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RESEARCH ON BUILDING ACTIVITY TYPE SELECTION ALGORITHM: A MULTI-FACTOR DECISION-MAKING MODEL FOR MAJOR REPAIRS AND MODERN RENOVATIONS

Abstract : This paper addresses the decision-making dilemma in the field of building maintenance and renovation, proposing a multi-factor analysis-based algorithm for selecting between major repairs and modernization. The study draws on the analytical methods of Russian scholars Stolyarov et al. regarding building cost factors under escrow financing conditions, constructing a comprehensive evaluation system encompassing five dimensions: technical, economic, legal, social, and environmental. The Analytic Hierarchy Process (AHP) is used to determine the weights of each factor, and a decision-making model is established using the TOPSIS method. The algorithm is implemented using MATLAB. A case study verifies the feasibility and effectiveness of the algorithm, providing a scientific tool for building management decision-making.

Keywords : building maintenance; major repairs; modernization; multi-factor decision-making; analytic hierarchy process (AHP); TOPSIS; MATLAB implementation

Introduction

With the continuous increase in the stock of urban buildings, the problem of building aging is becoming increasingly prominent. According to data from the China Academy of Building Research, as of the end of 2023, approximately 35% of existing urban buildings in my country had reached or exceeded their design service life, facing the need for maintenance and renewal. Building managers often face a dilemma when dealing with aging buildings: major repairs or modern renovations. Major repairs focus on restoring the original function and safety of the building, while modern renovations aim to improve the building's performance, functionality, and aesthetics to meet modern usage needs.

1. Theoretical basis and related research

(1) Research Background

With the continuous increase in the stock of urban buildings, the problem of building aging is becoming increasingly prominent. According to data from the China Academy of Building Research, as of the end of 2023, approximately 35% of existing urban buildings in my country had reached or exceeded their design service life, facing the need for maintenance and renewal. Building managers often face a dilemma when dealing with aging buildings: major repairs or modern renovations. Major repairs focus on restoring the original function and safety of the building, while modern renovations aim to improve the building's performance, functionality, and aesthetics to meet modern usage needs.

(2) Research Questions

The selection of building activity types involves complex, multi-factor decision-making issues, including technical feasibility, economic efficiency, regulatory requirements, social impact, and environmental sustainability. Traditional decision-making methods often rely on experience-based judgment, lacking systematicity and scientific rigor, and are prone to decision-making biases and resource waste.

(3) Research purpose and significance

This research aims to develop a scientific decision support algorithm to help building managers make informed choices between major renovations and modernization. The significance of this research lies in:

a) Improve the scientific basis of building maintenance decisions

b) Optimize resource allocation and improve the efficiency of fund utilization.

c) Promote sustainable development of buildings and urban renewal

d) To provide reference for the formulation of relevant policies and standards.

(4) Research methods and structure

This paper employs a combination of literature review, case analysis, and mathematical modeling. The paper is structured as follows: Chapter 2 reviews relevant literature; Chapter 3 constructs the factor system and algorithm model; Chapter 4 introduces the MATLAB implementation; Chapter 5 conducts case verification; and Chapter 6 summarizes and offers suggestions.

2. Literature Review

(1) Classification of building maintenance and renovation

Building maintenance activities can be divided into three categories: routine maintenance, major repairs, and modernization. Major repairs refer to the repair or replacement of the building's main structure or major systems to restore its original functionality and safety level. Modernization involves upgrading the building's functionality, improving its performance, or updating its appearance to meet new usage requirements or standards.

(2) Current Status of Policy Factor Research

Scholars both domestically and internationally have conducted extensive research on the factors influencing building maintenance decisions. Stolyarov et al. (2025), in their study of building costs under escrow financing, categorized influencing factors into five types: technical, economic, legal, social, and physical geography, and analyzed their impact according to the project lifecycle stage. Similarly, the selection of building activities also needs to consider multi-dimensional factors.

(3) Decision-making models and methods

The decision-making methods used in existing research include:

a) Cost-benefit analysis (CEA)

b) Life Cycle Cost Analysis (LCCA)

c) Multi-criteria decision analysis (MCDA)

d) Fuzzy comprehensive evaluation method

Among them, the method combining the Analytic Hierarchy Process (AHP) and TOPSIS has shown good results in multi-factor decision-making.

3. Research Framework and Algorithm Design

(1) Construction of factor system

Based on literature review and expert interviews, this paper constructs an evaluation system comprising 5 primary indicators and 20 secondary indicators, as shown in the table below:

Primary indicators	**Secondary indicators**	**Quantification unit**
C1 technical factors	C11 Building Structural Safety Level	Levels 1-5
	C12 Equipment System Aging Level	%
	C13 Modification Technology Complexity	Levels 1-5
	C14 Construction Period	moon
C2 Economic Factors	C21 initial investment cost	Ten thousand yuan
	C22 Investment Recovery Period	Year
	C23 Operation and Maintenance Costs	10,000 yuan/year
	C24 Asset Appreciation Potential	Levels 1-5
C3 Law and Policy factors	C31 Planning Permit Difficulty	Levels 1-5
	C32 Requirements for the Protection of Historic Buildings	Levels 1-5
	C33 Compliance with Energy Conservation and Emission Reduction Policies	Levels 1-5
	C34 Subsidies and Tax Incentives	Ten thousand yuan
C4 Social Factors	C41 User Satisfaction Improvement	Levels 1-5
	C42 Improved social image	Levels 1-5
	C43 Functional Adaptability	Levels 1-5
	C44 Community Impact	Levels 1-5
C5 Environmental Factors	C51 reduces energy consumption	%
	C52 Material Recycling Rate	%
	C53 carbon emissions reduced	%
	C54 Ecological Impact	Levels 1-5

(2) Algorithm design

The AHP-TOPSIS hybrid decision-making model requires determining weights and conducting a comprehensive evaluation.

