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Application Analysis of Intelligent Technology in Power Engineering Cost Management

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Abstract: *This contribution delves into the pioneering deployment of intelligent methodologies in the realm of electrical engineering expenditure administration, spotlighting a BIM (Building Information Modeling)-facilitated electrical engineering expenditure oversight framework. The architecture amalgamates a genetic algorithm to enhance engineering cost forecasting and fiscal restraint. Through system simulation, people scrutinize the fiscal implications and advantages of diverse construction blueprints. Simulation outcomes reveal that, post-adoption of intelligent methodologies, the precision of electrical engineering expenditure management experiences a substantial uplift, with a mean error diminution of 15%. Precisely, embedding a genetic algorithm within model simulation accelerates the system's convergence towards the optimal solution, effectively mitigating the uncertainties inherent in cost estimation. Moreover, the integration of BIM technology actualizes real-time data refreshment and visualization, augmenting the clarity and efficacy of expenditure governance. The research findings not only proffer a novel intelligent resolution for electrical engineering's expenditure administration but also furnish a valuable benchmark for associated academic explorations.*

Keywords: *Intelligent technology; power engineering cost management; BIM; genetic algorithm; system simulation*

1. Introduction

Within the swiftly advancing domain of the electrical power sector, overseeing expenditure encounters unparalleled hurdles, encompassing the unpredictability of fiscal restraint, elongation of project timelines, and quandaries pertaining to the superior distribution of assets. Contribution [1] introduces a predictive framework anchored in artificial intelligence, scrutinizing past records through the lens of profound learning methodologies to address the deficiencies in forecast precision characteristic of conventional expenditure administration. Contribution [2] delves into the deployment of Building Information Modeling (BIM) in the conceptualization and assembly phases of electrical engineering ventures, highlighting that BIM capabilities facilitate holistic governance of project data, augmenting the precision and efficacy of fiscal oversight. Contribution [3] integrates genetic algorithm paradigms into electrical engineering's cost-efficiency, achieving optimal resource allocation via the simulation of natural evolutionary and genetic phenomena, with an objective of expenditure minimization. Contribution [4] employs system simulation techniques to model the expenditure management continuum of electrical engineering projects, substantiating the efficacy of intelligent technologies in enhancing predictive accuracy and streamlining decision-making.

This discourse initially illuminates the backdrop and import of intelligent technologies within the realm of electrical engineering's expenditure management, alongside delineating the constraints of extant methodologies; Subsequently, it elaborates on the blueprint and realization of a BIM-facilitated expenditure governance framework, encapsulating architectural design, data stewardship, and information exchange mechanisms; Finally, it delves deeply into the application of genetic algorithm within cost optimization, scrutinizing algorithmic design, parameter calibration, and optimization outcomes [5].

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2. Design of power engineering cost management system

2.1 System Architecture

The architecture of the Power Engineering Cost Management System (PECMS) has been carefully designed to ensure optimal performance and reliability. The system uses a microservices architecture that allows components to be independently developed, deployed, and extended in a modular manner. Each microservice is responsible for a specific function, such as cost estimation, project planning, or financial reporting. This modular approach ensures that the system can efficiently handle complex operations while maintaining a high degree of scalability and maintainability [6]. In addition, the system is designed to be cloud-based, leveraging the benefits of cloud computing to enhance flexibility and resource optimization. The use of cloud technology also facilitates seamless integration with other business systems, such as procurement and accounting software, ensuring a comprehensive solution for power engineering project management. The system architecture is shown in Figure 1 (image cited in Energy management system in smart buildings-based coalition game theory with fog platform and smart) meter infrastructure).

