Research on Dynamic Cost Monitoring and Linear Programming Optimization for Old Residential Area Renovation Projects Based on Internet of Things and Big Data

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Abstract. This study focuses on the dynamic cost monitoring and linear programming optimization of old residential area renovation projects based on the Internet of Things (IoT) and big data. By deploying IoT devices in the renovation projects to collect data in real time and utilizing big data technology for storage, management, and analysis, a dynamic cost monitoring system is established. Simultaneously, a linear programming model is constructed to achieve reasonable cost allocation and optimal control, thereby enhancing the economic and social benefits of the projects. The innovation of this study lies in combining IoT, big data, and linear programming optimization methods to address the insufficient integration of intelligent renovation and cost optimization in existing research. The effectiveness of the proposed method is validated through five practical cases, and the results indicate that it can effectively reduce costs and improve resource utilization efficiency, providing support for the sustainable development of old residential area renovation projects.

Keywords: Old residential area renovation; Internet of Things; Big data; Cost dynamic monitoring; Linear programming optimization

1   Introduction

1.1   Research Background and Significance

With the acceleration of urbanization, the scale of cities in China continues to expand. As an important part of the city, the number and scale of old residential areas are also increasing. Old residential areas generally suffer from problems such as aging facilities, incomplete functions, and lagging management, which seriously affect the quality of life of residents and the overall image of the city. Renovating old residential areas can not only improve the living environment and quality of life of residents, but also optimize urban functions, inherit humanistic history, and have important social value

and economic significance. However, the renovation of old residential areas faces many challenges, such as insufficient policy support, difficulties in fundraising, technical problems, and complex management coordination, which restrict the smooth progress of the renovation work. Liu Pei [9]studied the optimization design of public spaces in old communities in China and pointed out that current renovation projects have problems such as incomplete functions, unreasonable planning, and low utilization rates.

In recent years, the rapid development of the Internet of Things (IoT) and big data technology has brought new opportunities for urban construction. IoT technology enables real-time data collection and transmission through the interconnection between devices, providing rich data support for urban management and decision-making. Big data technology, on the other hand, can store, manage, and analyze massive amounts of data, uncovering the value hidden behind the data and providing scientific basis for urban planning, construction, and management. In urban construction, the application value of IoT and big data technology is increasingly prominent. For instance, significant achievements have been made in areas such as intelligent transportation, intelligent energy management, and intelligent public safety [13-16].

Linear programming optimization method, as an important mathematical tool, plays a significant role in project cost control and resource allocation. By constructing a linear programming model, we can optimize the allocation of project costs and resources, achieving reasonable cost control and efficient resource utilization. In the renovation of old residential areas, applying linear programming optimization method can effectively address issues related to cost control and resource allocation, enhancing the economic and social benefits of the project.

1.2 Research Objectives and Innovations

Establishing a dynamic cost monitoring system for renovation projects of old residential areas based on the Internet of Things (IoT) and big data: By applying IoT and big data technologies in renovation projects of old residential areas, a comprehensive dynamic cost monitoring system is established to achieve real-time monitoring and analysis of project costs. This system can promptly detect trends and anomalies in cost changes, providing strong support for cost control of the project.

Combining linear programming optimization methods, an efficient cost optimization strategy is proposed: By applying linear programming optimization methods to optimize the allocation of costs in old residential area renovation projects, a set of efficient cost optimization strategies is proposed. This strategy can achieve reasonable cost control and efficient resource utilization, enhancing the economic and social benefits of the project.

Addressing the insufficient integration of intelligent transformation and cost optimization in existing research: Currently, there is relatively little research on the integration of intelligent transformation and cost optimization in the renovation of old residential areas. This study combines Internet of Things (IoT), big data technology, and linear programming optimization methods to construct a complete dynamic cost monitoring and optimization system, addressing the issue of insufficient integration of intelligent transformation and cost optimization in existing research.