First, the AHP weights need to be determined by constructing a judgment matrix and inviting experts to compare the importance of the indicators pairwise. Second, the weight vectors need to be calculated using the eigenvalue method. Finally, a consistency check is performed to ensure that $CR < 0.1$.

For the comprehensive evaluation of TOPSIS, it is necessary to construct a decision matrix and collect data on each scheme under each indicator; then, the data should be standardized to eliminate the influence of dimensions; a weighted standardization matrix should be calculated, and positive and negative ideal solutions should be determined; finally, the relative closeness of each scheme to the ideal solution should be calculated.

(3) Decision-making rules

Define the following decision thresholds:

a) If the score for Option A (Major Repair) is greater than the score for Option B (Modern Renovation) + 0.1, select Major Repair.

b) If the score of Option B is greater than the score of Option A + 0.1, select Modern Renovation.

c) If the score difference between the two options is ≤0.1, it is recommended to conduct a sensitivity analysis or supplementary evaluation.

4. MATLAB algorithm implementation

(1) The mathematical model is constructed using MATLAB software. The construction process is as follows:

```
% Main program framework
clear; clc
Step 1: Input Data
[criteria_names, subcriteria_names, weights] = input_data();
Step 2: Collect solution data
[project_data, normalization_type] = collect_project_data();
Step 3: Data Standardization
normalized_data = normalize_data(project_data, normalization_type);
Step 4: Calculate AHP weights (or directly input the weights)
if isempty(weights)
weights = calculate_ahp_weights();
end
Step 5: TOPSIS Calculation
[ranking_scores, ranking_order] = topsis_method(normalized_data, weights);
Step 6: Results Output and Visualization
output_results(ranking_scores, ranking_order, criteria_names, subcriteria_names);
```

5. Case Validation

(1) Case Background

An office building in a certain city, built in 1990, with a floor area of 8,000 square meters, is currently facing the following problems:

a) Falling exterior wall tiles pose a safety hazard.

b) Low energy efficiency of HVAC systems

c) The office layout is not adapted to modern office needs

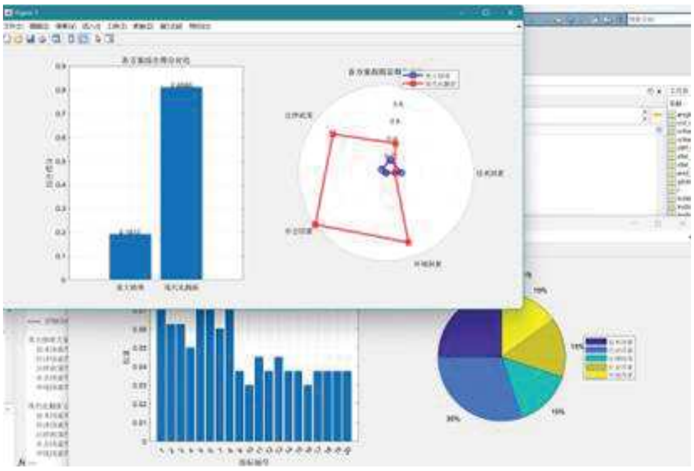
d) Lack of intelligent management system

(2) Scheme data

plan	Repair items	Construction period	Budget
Option A Major renovation	Repair exterior walls and structure	8 months	12 million yuan
	Replace some aging equipment		
Option B Modern renovation	Complete renovation of the facade	12 months	25 million yuan
	Replace all equipment systems		
	Redesigning office space		
	Add intelligent systems		

(3) Decision-making process

Using MATLAB for decision analysis, after inputting various indicator data, the following results were obtained:



(4) Sensitivity analysis

Adjust the key weights by ±20% and observe the stability of the results:

The results show that the decision-making outcome has good stability.

6. Conclusions and Recommendations

(1) Research conclusions

This paper successfully constructs a multi-factor decision-making model for the selection of architectural activity types, covering five dimensions: technology, economy, law, society, and environment.

The proposed AHP-TOPSIS hybrid algorithm can effectively handle multi-criteria decision problems, and its MATLAB implementation makes the algorithm practical and operable.

Case studies demonstrate that the algorithm can provide scientific decision support for building managers, helping them make informed choices between major repairs and modernization renovations.

(2) Management suggestions

a) Establish a building maintenance decision database to accumulate case data and expert experience.

b) Regularly update the indicator system and weights to reflect policy changes and technological developments.

c) Adjust algorithm parameters and decision rules according to the specific characteristics of the project.

d) Integrate algorithms with BIM technology to achieve automatic data acquisition and analysis.

(3) Research limitations and prospects

a) Limitations:

Indicator weights depend on expert subjective judgment

Some social and environmental indicators are difficult to quantify.

Uncertainty and risk appetite were not taken into account.

b) Outlook:

Introducing fuzzy mathematics to handle uncertain information

Determining weights by combining machine learning

Develop a web-based decision support system

Extending its application to other types of building decisions

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