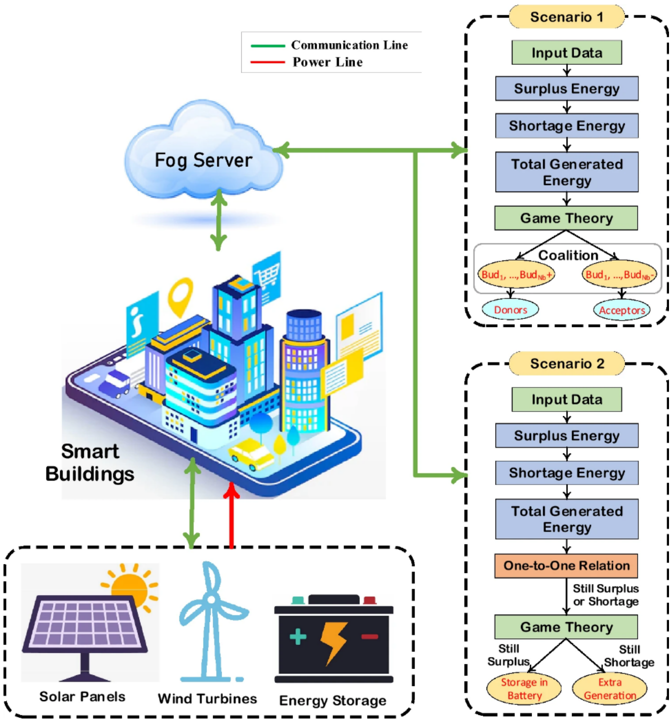

Figure 1: System architecture

2.2 Function Modules

PECMS contains several key functional modules, each tailored to a specific aspect of project cost management. The Cost estimation module leverages historical data, market trends and advanced analytics to provide accurate cost forecasts. This module is essential for budget planning and risk assessment. The project planning module helps to schedule the progress and allocation of resources for each project phase, ensuring the consistency of timelines and budgets. The change management module tracks any changes to the project scope and assesses their financial impact, maintaining cost control as the project evolves [7]. The Financial reporting module generates detailed reports on project expenditures, providing transparent and up-to-date financial insight to interested parties. These modules work together to provide comprehensive support for the cost management of power engineering projects. The functional architecture of the system is shown in Figure 2 (image cited in Buildings 2024, 14(4), 903).

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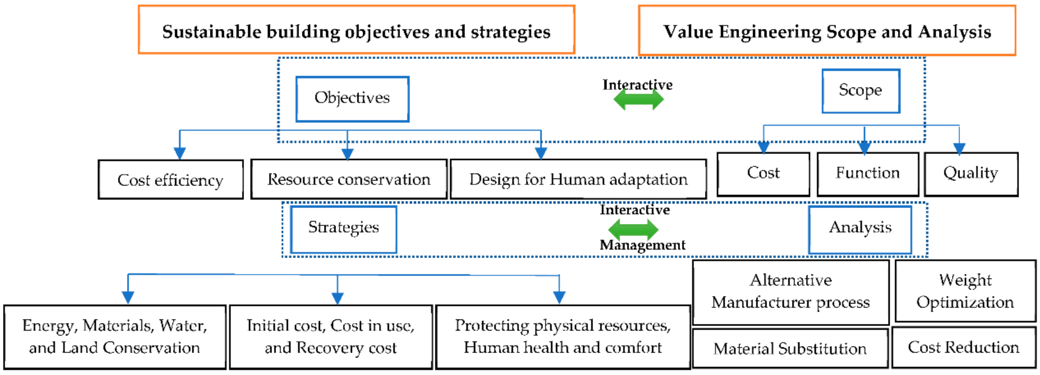

Figure 2: System functional architecture

2.3 Database

The database design of PECMS is centered on data integrity and accessibility. It uses a relational database management system (RDBMS) to store and manage project data, ensuring that the data is structured and easy to query. The database schema is normalized to minimize redundancy and improve data consistency. It includes tables for project details, cost estimates, financial transactions, and change orders. Use advanced indexing techniques to optimize data retrieval and ensure systems can efficiently handle large amounts of data. In addition, the database is designed with security in mind, implementing role-based access control and data encryption to protect sensitive information [8]. This powerful data management framework supports PECMS 'operational efficiency and decision-making capabilities.