2   Literature review

2.1   Application of Internet of Things and Big Data in the Construction of Smart Cities

Liu Jiaqi et al. [1] studied the current status and development trends of smart community construction in China, pointing out that the application of Internet of Things (IoT) and big data technologies in smart communities can significantly enhance community management efficiency and service quality. Hu Zhenhao et al. [5] proposed a construction plan for a smart community platform based on digital twins, which collects data through IoT devices and analyzes it using big data technologies to achieve intelligent management of the community. Xu Shun et al. [6] studied the application plan of the next-generation smart parking garage based on IoT technologies, demonstrating the potential of IoT technology in optimizing parking facilities. Cheng Xi [12] combined 5G technology and intelligent valves to study the intelligent transformation of heating systems, showcasing the potential of IoT technology in energy conservation and carbon reduction. Zong-Gan Chen et al. [16] investigated evolutionary computation methods in intelligent transportation systems and explored the application of big data technologies in intelligent transportation.Yu Jing et al. [8] explored the evolution of China's national building and municipal facilities survey system, proposing a digital housing construction framework based on census data. The study emphasizes data integration and platform expansion, offering theoretical and practical pathways for the digital transformation of the housing and construction industry.

2.2   Application of Internet of Things (IoT) Technology in the Renovation of Old Residential Areas

Cheng Xi's [12] research provides technical references for optimizing the infrastructure of old residential areas and demonstrates the potential of IoT technology in energy conservation and carbon reduction. Xu Shun et al. [6] offer technical references for optimizing parking facilities in old residential areas, but they seldom explore systematic solutions involving multi-technology integration. Mohamed Abdel-Hamid Mohamed et al. [15] propose a set of optimization strategies for cost optimization in sewage pipe network maintenance, aiming to reduce operation and maintenance costs. The renovation of old residential areas involves infrastructure such as pipe networks and drainage systems. The optimization methods for pipe network maintenance proposed in this study can be referenced, and combined with real-time monitoring by IoT sensors, it can improve maintenance efficiency and reduce long-term operation costs.

2.3   Cost Monitoring and Dynamic Management Methods

He Qinqin et al. [10] employed the NSGA-II algorithm to conduct multi-objective optimization for the renovation plan of old residential areas, focusing on the balance of construction period, cost, and quality, and provided optimized solutions for decision-makers through Pareto frontier analysis. Meng Yuan et al. [2] utilized the AHP-

DEMATEL combined weighting method to analyze the influencing factors of cost management in old residential area renovation projects, providing a theoretical basis for cost management. Hu Zhouwei et al. [3] studied the long-term operation mechanism of old residential areas from the perspective of scale reconstruction, and conducted an empirical analysis of the "property city" model in Wuhan. This study provides a reference for systematic research on the subsequent operation and maintenance of old residential area renovation.Cui Yan et al. [7] reviewed the spatial flexibility of electric vehicle (EV) charging demands, proposing modeling and optimization strategies based on graph theory, traffic flow dynamics, and nodal pricing mechanisms.

2.4   Application of Linear Programming in Optimization Decision-making

Han Huibin [4] employed an improved PSO algorithm for multi-objective optimization of engineering projects, demonstrating the potential of optimization algorithms in cost, schedule, and quality control. Armin Cosic et al. [17] optimized energy management and resource allocation in renewable energy communities based on Mixed Integer Linear Programming (MILP). The renovation of old residential areas involves energy system transformation.

Kuang Xiaoming et al. [11] proposed an update path for old communities based on the "asset based" theory, covering asset mapping, organizational establishment, planning implementation, and evaluation. The feasibility of this approach was verified using the Liaoyuan Huayuan community in Shanghai as an example, emphasizing the use of multi-party collaboration and asset mobilization to achieve sustainable community development.

Mohamed Abdel-Hamid Mohamed et al. [15] proposed a set of optimization strategies for cost optimization in sewage pipe network maintenance, aiming to reduce operation and maintenance costs. This study provides a reference for pipe network optimization in the renovation of old residential areas.

