

Research on Optimization of Residential Special Maintenance Fund Management Based on Multi-Agent Collaboration

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Abstract: The management of special residential maintenance funds is a key link to ensure the sustainable use of housing. Based on the multi-agent collaboration theory, this paper constructs a multi-agent collaborative model for residential special maintenance fund management, and quantitatively analyzes the synergistic relationship of each subject in fund management through joint goal planning and collaborative constraint satisfaction. The study finds that there are problems in the current management of special residential maintenance funds in terms of deposit, management and use of public revenue, and through multi-subject collaborative optimization measures such as strengthening system construction, improving the level of informatization, and strengthening supervision, it could effectively improve the efficiency of fund management, ensure the safety and rational use of funds, and provide new theoretical and practical ideas for the management of special residential maintenance funds.

Keywords: Residential Special Maintenance Fund; Multi-Agent Collaboration; Joint Goal Programming; Management Optimization

1. Introduction

As the "pension" of the house, the special maintenance fund for residential housing is crucial to ensure the maintenance, renewal and transformation of common parts of the house and shared facilities and equipment after the warranty period expires. With the development of our country's real estate market, the scale of special residential maintenance funds continues to expand, but many problems are exposed in the management process, such as difficulty in depositing funds, poor management of public revenues, and low efficiency of use. The multi-subject collaboration theory emphasizes the

collaborative cooperation of multiple independent subjects to complete complex tasks and apply them to the management of residential special maintenance funds, which helps to integrate the forces of government departments, owners, property service enterprises and other parties, optimize the fund management process, and improve management efficiency. Therefore, it is of great practical significance to study the optimization of residential special maintenance fund management from the perspective of multi-subject collaboration.

The innovation of this study is the construction of a multi-agent collaborative model. From a systematic perspective, this study incorporates multiple entities such as the government, owners, property enterprises, and financial institutions into a unified framework to analyze the interaction and synergy mechanism between each subject. By constructing this model, it provides a new research perspective and optimization ideas for the management of residential maintenance funds, which helps to break the information barriers and management barriers between various subjects, improve management efficiency, and realize the scientific, standardized and efficient management of maintenance funds.

2. Current Research and Theoretical Basis

2.1 Current Research

Foreign countries started early in the management of housing maintenance funds and formed a relatively complete policy, regulation and management system. The United States has passed legislation to clarify the rules for the raising, use and management of residential maintenance funds, adopting a trust fund model and being managed by professional financial institutions to ensure the safety and value-added of funds [1]. Japan implements a housing repair reserve fund system, in which owners pay funds

regularly according to factors such as house area and age, and the use of funds must go through strict approval procedures, and a complete information disclosure system has been established to protect the owner's right to know [2]. In the research of management models, market-oriented operation and professional management are emphasized, and third-party institutions are emphasized to participate in management to improve management efficiency and transparency. In terms of use efficiency, focus on the rational allocation and efficient use of funds, and ensure the smooth implementation of maintenance projects through scientific budget management and project evaluation [3-5]. The research on residential maintenance fund management in China has gradually deepened with the development of the real estate market. In terms of policies and regulations, our country has issued a series of relevant policies, such as the "Measures for the Management of Residential Special Maintenance Funds", which provide a basic legal framework for the management of maintenance funds. In the study of management models, domestic scholars have discussed various modes such as government-led, owner-autonomy and market-oriented management, and analyzed the advantages, disadvantages and applicable conditions of different models. In terms of use efficiency, the study points out that there are problems such as complex approval process and information asymmetry that affect the efficiency of fund use, and it is proposed that the approval process should be simplified and an information management platform should be established to improve the transparency and efficiency of fund use [6,7]. However, at present, domestic research is relatively weak in multi-agent collaborative management, lacking systematic model construction and empirical analysis, and the research on how to effectively integrate the forces of the government, owners, property enterprises and other parties to improve management efficiency is not in-depth enough.

2.2 Theoretical Basis

The theory of public goods holds that public goods have the characteristics of non-rivalry and non-excludability. Residential common parts and shared facilities and equipment belong to the category of public goods [8]. For example, the fire-fighting facilities in a community: one owner's use does not affect

other owners' use, and it is impossible to exclude other owners from enjoying the safety guarantee brought by them. This determines that the maintenance, renewal and transformation of these public goods cannot be completely provided by individuals relying on the market mechanism, and collective action is needed to solve the funding problem. The residential special maintenance fund is precisely the embodiment of such collective action. Through the joint investment of owners, it ensures the normal maintenance and use of public goods.

The principal-agent theory refers to the fact that in economic activities, due to information asymmetry, the principal (owner) entrusts certain decision-making powers to the agent (such as property enterprises, owners' committees, etc.), but the agent may make decisions inconsistent with the principal's interests out of consideration for its own interests [9]. In the management of residential special maintenance funds, owners, as the owners of the funds, entrust the management and use of the funds to entities such as property enterprises or owners' committees. Property enterprises may cut corners in maintenance projects to reduce costs, or members of the owners' committee may embezzle maintenance funds for personal gain by taking advantage of their positions. This requires the establishment of effective supervision mechanisms and incentive mechanisms to reduce the negative impact caused by principal-agent problems and ensure the safety and rational use of maintenance funds.