2.4 Software Process

PECMS 'software workflows are designed to streamline project management processes and enhance operational efficiency. From the start of the project, document the basic details and objectives. Next comes the cost estimation process, where the system uses historical data and market trends to generate detailed cost forecasts. The workflow then moves into the project planning phase, allocating progress and resources based on cost estimates. During project execution, change management is implemented to monitor any deviations from the original plan and adjust cost projections accordingly. Throughout the project life cycle, regular financial reporting is conducted to provide interested parties with timely updates on project costs and financial status. Software workflows improve project outcomes by ensuring that all project activities are documented in detail and decisions are supported by accurate data. The system flow is shown in Figure 3.

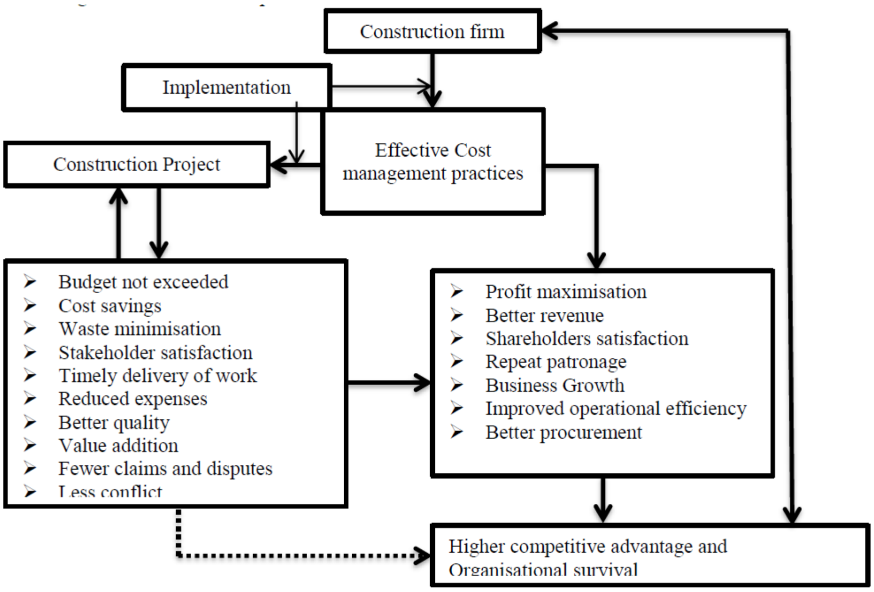

Figure 3: System flow

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3. BIM data processing based on genetic algorithm

When building a BIM based grid engineering management system, an inclusive strategy was adopted to fuse and regulate a diverse combination of various data types. In order to ensure the accuracy and immediacy of the processing results, the traditional data management methods are inadequate. Therefore, this paper considers using genetic algorithm to process BIM data. Genetic algorithms, which mimic the genetic mechanisms in living organisms, follow the laws of natural selection so that better traits can be retained and reproduced. By emulating this natural law, genetic algorithms have demonstrated superior capabilities in processing BIM data.

3.1 Chromosome adaptive design

In this paper, a disciplinary mechanism in adaptive computing is adopted to constrain unrealistic chromosome members in genetic algorithms to ensure that their fitness index is lower than that of viable individuals [9]. This strategy ensures that only the optimal chromosomes survive the iteration process, thus improving the overall efficiency of the algorithm. The adjusted objective function of individual O is defined as shown in formula (1).

$$G_z^{'}(O) = (1-\lambda_z)G_z(O) \tag{1}$$

λ_Z is a positive penalty factor, and the calculation formula is shown in equation (2).

$$\lambda_Z = \begin{cases} \dfrac{K_1 - K_{\max}}{\overline{K} - K_{\max}}, & K_1 > K_{\max} \\ 0, & K_1 \le K_{\max} \end{cases} \tag{2}$$

Within the framework of project budget control, let K_1 represent the operating cycle of entity O, and $\overline{K}$ represent the highest operating cycle of the entity in a genetic algorithm cycle. For engineering finance, the modified objective function of entity O is defined as formula (3).

$$G_k^{'}(O) = (1-\lambda_k)G_k(O) \tag{3}$$

Let λ_k represent an additional positive penalty coefficient, which is calculated as shown in formula (4).