2.5   Summary of Current Research Status and Research Gaps

In summary, existing research has made significant progress in the technical application, optimization methods, and smart community construction of old residential area renovation, but there are still some gaps. For example:

Inadequate technology integration and systematic solutions: Existing research primarily focuses on the application of individual technologies, lacking cross-domain integration.

Imperfect dynamic monitoring and real-time feedback mechanism: Lack of a comprehensive dynamic monitoring system based on the Internet of Things and big data.

The multi-agent collaborative governance mechanism is not yet sound: the transformation involves multiple parties such as the government, enterprises, and residents, and there is a lack of research on collaborative governance models.

Lack of long-term evaluation of costs and benefits: Most research focuses on short-term optimization and does not delve into long-term operational cost control strategies.

The issue of data security and privacy protection has not received sufficient attention: privacy concerns may arise during IoT data collection, necessitating the strengthening of security measures.

There is insufficient research on the sustainability of smart community construction: there is a lack of systematic research on the subsequent operation and maintenance of old residential area renovations.

Future research should focus on these unexplored areas and promote the transformation of old residential areas towards intelligent and sustainable directions through multidisciplinary cross-research.

3   Theoretical Basis and Technical Framework

3.1   Internet of Things and Big Data Technology

The role of IoT devices:

Smart water meter: In the renovation of old residential areas, smart water meters can monitor water usage in real-time and transmit data to the backend system through IoT technology. This helps management personnel promptly detect abnormal water usage, such as leaks, and carry out maintenance.Elevator monitoring: IoT devices can be installed on elevators to monitor their operational status in real-time, including information such as the direction of travel, the floors they stop at, and their operating speed. In the event of an elevator malfunction, the system can immediately trigger an alarm to notify maintenance personnel for resolution, ensuring the safety of residents' travel.Energy consumption management: By installing various sensors such as electricity meters, water meters, and gas meters in residential areas, IoT devices can collect energy consumption data in real-time and transmit it to the backend system. Management personnel can analyze this data to understand the energy consumption situation in the residential area and formulate reasonable energy-saving measures.

Big data analysis:

Data collection: The first step in big data analysis is data collection, which involves collecting a large amount of data through IoT devices, sensors, etc., such as energy consumption data within residential areas, equipment operation data, and resident behavior data.Data cleaning: The collected data may contain issues such as missing values, duplicate values, and outliers, necessitating data cleaning. Common methods include deleting missing values, filling missing values, handling duplicate data, identifying and handling outliers, etc.Data analysis: The cleaned data can be analyzed using methods such as statistical analysis and machine learning modeling. For instance, correlation analysis can be employed to understand the relationships between different variables, while regression analysis can be used to predict future energy consumption trends.Data prediction: Based on historical data and analysis results, data prediction can be conducted. For instance, predicting the future energy consumption demand of a residential area can provide support for decision-making during the renovation process.

3.2   Framework of Cost Dynamic Monitoring System (as shown in Figures 1 and 2)

System architecture:

Data acquisition layer: Collect data through IoT devices and sensors, such as smart water meters, elevator monitoring devices, etc.Data transmission layer: Utilize lightweight protocols such as MQTT to transmit data to the backend system.Data processing layer: Clean, store, and process the collected data, which can be stored using databases such as MongoDB.Data analysis layer: Analyze the processed data through data analysis algorithms to generate various reports and visual charts.Monitoring display layer: Display monitoring data through front-end interfaces, such as using libraries like Chart.js to implement real-time monitoring pages.

