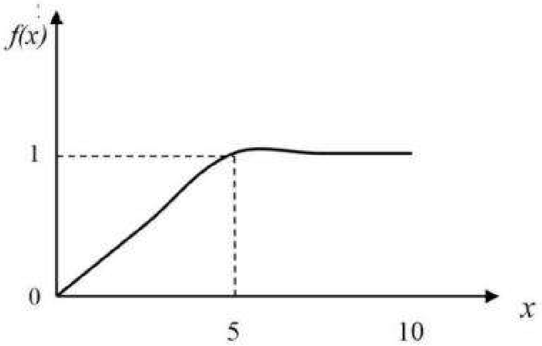

Figure 7. The whitening weight function for grey cluster number ⊗ 5

$$f_5(x) = \begin{cases} \frac{x}{5}, & x \in [0,5] \\ \frac{10-x}{5}, & x \in [5,10] \\ 0, & x \notin [0,10] \end{cases} \tag{7}$$

The evaluation coefficient for the level *s* grey class is denoted as $\eta_{ij,s}$ and the calculation formula is:

$$\eta_{ij,s} = \sum_{k=1}^{m} f_s(\eta_{ij,k}) \tag{8}$$

where, m – the number of experts

The sum of all grey classes in the evaluation index is η_{ij} and it is calculated by the formula:

$$\eta_{ij} = \sum_{k=1}^{s} f(\eta_{ij,k}) \tag{9}$$

The next step is to calculate the grey weight vector for the level s grey class of secondary index:

$$R_{ij.s} = \frac{\eta_{ij,s}}{\eta_{ij}} \tag{10}$$

Then, the weight vector Rij for the *j-th* risk belonging to *i-th* group is:

$$R_{ij} = [R_{ij,1}\,, R_{ij,2}\,, R_{ij,3}\,, R_{ij,4}\,, R_{ij,5}] \tag{11}$$

The risk evaluation levels are five, and the corresponding numerical values for risk levels are: P = [1, 2, 3, 4, 5]. The evaluation grade G for each risk can be calculated as follows:

$$G_{ij} = R_{ij} * P^T \tag{12}$$

4. RESULTS AND DISCUSSIONS

Table 2 provides information about the respondents' educational background, working experience and job position in the company. Workers in the GB industry show a variety in working experience, job positions and educational backgrounds. In total, 40 professionals in the GB industry have participated in a questionnaire survey. More than half of the respondents, 62.5% of them, have a college degree. Regarding working experience, 50% of them have between 10 and 20 years of working experience in the GB industry. Mainly, 50% of them are employed as project engineers in the company.

Table 2. Respondent's background

Educational Background		Working experience		Job Position	
College degree	25	Less than 5 years	5	Project Manager	6
Bachelor degree	10	5 – 10 years	7	Civil Engineer	20
Master degree	5	10 – 15 years	12	Designer	8
PhD degree	0	15 – 20 years	8	Safety Director	6
		More than 20 years	8	Other	0

Firstly, the clustering coefficient of each index is calculated. For example, the evaluation of risk R_{11} for the grey grade is calculated:

Class s = 1: $\eta_{11,1} = \sum_{k=1}^{40} f_1(\eta_{11,k}) = f_1(\eta_{11,1}) + f_1(\eta_{11,2}) + \cdots + f_1(\eta_{11,40}) = 1.5$

Class s = 2: $\eta_{11,2} = \sum_{k=1}^{40} f_2(\eta_{11,k}) = f_2(3) + f_2(3.5) + \cdots + f_2(3) = 30.75$

Class s = 3: $\eta_{11,3} = \sum_{k=1}^{40} f_3(\eta_{11,k}) = f_3(3) + f_3(3.5) + \cdots + f_3(3) = 27.50$

Class s = 4: $\eta_{11,4} = \sum_{k=1}^{40} f_4(\eta_{11,k}) = f_4(3) + f_4(3.5) + \cdots + f_4(3) = 30.25$

Class s = 5: $\eta_{11,5} = \sum_{k=1}^{40} f_5(\eta_{11,k}) = f_5(3) + f_5(3.5) + \cdots + f_5(3) = 28.5$