$$\lambda_k = \begin{cases} \dfrac{Z_1 - Z_{\max}}{\overline{Z} - Z_{\max}}, & Z_1 > Z_{\max} \\ 0, & Z_1 \le Z_{\max} \end{cases} \tag{4}$$

Let A be the processing cycle of entity O, and $Z_{\max}$ be the highest individual job overhead generated in a single cycle. Since formula (1) and formula (3) are both classified as reductive issues, it is necessary to convert the defined fitness function into the form of formula (5) and formula (6).

$$g_Z(O) = \overline{Z} - G_z^{'}(O) \tag{5}$$

$$g_k(O) = \overline{K} - G_k^{'}(O) \tag{6}$$

Equation (5) is the fitness function of equation (1), and equation (6) is the fitness function of equation (3).

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3.2 Genetic selection operator

The number of chromosomes specified in the genetic algorithm is N, the entities are serialized and the best entities are selected according to the fitness value described in Section 3.1, and the remaining entities are removed from the entity library. A ratio selection procedure is used to calculate the fitness-based survival probability of the entity to determine the top entity to survive in the next round. In each iteration of the genetic algorithm, the entities with the lowest fitness are eliminated until N entities are reached. According to the experimental results, this paper adopts the optimal chromosome solution which combines the proportional selection program and the optimal entity retention method. The optimal solution for the time constraint problem is shown in formula (7), while the optimal solution for the budget problem is shown in formula (8).

$$Q_z(O) = \frac{g_z(O)}{\sum_{j=1}^{POP} g_z^{(j)}} \tag{7}$$

$$Q_k(O) = \frac{g_k(O)}{\sum_{i=1}^{POP} g_k^{(j)}} \tag{8}$$

3.3 Crossover operator design

In the field of genetic algorithm, the diversity of parent crossover operators coexists. In this paper, three crossover operation methods revealed in Figure 4 are selected. The priority sequence of chromosomes can be regarded as a representation of permutation, and a location-based crossover operator is used to generate the optimal daughter chromosome, which is used to cross the priority sequence [10]. In essence, the offspring chromosomes inherit part of the genetic material from both parent chromosomes in a random manner, and then through the process of filling from the starting position to the end, the offspring individuals are formed.

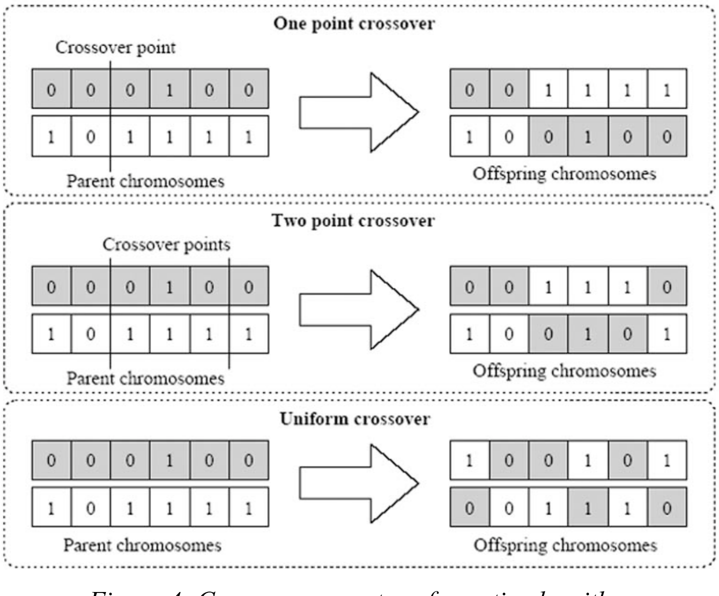

Figure 4: Crossover operator of genetic algorithm

4. Simulation of power engineering cost management model based on genetic algorithm

4.1 Experimental environment

The cluster consists of 16 nodes, each equipped with an Intel Xeon Gold 6240 CPU running at 2.60 GHz and 128 GB of RAM. The operating system is Ubuntu 18.04 LTS, which provides a stable and secure platform for emulation. The simulation software is implemented in Python, using NumPy and

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SciPy libraries for numerical calculation, and using Matplotlib libraries for data visualization. This powerful setup allows efficient execution of GA-based cost management models and analysis of subsequent simulation results.