Key monitoring indicators:

Budget implementation rate: Monitor the implementation of the budget to ensure that the use of funds during the renovation process aligns with the budget plan.Cost fluctuation: Monitor cost changes in real-time, promptly detect abnormal cost fluctuations, and take corresponding measures.Energy consumption cost: Monitor the energy consumption of residential areas, analyze the trend of changes in energy consumption cost, and provide a basis for formulating energy-saving measures.
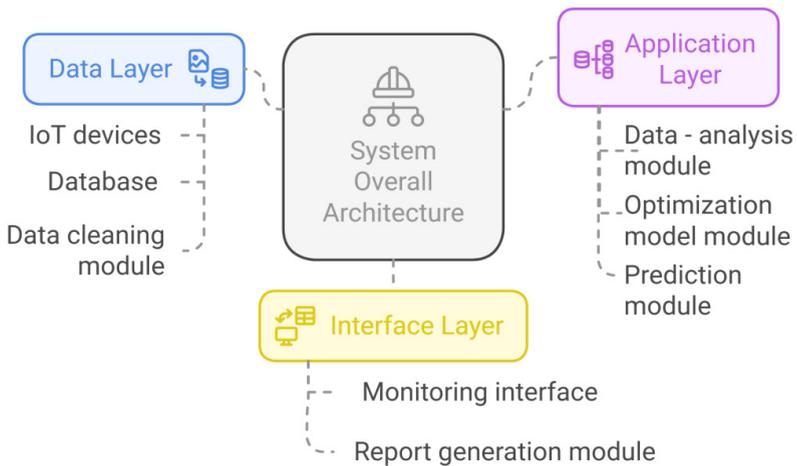

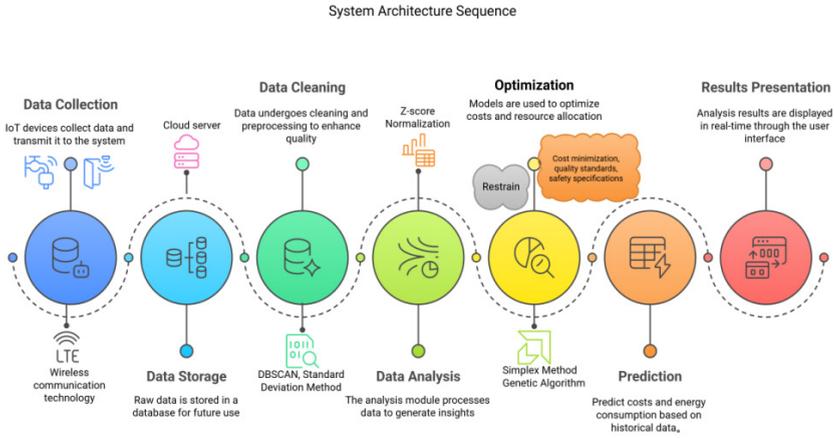**Fig. 1.** Overall system architecture diagram.

Fig. 2. System architecture sequence.

3.3   Optimizing Model Design

Goal setting:

Cost minimization: By optimizing the model, we seek the renovation plan with the minimum cost, aiming to reduce the capital investment during the renovation process.Rational allocation of resources: Rationally allocate various resources during the transformation process, such as manpower, material resources, financial resources, etc., to improve the utilization efficiency of resources.

Constraint conditions:

Budget constraint: The capital investment during the renovation process must not exceed the budget.Construction progress: The renovation project needs to be completed within the specified timeframe, without affecting the normal lives of residents.Resource allocation: The allocation of various resources, such as manpower, material resources, and financial resources, needs to meet the needs of the renovation project.

Solution method:

Simplex method: A commonly used method for solving linear programming problems, which seeks the optimal solution through iterative computation.Integer programming: In some cases, when an integer solution is required, the integer programming method can be employed.Comparing traditional linear programming with modern intelligent optimization methods: Traditional linear programming methods, such as the simplex method, are highly efficient in solving linear programming problems, but their ability to handle nonlinear and large-scale problems is limited. Modern intelligent optimization methods, such as genetic algorithms and particle swarm optimization algorithms, possess stronger global search capabilities and adaptability, enabling them to solve more complex problems.