The sum of the grey clustering evaluation coefficient η_{11} and the weight vector R_{11} is:

$$\eta_{11} = \sum_{k=1}^{5} f(\eta_{11,k}) = 1.5 + 30.75 + 27.5 + 30.25 + 28.5 = 118.5$$

$$R_{11} = \left[R_{11,1}\,, R_{11,2}\,, R_{11,3}\,, R_{11,4}\,, R_{11,5}\right] = [0.01, 0.26, 0.23, 0.26, 0.24]$$

The evaluation grade for risk R_{11} is:

$$G_{11} = R_{11} * P^T = [0.01, 0.26, 0.23, 0.26, 0.24] * [1, 2, 3, 4, 5]^T = 3.46$$

Similarly, the values for each risk are calculated based on this procedure. The results are shown in Table 3. The experts have evaluated that the most critical risks in GB projects are construction accidents, design errors, inaccurate GB investment estimation, absence of site-specific design considerations, designs with poor constructability and the quality problems of GB materials. Inaccurate GB investment estimation is ranked the highest among the risks in the group decision-making and planning phase. Hence, the accurate budget estimation in the planning phase and allocation of resources are important for the successful completion of the GB project. In the design phase, three risks appear among the critical risks. Site-specific considerations are essential for ensuring that the building is well-suited to the environment and can further affect operational efficiency. Poor constructability can affect the project timeline and cost as well as the ability to execute the design as planned. Design errors can contribute to delays in the project, rework and increased cost. Hence, there is a need for thorough design review and quality control. The highest-ranked risk is construction accidents from the construction phase. Safety on a construction site is essential. Some of the measures are that workers have proper training for the GB industry and wear health and safety equipment during their work. For monitoring workers and inspecting whether they wear proper equipment, the project manager is responsible.

Table 3. The values for risk factors in GB projects

Groups	Risk factors	Value
Decision making and planning	R_{11}: Inexperienced green building consultants	3.46
	R_{12}: Incomplete green building law and regulations	3.13
	R_{13}: Misaligned green building project objectives	3.16
	R_{14}: Inaccurate green building investment estimation	4.10
Design phase	R_{21}: Poor quality of GB design schemes	3.39
	R_{22}: GB design innovations	3.46
	R_{23}: Designs with poor constructability	3.84
	R_{24}: Absence of site-specific design considerations	4.07
	R_{25}: Design changes	3.80
	R_{26}: Design errors	4.41
Construction phase	R_{31}: Lack of GB construction experience personnel	3.39
	R_{32}: Innovative equipment for assembling GB products	2.84
	R_{33}: Lack of products meeting GB requirements	3.48
	R_{34}: Changes in the price of labour	3.29
	R_{35}: The quality problems of GB materials	3.84
	R_{36}: Changes in the prices of GB materials	3.36
	R_{37}: Construction accidents	4.44
	R_{38}: Delays in material and equipment delivery	3.58
	R_{39}: Influence of weather on GB materials	2.92
	$R_{3,10}$: Lack of suppliers for GB materials	3.82
	$R_{3,11}$: Force Majeure	3.55
Operation and maintenance phase	R_{41}: Lack of experienced property management	3.80
	R_{42}: Absence of regular maintenance of equipment	2.84
	R_{43}: Unclear responsibility sharing for future upgrades	2.74
	R_{44}: Deterioration of GB materials	2.74
	R_{45}: Lack of maintenance of GB materials	3.43

On the other hand, the least critical risks are the deterioration of GB materials during the operation and maintenance period, unclear responsibility sharing for future upgrades, absence of regular maintenance of equipment and innovative equipment for assembling GB products. These risks are mainly in the operation and maintenance phase.

5. CONCLUSIONS

In this study, the grey cluster assessment method is used to assess and manage the risks in GB projects. Initially, a combination of literature review analysis and survey methods is employed to identify potential risk factors that could impact the results of the project lifecycle, followed by the development of a corresponding risk assessment structure. Finally, this study applies the grey comprehensive assessment method to explore in depth and assess every risk in GB projects and detect the most critical risks. This study shows that the most critical risks are: construction accidents, design errors, inaccurate GB investment estimation, absence of site-specific design considerations, designs with poor constructability and the quality problems of GB materials. Half of these risks belong to the design phase. Hence, the design phase is a critical phase, and additional attention needs to be paid in the design phase. At the same time, the research also puts forward the corresponding risk mitigation measures and ideas, aiming to provide scientific decision support for the risk management of GB projects. On the other hand, the least critical risks in GB projects are the deterioration of GB materials during the operation and maintenance period, unclear responsibility sharing for future upgrades, absence of regular maintenance of equipment and innovative equipment for assembling GB products. The findings show that the maintenance and operation phase is the least critical phase. The future direction is to implement the combinations of different methods and the grey cluster method to assess the risks in GB projects and the overall risk of a project. Further.

