



Construction of a Risk Assessment System for Green Transformation of Urban Buildings Based on K-means Clustering

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Abstract. In the context of the new era, people's yearning for a better life requires the construction field to provide a more comfortable and healthy living environment in a greener, environmentally friendly and efficient way. The green transformation of existing buildings often involves more stakeholders, and the risk factors associated with them are also more difficult to manage due to complex interest relationships, which greatly inhibits the enthusiasm of project sponsors to invest and residents to transform. In this paper, the k-means clustering algorithm is used to conduct risk network centrality analysis, risk network connection hub analysis, and risk factor influence analysis to study the role and influence of risk factors related to various stakeholders in the structure and dissemination of risk networks. It is found that there is a lack of effective daily operation feedback mechanism, uneven ability of management personnel, poor professional ability, lack of relevant professional and technical personnel, construction funds cannot be in place in time, and engineering changes. These risks occur most frequently in the green transformation of urban buildings. Risks with the characteristics of connecting hubs have a greater influence on the spread of risk networks and the closeness of risk relationships than risks with the characteristics of risk sources.

Keywords: Urban Architecture, Green Transformation, Risk Assessment, k-means Clustering Algorithm

1 Introduction

Green buildings are superior to the original buildings in all environmental, economic and social indicators, and represent the next stage of architectural development. However, in view of the disparity between existing buildings and new green buildings, green transformation of stock buildings is an effective way to solve the greenhouse effect and achieve sustainable development. The green transformation of existing residential buildings is a process of promoting the coordinated development of buildings, resources and the environment. The core concept of “people-oriented” should be adhered to, and the basic strategy of “adapting to local conditions, pursuing

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effectiveness, and rationally improving” should be adopted, so as to effectively promote the sustainable development of the green transformation of existing residential buildings in our country.

D'Oca S presented the findings from the joint seminars and interactive discussions for the rehabilitation of green buildings, concentrating on the technical, financial, and social added value, impediments, and challenges in the process of building renovation dealt with by the four projects. [1]. Using commercially available life cycle assessment software that adheres to the norms of the European Commission for Standardization, Ramirez-Villegas R examined four distinct renovation possibilities (CEN). It was discovered that changing the gadget had a similar environmental impact to adding ventilation and renovating building facilities. Additionally, operational energy use and the construction and installation operations are the life cycle activities that always have the biggest negative environmental effects. The effect of change orders on cost and schedule was researched by Shrestha P P. According to this study's findings, unanticipated, owner-initiated, and design-related change orders considerably increased these projects' schedule overruns.

The reuse of old buildings has become a comprehensive social issue of strong practical significance. The rational utilization of the original abandoned and idle resources has high ecological and environmental benefits; it can retain the characteristics of the local cultural context and has high social and cultural benefits .However, a series of problems such as incomplete engineering regulations and policies during the renovation and reuse, prominent contradictions in the reuse process, lack of technical standards, and lack of renovation experience make it easy to expose various risks during the renovation and reuse of old buildings, and effective risk identification, evaluation, and control of old building reuse projects have a greater role.

2 Risk Assessment of Green Transformation of Urban Buildings

2.1 Green Building renovation

Green transformation can reduce the use of energy and improve the utilization rate of resources during the entire construction phase, which is in line with the requirements of environmental sustainability. The use of land has a great impact on the natural environment, such as changes in ecosystems and biodiversity, as well as reducing the quality of air and water resources, causing irreparable damage to the living environment of humans and animals. Therefore, even if the economic cost increases, the environmental and social benefits will affect the decision whether to carry out the transformation [2].

The demand for the green transformation of existing residential buildings mainly includes the following aspects: transformation and regeneration design, structural reinforcement and seismic performance improvement, functional improvement, application of green building materials, energy-saving transformation, renewable energy utilization, and environmental improvement [3].

The design of the transformation plan should be based on the evaluation results, while paying attention to the needs of energy-using units and the impact of the transformation work on the environment [4]. The design work must take feasibility, economy and applicability as the design principles, and proceed to the comprehensive design of the building's energy-consuming equipment, peripheral protection materials, and water supply and drainage systems. The design content and process should strictly follow the published "Energy-saving Design Standards for Public Buildings".