3. The Current Situation and Problems

3.1 Deposit of Funds

At present, our country mainly relies on the owner to handle online signing or real estate rights registration to collect the first phase of residential special maintenance funds. For owners who have not registered real estate, there is a lack of effective measures to collect funds. For residential communities that have been delivered before the implementation of the "Measures for the Administration of Special Residential Maintenance Funds", if the owner does not need to handle real estate registration, it is extremely difficult to collect maintenance funds. In addition, the adjustment of

maintenance fund deposit standards lags behind and cannot keep up with economic growth, inflation and rising costs in the construction industry.

3.2 Public Revenue Management

According to the current management measures, public revenues such as rental income from property services and elevator advertising revenues in residential communities shall be used to deposit maintenance funds after deducting other funds agreed by the office of the owners' committee and the general meeting of owners. However, at this stage, it is common for owners committees to not perform their statutory duties in place. The public revenue of some communities has not been transferred to the maintenance funds on time, or even misappropriated.

3.3 The Using of Funds

Before the implementation of the Civil Code, according to the Measures for the Administration of Special Residential Maintenance Funds, the withdrawal and use must be discussed and approved by the owners whose exclusive part accounts for more than two-thirds of the total area of the building and more than two-thirds of the total number of owners. After the implementation of the Civil Code, although the conditions for withdrawal and use were adjusted to double "two-thirds" participation in voting and double "majority" approval, some owners did not have enough understanding of the management and use of special maintenance funds, and their enthusiasm for participating in property management was not high, and the use of funds was still not smooth.

3.4 Insufficient Participation of Financial Institutions

At present, most financial institutions are only responsible for fund storage, and their participation in capital appreciation, risk control and other aspects is low, and they do not give full play to their professional advantages, affecting the efficiency and effectiveness of fund management.

4. The Model of multi-Subject Collaboration

4.1 Multi-Agent System (MAS)

Multi-agent system (MAS) is composed of

multiple autonomous agents, which have autonomous decision-making capabilities [10], and have three characteristics: reactivity (responding to environmental changes), initiative (goal-driven behavior), and interactivity (communication with other agents) [11]. In the management of special residential maintenance funds, government departments, owners, property service enterprises, financial institutions, etc. could be regarded as different agents to achieve effective management of funds through mutual cooperation.

4.2 Application of Synergy Theory in the Management of Residential Special Maintenance Funds

4.2.1 Joint goal planning

The overall goal of residential special maintenance fund management is decomposed into a set of sub-goals. For example, ensuring the safety of funds, improving the efficiency of use, and ensuring fairness and justice are taken as the overall goals, and further decomposed into sub-goals such as improving the fund deposit mechanism, standardizing the management of public revenues, and simplifying the process of fund use. All subjects work together around these sub-goals to achieve the overall goal.

4.2.2 Cooperative constraint satisfaction (CCSP) Resource conflicts are resolved through constraint propagation algorithms. In the management of special residential maintenance funds, resource conflicts may be reflected in the allocation of funds and the priority of maintenance projects. For example, when multiple maintenance projects apply for funds at the same time, the constraint propagation algorithm could be used to determine the fund allocation plan and resolve resource conflicts by setting constraints such as the urgency of the maintenance project and the limit of fund quotas.

4.2.3 Role model

In the management of residential special maintenance funds, clarify the responsibilities and interactive interfaces of each subject in the management of residential special maintenance funds. Government departments play the role of regulators, responsible for formulating policies and supervising the use of funds; The owner is the owner of the fund and has the right to make decisions and supervise; As the executor, the property service enterprise is responsible for the declaration, implementation and fund use records of maintenance projects; The fund

manager of the financial institution is responsible for storage, value-added, etc. According to the contribution of each subject in different links, standardize the behavior of each subject, improve the enthusiasm of each subject to participate in collaboration, and promote collaborative management.

4.2.4 Normative model

Establish rules of collaborative behavior, such as prioritizing resource access. In the process of using funds, for emergency maintenance projects involving public safety, such as elevator failures, roof leaks, etc., set rules for the priority use of funds to ensure that maintenance work is carried out in a timely manner and ensure the safety of residents' lives.

5. Construction of A Multi-Subject Collaborative Model for the Management of Special Residential Maintenance Funds

5.1 Model Assumptions

Suppose there are four entities in the system: government department (G), owner group (O), property service enterprise (P), and financial institution (F). Each subject makes independent decisions, with the goal of maximizing its own interests, and considering the realization of the overall goal.

5.2 Subject Behavior Analysis

5.2.1 Government departments

Behavior includes formulating policies, supervising the use of funds, providing guidance, etc., with the goal of ensuring the safety of funds, standardizing management, and safeguarding the public interest.

5.2.2 Owner group

Behaviors include paying maintenance funds, participating in maintenance decisions, supervising the use of funds, etc., hoping that the funds will be used rationally to protect residential maintenance and their own rights and interests.