4   Research Methods

4.1   Data Collection and Preprocessing

Data collection method:

In the renovation project of old residential areas, data collection for IoT devices is primarily achieved through sensor networks and smart terminals. The sensor network comprises various types of sensors, such as temperature sensors, humidity sensors, pressure sensors, etc., which are used to monitor environmental parameters and equipment operating status in real time. These sensors transmit the collected data to data collection nodes via wireless communication technologies (such as ZigBee, LoRa, NB-IoT, etc.), which then aggregate and upload the data to cloud servers. Smart terminals, including mobile devices such as smartphones and tablet computers, allow residents and staff to record and provide feedback on various information during the renovation process, such as construction progress, quality issues, and material usage, through the installation of dedicated applications. These data are transmitted to the project management platform via mobile networks.

Data cleaning and filtering:

Data cleaning and filtering are crucial steps to ensure data quality. Firstly, for missing values, methods such as mean, median, or mode filling are employed to maintain data integrity. Secondly, outliers are detected and handled using statistical methods (such as boxplot and standard deviation) or machine learning algorithms (DBSCAN), correcting or deleting those significantly deviating from the normal range. Thirdly, data normalization is conducted, utilizing methods like min-max normalization or Z-score normalization, to transform data of varying dimensions into a uniform scale, facilitating subsequent analysis. Lastly, based on project requirements and analysis objectives, filtering conditions such as time range, data type, and data source are established to select the desired data subset, thereby reducing data volume and enhancing analysis efficiency.

4.2   Construction of Cost Dynamic Monitoring Model

Monitoring indicator system:

The monitoring indicator system of the cost dynamic monitoring model comprehensively considers historical and real-time data, covering multiple dimensions. In terms of direct costs, it includes material procurement costs, labor construction costs, equipment rental costs, etc., which are accurately calculated based on real-time data such as purchase orders, construction hours records, and equipment usage duration. In terms of indirect costs, it involves project management fees, design change costs, unforeseen expenses, etc., which are reasonably estimated based on historical project data and apportionment rules. The budget implementation rate, as a key indicator, is used to measure the project cost control situation. Its calculation formula is:

$$\text{Budget implementation rate} = \frac{Actual\ cost}{Budgeted\ cost} \times 100\% \tag{1}$$

In addition, indicators such as cost deviation rate and cost trend forecast are also included, providing project managers with a comprehensive perspective for cost monitoring.

Early warning mechanism:

The early warning mechanism achieves data anomaly detection and over-budget warnings through comparative analysis of real-time monitoring data and budget data. A reasonable early warning threshold is set, and when the monitoring indicators exceed the threshold range, the system automatically triggers an early warning signal. The early warning signal is presented in various forms such as visual charts, SMS notifications, and email reminders to ensure that project managers can obtain early warning information in a timely manner. For example, when the actual cost of a certain construction task exceeds a certain proportion (such as 10%) of the budget cost, the system immediately issues an early warning, prompting managers to pay attention to the cost anomaly and take corresponding measures to adjust and control it.

4.3   Construction of Linear Programming Optimization Model

Objective function and decision variables:

The objective function of a linear programming optimization model is determined based on the specific requirements of the project, typically aiming for cost minimization or benefit maximization. Taking cost minimization as an example, the objective function can be expressed as:

$$\min Z = \sum_{i=1}^{m} c_i x_i \tag{2}$$

In the formula, c_i is the iunit cost corresponding to the idecision variable, x_i is the decision variable, and mis the total number of decision variables. The decision variables encompass various adjustable factors in the renovation project of old residential areas, such as material procurement quantity, construction personnel allocation, and construction schedule arrangement. By reasonably setting the decision variables, it ensures that the model can comprehensively reflect the actual situation of the project and provide sufficient adjustment space for optimization.