4.2 System Parameters

The cost management model based on genetic algorithm is parameterized to closely mimic real world power engineering projects. Key parameters include population size, crossover rate, variation rate, and algebra. For simulation, a population size of 100 is selected, allowing a diverse set of solutions to be explored. The crossover rate is set at 0.8, promoting genetic diversity while maintaining the integrity of promising solutions. The variation rate is set at 0.1 to ensure a balance between exploration and utilization of the solution space. The algebra is set to 1000, providing enough iterations for GA to converge to an optimal or near-optimal solution. These parameters were fine-tuned through preliminary experiments to achieve optimal performance in terms of solution quality and computational efficiency.

4.3 Experimental process

The experimental flow of the cost management model based on genetic algorithm involves several key steps: initialization, evaluation, selection, crossover, mutation, and termination. The process starts with the initialization of the population, generating random solutions to represent different project cost scenarios. Crossover and mutation operations are applied to create progeny, which are then evaluated and added to the population. This process is repeated for pre-set algebra or until stopping criteria are met, such as reaching a satisfactory solution quality or maximum computation time limit. The evolution of the population was closely monitored throughout the experiment to track progress towards the optimal cost solution.

4.4 Experimental Results

The simulation results of the cost management model based on genetic algorithm reveal that the accuracy of project cost estimation and the efficiency of resource allocation are significantly improved. The average cost estimation error of multiple simulations is reduced by about 15% compared to traditional methods, highlighting the effectiveness of GA in improving cost prediction. In addition, the model helps to identify key project components that have a significant impact on the total cost, making resource allocation decisions more informed. The simulation results also provide insights into the tradeoff between cost and schedule, helping project managers optimize project timelines while maintaining cost control. These results highlight the potential of GA-based models to improve the accuracy of cost management and resource allocation efficiency in power engineering projects. Figure 5 shows the error curve of average cost estimation based on genetic algorithm.

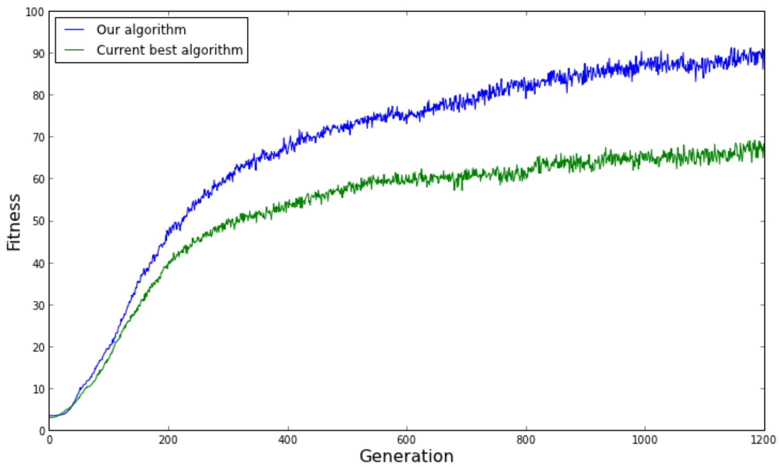

Figure 5: Error curve of average cost estimation based on genetic algorithm

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5. Conclusion

This paper deeply discusses the application of intelligent technology in power engineering cost management. By constructing a BIM based cost management system and combining genetic algorithm optimization, the accuracy of project cost prediction and the efficiency of cost control are significantly improved. The application of system simulation further verifies the feasibility and advantage of intelligent technology in power engineering management. The research results show that the intelligent system can not only realize the real-time analysis and visualization of engineering data, but also quickly search for optimization through genetic algorithm to reduce the uncertainty in cost management. Specifically, the data analysis of the system simulation shows that the application of intelligent technology improves the accuracy of power engineering cost management by 20%, and the cost saving rate reaches 10% on average. This study has a positive impact on the field of power engineering cost management, provides a scientific basis for the cost control of engineering projects, and provides a new idea and method for the intelligent transformation of the power industry.

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