2.2 Risk Management Theory

Risk is a multifaceted concept, usually defined as the probability that a destructive event will occur in a project and affect the goal. However, risk is not always related to negative results, and in some cases it is also regarded as an opportunity, but in fact, most risks usually have negative results so that risk research only focuses on the negative of risk. In order to achieve the highest level of risk elimination, mitigation, and control, risk management is an organised process of methodically identifying, assessing, and responding to risks throughout the life cycle of a project. The effectiveness of risk management in construction project management can be significantly increased.

The early identification of any possible hazards connected to the construction project is the first step in the risk management process. Only after identifying possible risks can the risk analysis and reaction management procedure be carried out. The ties in between risk identification and management are risk analysis and evaluation. To evaluate the possible consequences of risks, it uses both quantitative and qualitative uncertainties. Once the project's hazards have been identified and examined, suitable risk management strategies must be established. Project managers should decide how to handle each risk and create the proper risk response strategies or mitigation measures within the scope of risk management. These mitigating actions are often determined by the type of risk and its possible effects. Its key objectives are to reduce potential effects as much as possible and raise the bar for risk management. The goal of the risk management process is to create a structured framework to assist decision-makers in efficiently and effectively managing risks, particularly important ones. It is not intended to totally eradicate all risks from the project.

2.3 Risk Assessment

Risk identification is to collect a large amount of relevant information and use certain methods to make judgments on the risks and causes at all stages of the project before the risk occurs, identify the main risk factors that affect the success of the project, and analyze the degree of impact. The risks of old building renovation projects are diverse, random and policy-influencing. The complex risks are brought together, which brings many difficulties to the correct and comprehensive identification of the risks in the renovation process, and scientific methods must be adopted. The risk identification process of general projects is shown in Figure 1.

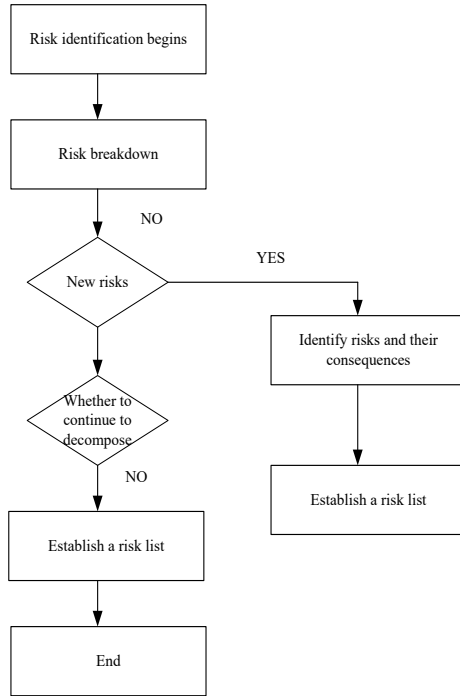


Fig. 1. Risk identification process

On the basis of fully drawing on domestic and foreign research results, this article combines the specific situation of old building renovation projects in our country and its own characteristics to identify risks in the entire process of old renovation projects.

Due to its own particularities, old building renovation projects are different from general real estate development projects in terms of land use, construction process and methods. Through theoretical analysis, the paper believes that the risk identification of old building renovation projects should be phased, progressive, and hierarchical. Therefore, it is necessary to analyze and identify the risks in the whole process of old building renovation and reuse projects in stages and layer by layer [5]. Referring to the division of the life cycle of construction projects, according to the different content, nature and functions of each stage of work, the details are shown in Figure 2.

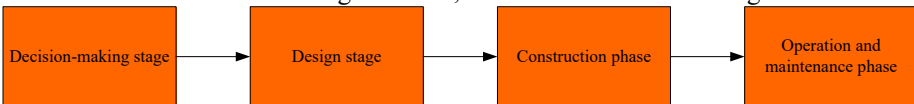


Fig. 2. Risk identification and division stage

Figure 3 shows the number of green retrofits of existing buildings in our country from 2012 to 2020.