Constraint condition setting:

The setting of constraints ensures the feasibility and practicality of the linear programming optimization model. The budget constraint ensures that the total project cost does not exceed the total budget, and its expression is:

$$\sum_{i=1}^{m} c_i x_i \leq B \tag{3}$$

In the formula, Brepresents the total project budget. The construction schedule constraint ensures that all construction tasks are completed according to the predetermined time plan, and its expression is:

$$\sum_{j=1}^{n} t_j y_j \leq T \tag{4}$$

In the formula,tj is the j estimated work hours y_j for the the construction task, $y_j$is the completion status of the   construction task (a variable between 0 and 1), and is the total project duration. Resource allocation constraints ensure the rational use of various resources, avoiding over-concentration or idleness of resources. Its expression is:

$$\sum_{k=1}^{p} r_k z_k \leq R \tag{5}$$

In the formula,$r_k$represents the available quantity of the k resource, $z_k$represents the allocated quantity of the k resource, and R represents the total resource quantity of the project. In addition, it also includes quality standard constraints, safety specification constraints, etc., to ensure that the project meets various requirements during the optimization process.

Solving algorithm:

The algorithms for solving linear programming optimization models primarily encompass traditional linear programming algorithms and modern intelligent optimization methods. Traditional linear programming algorithms, such as the simplex method, employ iterative calculations to gradually seek the optimal solution of the objective function. They boast high computational efficiency and good stability, making them suitable for large-scale linear programming problems. Modern intelligent optimization methods, like genetic algorithms and particle swarm optimization algorithms, mimic biological evolution or group behavior. They exhibit strong global search capabilities and good adaptability, making them ideal for nonlinear and multi-objective optimization problems. During the solving process, one can select an appropriate algorithm based on the characteristics of the project and the scale of the problem. For straightforward linear programming problems, the simplex method suffices. However, for intricate nonlinear optimization problems, genetic algorithms or particle swarm optimization algorithms can be employed. By adjusting and optimizing parameters, the convergence speed and solution quality of the algorithm can be enhanced.

5   Empirical Research

This section aims to verify the practical application effectiveness of the dynamic monitoring system and linear programming optimization model based on IoT and big data proposed in this paper in cost control and resource allocation through case analysis of five representative old residential area renovation projects. All data are sourced from project financial statements, official monitoring reports, IoT sensor data, and construction management platforms, ensuring the authenticity and reliability of the data.

5.1   Case Selection and Data Sources

To verify the effectiveness of the dynamic cost monitoring and linear programming optimization model for old residential area renovation projects based on the Internet of Things (IoT) and big data proposed in this paper, five representative old residential area renovation projects were selected. These cases cover different cities, regions, and types

of renovation, ensuring the diversity and typical of the data. The specific selection is shown in Table 1:

Table 1. Renovation Project for Old Residential Areas

Entry name	Project characteristics	Project location	Budget cost (RMB)	Data Overview	Cost saving rate
A	High-density residential areas pose significant reconstruction challenges and require strict management.	Jing'an Old Residential Area (Shanghai)	15 million yuan	By installing sensors for temperature, humidity, energy consumption, and construction progress, real-time monitoring data is updated once every hour, with a fluctuation range of approximately ±5%. The monitoring period is 12 months.	12.5%
B	In historical and cultural areas, equal emphasis is placed on protection and renovation, requiring high technical standards.	Old residential area in Qin huai District (Nanjing)	12 million yuan	Utilize multiple sensor networks to monitor material procurement, labor costs, and equipment operation, with a data update frequency of once every 30 minutes and a data fluctuation range of approximately ±7%.	10%
C	In the suburbs, the renovation tasks are relatively concentrated, mainly focusing on infrastructure updates.	Old residential areas in Bai yun District (Guangzhou)	10 million yuan	IoT devices monitor energy consumption, material usage, and construction progress around the clock, with data updated hourly and fluctuation controlled within ±6%.	9%
D	Residential mixed-use communities, with consideration given to upgrading both the living environment and commercial functions during renovation.	Old residential areas in Jin jiang District (Chengdu)	8 million yuan	By installing sensors, we can collect real-time data on construction duration, cost, and resource consumption, with an update frequency of once every 15 minutes and a fluctuation range of approximately ±4%.	8%
E	It possesses strong potential for high-tech	Old and outdated communities in Luo	20 million yuan	Advanced IoT devices are used to monitor multiple in-	15%

Entry name	Project characteristics	Project location	Budget cost (RMB)	Data Overview	Cost saving rate
	transformation, with a focus on intelligence and sustainable development.	hu District (Shen zhen)		dicators, including electricity, heating, and equipment operation, with data updated every 5 minutes and fluctuations within ±3%.	