REFERENCES

[1] Li Qianwen, Long Ruyin, Chen Hong, Chen Feiyu, and Wang Jiaqi: **Visualized analysis of global green buildings: Development, barriers and future directions.** *Journal of Cleaner Production*, Vol. *245*, 118775, 2020, https://doi.org/10.1016/j.jclepro.2019.118775

[2] Matloob Huma: **Towards Sustainable Architecture: Exploring Innovative Materials, Construction Technology, and Design Concepts for Eco-Friendly Buildings**, *Engineering Headway*, Vol. 11, 35-43, 2024: https://doi.org/10.4028/p-wB5308

[3] Zhang Yinqi, Wang He, Gao Weijun, Wang Fan, Zhou Nan, Kammen Daniel M., and Ying Xiaoyu: **A survey of the status and challenges of green building development in various countries**, *Sustainability*, Vol. 11, No. 19, 5385, 2019, https://doi.org/10.3390/su11195385

[4] Likhacheva Sokolowski, Irina, Aditi Maheshwari, and Ayesha Malik: **Green buildings: a finance and policy blueprint for emerging markets**, 2019.

[5] Nguyen Hung Duy and Macchion Laura, **Exploring critical risk factors for Green Building projects in developing countries: The case of**

Vietnam, *Journal of Cleaner Production*, Vol. 381, 135138, 2022, https://doi.org/10.1016/j.jclepro.2022.135138

[6] Hwang Bon-Gang, Xianbo Zhao, and Lene Lay Ghim Tan: **Green building projects: Schedule performance, influential factors and solutions**, *Engineering, Construction and Architectural Management*, Vol. 22, No. 3, 327-346, 2015, https://doi.org/10.1108/ECAM-07-2014-0095

[7] Wang Lina, Chan Daniel W., Darko Amos, and Oluleye, Benjamin I.: **A state-of-the-art review of risk management process of green building projects**, *Journal of Building Engineering*, Vol. 86, 108738, 2024, https://doi.org/10.1016/j.jobe.2024.108738

[8] Papadaki, D. M., Bakas, D. N., Ochieng, E. G., Karamitsos, D. I., & Kirkham, D. R. (2019). Big data from social media and scientific literature databases reveals relationships among risk management, project management and project success. *Project Management and Project Success (September 26, 2019)*.

[9] Naiming Xie, Bentao S. U., and Nanlei Chen: **Construction mechanism of whitenization weight function and its application in grey clustering evaluation**, *Journal of Systems Engineering and Electronics*, Vol. 30, No. 1, 121-131, 2019, DOI: 10.21629/JSEE.2019.01.12

[10] Shi Zhenxiang: **Research on Realization Approach of Green Building Based on Project Life Cycle Theory**, *International Conference on Construction and Real Estate Management 2019*. Reston, VA: American Society of Civil Engineers, 2019.

[11] Ghazal Iyad, and Sameh Monna: **Green building progress assessment: analysis of registered and certified buildings for LEED rating system**, *An-Najah University Journal for Research-A (Natural Sciences)*, Vol. 38, No.2, 137-142, 2024, https://doi.org/10.35552/anujr.a.38.2.2212

[12] Agha Azra, Shibani Abdussalam, Hassan Dyaa Hassa and Salmon Alexander, **Building research establishment environmental assessment methodology on the UK residential projects**, *International Journal of Construction Engineering and Management*, Vol. 9, No. 6, 183-189, 2020, 10.5923/j.ijcem.20200906.01

[13] Mahan Amin and Khorramrouei Reihaneh: **CASBEE Assessment System, a Technical Approach to Assessing the Environmental Sustainability of Green Buildings in Japan**, *Journal of Renewable and New Energy*, Vol. 10, No. 1, 177-187, 2023, https://doi.org/10.52547/jrenew.10.1.177