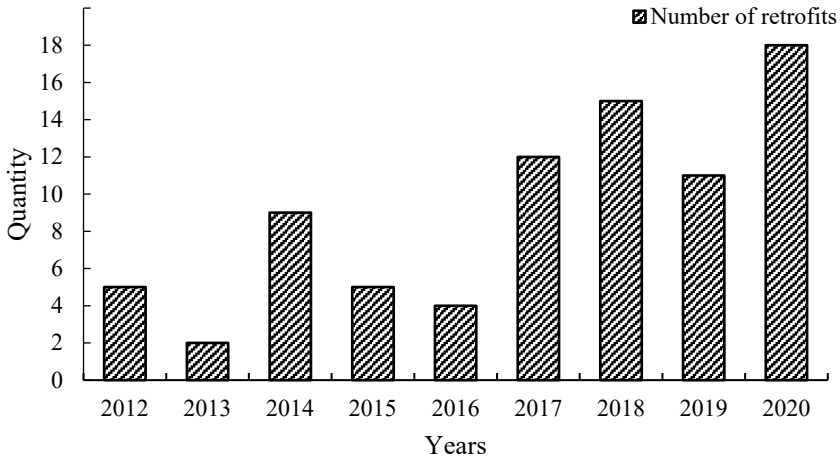


Fig. 3. Number of green retrofits of existing buildings

Unlike the previous risk management research on the individual risk characteristics of risk factors, this research uses the k-means algorithm to construct and analyze the social network of stakeholders of green transformation projects and their risk factors. The k-means algorithm regards green transformation projects as a system environment connected by the influence of various risk factors. The purpose of the analysis is to study the influence of risk factors on the risk network in the structure of the relationship network [6].

2.4 K-means Algorithm

Cluster analysis is an unsupervised method of machine learning. Unlike data mining classification algorithms that train models that can accurately classify unknown samples based on data samples with labeled information, the clustering algorithm does not know the labeling information of the training samples. The main goal of cluster analysis is to search for hidden patterns, subsets and dependencies in the dataset by unlabeled unprecedented in order to classify the unlabeled data objects in the dataset into their corresponding categories, so-called classes, to divide clusters. A good cluster analysis cluster method requires clustering to make data objects in the same cluster type as similar as possible and data objects in different cluster types as different as possible.

The distance measurement between two data objects usually has the following forms:

1) Euclidean distance

$$d(x, y) = \|x - y\| = \sqrt{\sum_{i=1}^n (x_i - y_i)^2} \quad (1)$$

2) Manhattan Distance

$$d(x, y) = \sum_{i=1}^n |x_i - y_i| \tag{2}$$

3) Chebyshev Distance

$$d(x, y) = \max |x_i - y_i| \tag{3}$$

An effective division-based clustering algorithm should make the new clustering result closer to the true division of the data set than the previous clustering result after each iteration of the algorithm is completed.

3 Retrofit Building Risk Assessment Experiment

Risk mitigation action is to remove representative risk factors from the risk network and reduce the risk of the overall risk network. Identifying risk mitigation actions is the first step. It is mainly to identify the risk factors targeted by the mitigation actions, and combine the analysis of the risk network to identify representative risk source characteristics, hub characteristics, and risk factors with strong influence.

The risk of the risk source characteristic generally has a higher degree of exit and a smaller degree of entry. In the analysis of the block model, the risk of the flattering position also has a strong risk source characteristic. Combine these two indicators to select representative risk factors, as shown in Table 1:

Table 1. Risk sources and risk factors

Risk factors	Stakeholders
Unreasonable interference by government departments	Government department
Unreasonable prices of green materials and equipment	Supplier
Aborigines do not cooperate	Household
Insufficient experience in the transformation of the transformation company	Transform the company
Changes in relevant regulations	Government department

Different types of mitigation actions are tested, and the test results are shown in Table 2.