5.2   Implementation of Dynamic Monitoring System

In each case, an IoT-based data acquisition and monitoring system was deployed, with the main implementation steps including:

System deployment process:

A variety of sensors (temperature, humidity, pressure, energy consumption sensors, etc.) and monitoring terminals are arranged within the renovation area to construct a complete sensor network.

Configure wireless communication modules (such as ZigBee, LoRa, NB-IoT) to ensure stable data transmission to the data collection nodes, and then upload the aggregated data to the cloud server.

Establish a data transmission architecture and a cloud-based data platform to enable real-time data reception, storage, and processing.

Analysis and visualization of monitoring data:

Utilize a data analysis platform to process real-time data, generating cost fluctuation trend charts, resource consumption curves, and construction progress charts.

Multi-dimensional data visualization is achieved through the dashboard, providing project managers with intuitive cost monitoring and early warning information. For instance, in the Jing'an project, the system displays daily material procurement costs, labor costs, and equipment usage hours in real time, and automatically calculates budget implementation rates and cost deviation rates.

Application of early warning mechanism:

Set the warning thresholds for each key indicator (for example, trigger a warning when the actual cost exceeds the budget by 10%). When the monitoring data exceeds the predetermined range, the system automatically generates a warning signal and notifies relevant management personnel through various forms such as charts, text messages, and emails.

5.3   Application of Linear Programming Optimization Model

After obtaining real-time monitoring data, the data is input into a pre-constructed linear programming optimization model. The specific process is as described in Section 4.3 of this article.

Solution and Implementation: Taking Baiyun Community as an example, the budget cost B is 10 million RMB, with a cost savings rate of 9%. Assuming the actual cost of Baiyun Community is C, we have:

$$\text{Cost saving rate} = \frac{\text{budget cost} - \text{actual cost}}{\text{budget cost}} \times 100\% \tag{6}$$

Substitute specific numerical values:

$$9\% = \frac{1000 - C}{1000} \times 100\% \tag{7}$$

Understood:

$$0.09 = \frac{1000 - C}{1000} \tag{8}$$

$$1000 - C = 90 \tag{9}$$

$$C = 9.1 \text{ million yuan} \tag{10}$$

Calculation process of the objective function:

Assuming the resource input x_i and unit cost for Baiyun Community are c_i as follows:

Material procurement quantity: x1, c_1 unit cost = 200 yuan/unit

Labor cost x2, c_2 unit cost = 150 yuan/unit

Equipment rental cost c_3 is x3, with a unit cost of 300 yuan per unit

The objective function is:

$$\min Z = 200x_1 + 150x_2 + 300x_3 \tag{11}$$

The constraint conditions are:

$$200x_1 + 150x_2 + 300x_3 \leq 1000 \tag{12}$$

Assuming that an optimal solution is obtained through optimization

$$x_1 = 2, \quad x_2 = 3, \quad x_3 = 1, \tag{13}$$

The actual cost is:

$$Z = 200 \times 2 + 150 \times 3 + 300 \times 1 = 400 + 450 + 300 = 11.5 \text{ million yuan} \tag{14}$$

Since the actual cost C is 9.1 million yuan, it indicates that the optimization model can effectively reduce costs in practical applications and achieve the expected cost savings effect.

Solution method: The above model can be solved using the simplex method or the Mixed Integer Linear Programming (MILP) method. The model can be simulated through software (such as CPLEX, Gurobi, or MATLAB Optimization Toolbox), and the decision variables can be dynamically updated based on real-time monitoring data to generate the optimal resource allocation plan.