[14] Koc Kerim, Kunkcu Handan, and Gurgun Asli Pelin: **A life cycle risk management framework for green building project stakeholders**, *Journal of Management in Engineering*, Vol. 39, No. 4, 04023022, 2023, https://doi.org/10.1061/JMENEA.MEENG-53

[15] Zainul Abidin Nazirah, and Shariffuddin Nadia Alina Amir: **Engaging consultants in green projects: exploring the practice in Malaysia**, *Smart and Sustainable Built Environment*, Vol. 8. No. 1, 80-94, 2019, https://doi.org/10.1108/SASBE-06-2018-0033

[16] Wuni Ibrahim, Bao Zhikang, Yevu S. Kwame, and Tetteh Mershack O.: **Theorizing the path dependencies and hierarchical structure of the multidimensional risks in green building projects**, *Journal of Building Engineering*, Vol. 68, 106069, 2023, https://doi.org/10.1016/j.jobe.2023.106069

[17] Guan Li, Abbasi Alireza, and Ryan Michael J.: **Analyzing green building project risk interdependencies using Interpretive Structural Modeling**, *Journal of Cleaner Production*, Vol. 256, 120372, 2020, https://doi.org/10.1016/j.jclepro.2020.120372

[18] Ifeanyichukwu Nkeleme Emmanuel, Anosike Nwabueze Michael, Ikenna Achigbu Onyemaeze, and Chidiebere Ukwunna Okechukwu: **Militating factors against the practice of green building as a new paradigm in construction projects**, *International Journal of Sustainable and Green Energy*, Vol. 10, No. 1, 13 – 18, 2021, doi: 10.11648/j.ijrse.20211001.13

[19] Zhao Xianbo, Hwang Bon-Gang, and Gao Yan: **A fuzzy synthetic evaluation approach for risk assessment: a case of Singapore's green projects**, *Journal of Cleaner Production*, Vol. 115, 203-213, 2016, https://doi.org/10.1016/j.jclepro.2015.11.042

[20] Verma Saurabh, Mandal Satya N., Robinson Spenser, Bajaj Deepak, and Saxena Anupam: **Investment appraisal and financial benefits of corporate green buildings: a developing economy case study**, *Built Environment Project and Asset Management*, Vol. 11, No. 2, 392-408, 2021, https://doi.org/10.1108/BEPAM-06-2020-0108

[21] Raouf Ayman M., and Al-Ghamdi Sami G.: **Framework to evaluate quality performance of green building delivery: project brief and design stage**, *Buildings*, Vol. 11, No. 10, 473, 2021, https://doi.org/10.3390/buildings11100473

[22] Yasinta Rezi Berliana, Pradana Muhammad Aldino, and Dahlia Dahlia: **Analyzing Green Building of Appropriate Site Development Requirements in High Rise Building**, *Jurnal Presipitasi: Media Komunikasi dan Pengembangan Teknik Lingkungan*, Vol. 21, No. 1, 132-143, 2024, https://doi.org/10.14710/presipitasi.v21i1.132-143

[23] Patil Monika, Samrudhi Boraste, and Pravin Minde: **A comprehensive review on emerging trends in smart green building technologies and sustainable materials**, *Materials Today: Proceedings*, Vol. 65, No. 2, 1813-1822, 2022, https://doi.org/10.1016/j.matpr.2022.04.866

[24] Zhang Zhiying, Liao Huchang, Chang Jiaying, and Al-barakati Abdullah: **Green-building-material supplier selection with a rough-set-enhanced quality function deployment**, *Sustainability*, Vol. 11, No. 24, 7153, 2019, https://doi.org/10.3390/su11247153

[25] Syamim Jaafar and Nor Aini: **A Review of Property Managers' Competency in Managing Green Buildings**, *Malaysian Journal of Sustainable Environment*, Vol. 3, No. 2, 1-29, 2017, https://ir.uitm.edu.my/id/eprint/29479

[26] Ismail Zul-Atfi: **Improving maintenance management practices on green building projects**, *Management of Environmental Quality: An International Journal*, Vol. 31, No. 4, 803-817, 2020, https://doi.org/10.1108/meq-05-2019-0093

[27] Liu Xiaojun, and Liu Xiaodan: **Analysis of the evolution game of stakeholders' behaviour in the operation stage of green buildings**, *Current Science*, Vol. 117, No. 5, 821-829, 2019, https://doi.org/10.18520/cs/v117/i5/821-829