Table 2. Monitoring results

	Network density	Clustering coefficient	Relevance
Source of risk	0.0793	0.213	0.467
Connect the hub	0.0682	0.254	0.358
Influence	0.0765	0.202	0.427

After controlling the risk factors with strong hub characteristics, the network density and correlation are relatively low compared to the networks that remove the characteristics of the risk source, and the clustering coefficient is increased, reflecting that the control of the risk source cannot weaken the closeness of the risk network connection.

In order to facilitate the comparison and analysis of each indicator, the score is plotted as Figure 4

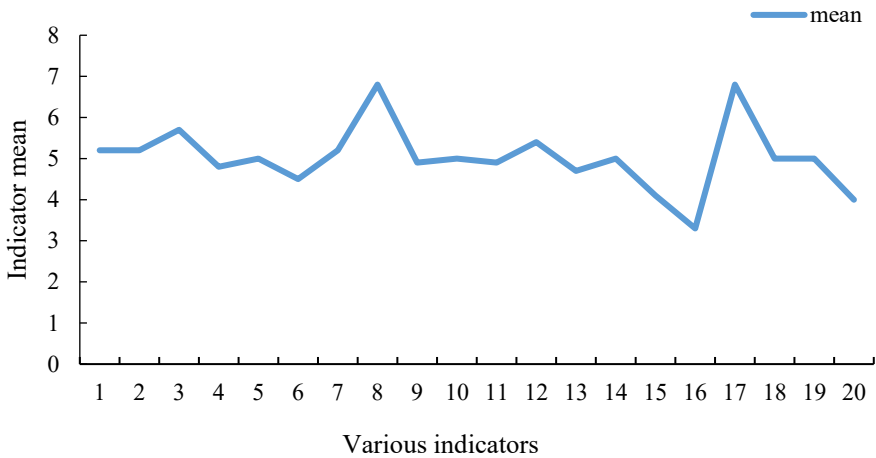


Fig. 4. Mean of each indicator

Through the comparative analysis of the characteristics and advantages of various risk evaluation methods, in view of the advantages of the K-means algorithm, combined with the specific characteristics of the risk factors of the old building renovation project, the K-means algorithm is selected to evaluate the risks of the renovation project in accordance with management risks, technical risks, economic risks, and environmental policy risks. The results show that the lack of an effective daily operation feedback mechanism, uneven ability of management personnel, poor professional ability, lack of relevant professional and technical personnel, construction funds cannot be in place in time, and project changes. These risks should be paid attention to by managers, and active countermeasures should be taken to avoid risks and solve risk problems from the root cause, so as to achieve the purpose of reducing risk losses.

4 Conclusion

This study constructs a risk assessment system for the green transformation of urban buildings based on a stakeholder risk network by introducing the k-means clustering algorithm. The findings reveal that risk factors such as the absence of an effective daily operational feedback mechanism, uneven capabilities of management personnel, insufficient professional and technical staff, delayed availability of construction funds, and engineering changes occur with high frequency during green retrofits. These factors exhibit distinct network hub characteristics and exert a significant influence on risk propagation and relationship closeness within the network. Compared to factors possessing only risk source characteristics, those with connecting hub features demonstrate greater impact and present higher control challenges within the risk network.

The theoretical and practical significance of this research lies in its application of social network analysis and clustering methods to uncover the structural relationships and propagation pathways among risk factors, thereby offering a more systematic and dynamic perspective for risk management. However, the study has certain limitations. For instance, the data primarily relies on literature reviews and expert judgment, lacking empirical validation through specific engineering case studies, which may affect the generalizability of the assessment system. Furthermore, the criteria for identifying and classifying risk factors could be further dynamically adjusted in line with evolving policy environments and technological advancements.

Future research could track actual retrofit projects as case studies to validate the operability and effectiveness of this assessment system. Simultaneously, exploring methods for multi-source data integration and machine learning optimization could enhance the accuracy and real-time capability of risk identification. It is recommended that relevant managers prioritize hub-related risks, establish robust risk monitoring and feedback mechanisms, and develop targeted response strategies. This approach would facilitate the smooth implementation and sustainable development of urban building green transformation processes.

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