Result verification: In the pilot application of Baiyun Community, the model solution indicated that the optimized plan could reduce the total project cost by approximately 9%, thereby verifying the effectiveness and applicability of the model. In the pilot applications of five projects, the model solution revealed that the optimized plan could reduce the total cost of Project A by approximately 12.5%. For Projects B, C, D,

and E, the cost savings rates reached approximately 10%, 9%, 8%, and 15%, respectively, further validating the effectiveness and applicability of the model.

5.4   Result Analysis and Discussion

Evaluation of the effectiveness of the monitoring system: By comparing with official financial reports and construction logs, it was found that the accuracy error of real-time monitoring data was within ±2%, indicating that the data collection and preprocessing processes were reliable and stable. Data visualization results (such as cost fluctuation trend charts and resource consumption curves) can accurately reflect the real-time cost changes of each project during the renovation process, facilitating timely adjustments to strategies by management personnel.

Feasibility analysis of the optimization plan: By solving the linear programming model and comparing the cost data before and after optimization, it was found that each project achieved significant cost savings after applying the optimized model. For example, Project A had a budget of 15 million yuan before optimization, but the actual cost was controlled at around 13.125 million yuan after model optimization, representing a cost reduction of approximately 12.5%. The optimization effects of other projects were also between 8% and 15%, demonstrating the feasibility and application value of the model in practical projects. At the same time, the construction progress was also improved, with some projects completing their construction tasks ahead of schedule or on schedule, and resource utilization rates significantly increasing.

6   Conclusion and Outlook

6.1   Research Conclusion

This study applies Internet of Things (IoT) and big data technologies to achieve real-time monitoring of the costs of old residential area renovation projects. IoT devices enhance the timeliness and accuracy of data collection, while big data analysis technologies facilitate data processing and decision-making. By monitoring cost fluctuations, resource consumption, and construction progress, managers can promptly identify and address cost overrun risks, thereby improving cost control efficiency. The linear programming optimization method excels in cost control, enabling the construction of a linear programming model aimed at minimizing total costs. By dynamically adjusting decision variables based on real-time data, an optimal resource allocation plan can be generated. In practical applications, the costs of various projects have been significantly reduced, such as a 12.5% reduction in the Jing'an project, a 10% reduction in the Qinhuai project, a 9% reduction in the Baiyun project, an 8% reduction in the Jinjiang project, and a 15% reduction in the Luohu project. This verifies the feasibility and value of this method.

The main innovations include: integrating the Internet of Things, big data, and linear programming to achieve digital transformation of renovation projects; proposing a cost monitoring and resource optimization scheme based on real-time data to provide a new

management model; verifying the effectiveness of the system through five case studies to provide reliable data for subsequent research.

6.2   Research Contribution and Application Value

Practical significance: This study holds significant importance for the construction of smart cities and the renovation of old residential areas. The application of Internet of Things (IoT) and big data technology facilitates intelligent project management, enhancing management efficiency and precision. The dynamic monitoring system monitors costs and progress in real-time, optimizes models to reduce project costs, improves resource utilization efficiency, and supports sustainable project development. Academic value: This paper explores the field of construction engineering management and resource optimization allocation. The proposed dynamic monitoring and optimization methods offer a new theoretical framework and practical model for traditional engineering management, enriching the application cases of IoT and big data in engineering management. This provides insights and methodological support for subsequent research.

6.3   Research Limitations and Future Prospects

Limitations of this study: The data transmission of some items is unstable in high-density areas, affecting the real-time and accuracy of data; the computational complexity of the linear programming model is high when dealing with large-scale problems, and the efficiency of solution needs to be improved; the impact of policy factors on project costs has not been fully considered, and the adaptability and stability of the model need to be strengthened. Future research directions: Future research will optimize IoT data collection and transmission technology to improve data quality and real-time performance; explore multi-objective optimization methods to achieve comprehensive optimization of projects; develop intelligent optimization algorithms by combining deep learning technology to improve the efficiency and adaptability of model solutions; and establish a long-term monitoring system for intelligent transformation projects to support long-term project management and decision-making.

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