5.2.3 Property service enterprises

The behavior includes declaring maintenance projects, organizing construction, managing accounts, etc., with the goal of meeting the needs of owners and obtaining reasonable benefits.

5.2.4 Financial institutions

The behavior includes fund storage, settlement, value preservation and appreciation, risk assessment, etc., with the goal of achieving

value-added and obtaining reasonable returns under the premise of ensuring the safety of funds.

5.3 Quantitative Analysis of Synergistic Relationships

5.3.1 Quantification of collaborative efficiency

If the collaborative efficiency of each subject in different links of fund management is E_k (k represents links, such as deposit, use, value-added, etc.), the participation of each subject in this link is a_{ik} (i represents the subject, $i = O, P, G, F$), and the contribution weight is b_{ik} , the collaborative efficiency E is:

$$E = \sum_{k=1}^m (\sum_{i=O,P,G,F} a_{ik} \times b_{ik}) \times w_k \quad (1)$$

wherein, m is the total number of management links, and w_k is the weight of each link, reflecting its importance in the overall management. a_{ik} the value range is $[0,1]$, 1 means full participation, 0 means no participation; b_{ik} determined according to the professional ability and responsibilities of each subject in the link, the sum is 1.

For example, in the capital appreciation link, the b_{Fk} of financial institutions may be higher because they have professional investment capabilities; In the decision-making process, the b_{Ok} of the owner is high. The overall synergy efficiency could be quantified through this formula, and the synergy effect of each subject could be evaluated.

5.3.2 Satisfaction of collaborative constraints

If the constraints are fund security ($C1$) usage compliance ($C2$), value-added goal achievement ($C3$), etc., the satisfaction of each subject to the constraints is S_{ij} (j is the constraint), and the weight of the importance of the constraints is u_j , then the satisfaction degree S is:

$$S = \sum_{j=1}^l (\min_{i=O,P,G,F} S_{ij}) \times u_j \quad (2)$$

where l is the total number of constraints. Take the minimum value of the satisfaction of each subject to reflect the "short board effect", if there is a subject that is not satisfied, the whole will be affected, and all subjects will strictly abide by the constraints.

6. Optimization Measures for the Management of Special Residential Maintenance Funds Based on Multi-Subject

Coordination

6.1 Strengthen System Construction and Improve Collaborative Rules

The property authority should strengthen research and demonstration, and improve the specific implementation measures of maintenance funds according to the actual changes in the installation cost of residential buildings. Establish a regular review mechanism, such as reviewing and adjusting the deposit standards of maintenance funds every three years according to factors such as economic growth and inflation; Formulate specific standards and procedures for renewal and reconstruction, and charge a certain percentage of late fees for overdue payments; Improve the binding renewal mechanism, link the renewal of maintenance funds with housing transactions, mortgages and other behaviors to ensure the sustainability of maintenance fund sources.

6.2 Improve the Level of Informatization and Promote Communication and Collaboration between Subjects

Strengthen the construction of maintenance fund information system, and create a comprehensive platform integrating the functions of maintenance fund deposit, disbursement, and publicity; Owners could query the balance and usage of maintenance funds in real time through the mobile APP or web page, and participate in the decision-making and voting of maintenance projects online; Property service enterprises could declare maintenance projects, upload construction progress photos and fund usage details in the system to improve the transparency and efficiency of fund management. At the same time, big data analysis technology is used to analyze and predict the trend of maintenance fund use and project cost, and provide data support for management decision-making.

6.3 Strengthen Supervision to Ensure the Safety and Rational Use of Funds

Further clarify the responsibilities of relevant departments and units in the management of special residential maintenance funds. government departments have increased supervision and inspection of the management of maintenance fund income and expenditure; The property authority shall refine and optimize the property supervision and management mechanism, and urge the community

neighborhood committee and property committee to effectively perform their property supervision duties; Establish a reward system for reporting, encourage owners to report irregular management and use of public revenues, abuse of maintenance funds, etc., and give certain rewards to whistleblowers after verification, enhance the enthusiasm of owners to participate in supervision, and ensure the safety and rational use of funds; Encourage financial institutions to develop value-added products suitable for maintenance funds, such as low-risk wealth management products and time deposit portfolios, to increase capital returns. Establish a regular evaluation mechanism for fund operation, which is jointly supervised by the government and owners to ensure that value-added goals are achieved.

7. Conclusions

Through the analysis of the current situation of residential special maintenance fund management, this paper finds that there are current problems in fund deposit, public revenue management and fund use. Based on the multi-agent collaboration theory, a multi-agent collaboration model for residential special maintenance fund management is constructed, and the collaboration efficiency and constraint satisfaction are quantitatively analyzed through the synergy relationship. It is proposed to strengthen system construction, improve the level of informatization, strengthen supervision and other multi-subject collaborative optimization measures to improve the efficiency of residential special maintenance fund management and ensure the safety and rational use of funds. Future research could further explore the application differences of multi-agent collaboration in the management of maintenance funds in different types of residential communities (such as old communities and new communities), as well as the impact of the introduction of new technologies such as blockchain on multi-agent collaborative management, so as to provide more complete theoretical and practical guidance for the management of special residential maintenance funds.

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