Construction of Dynamic Cost Control Model and Cost Optimization Research for Green Buildings Empowered by Low-Carbon Technology

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ABSTRACT To address the drawbacks of traditional cost control, such as static management and insufficient adaptability, this study focuses on low-carbon technology-enabled green buildings and constructs a dynamic cost control model to reveal the bidirectional impact mechanism of low-carbon technologies on project costs throughout the whole life cycle. As intelligent green buildings increasingly integrate electromagnetic sensing and wireless monitoring technologies for realtime operation management, dynamic cost evaluation has become an important component of sustainable infrastructure optimization. Based on whole-life-cycle theory and system dynamics, a dynamic control framework is established, and the integrated mechanism of “system dynamics (SD) + BP neural network” is developed to improve prediction accuracy. In addition, a full-life-cycle cost optimization strategy covering the design, construction, and operation stages is proposed, together with policy- and market-oriented supporting measures. Empirical validation using a university student cultural and sports center demonstrates that the model reduces the design-stage cost prediction deviation to 3.5% and achieves a 90% risk early-warning rate. After optimization, the whole-life-cycle cost is reduced by 9.8%, while carbon emission reduction increases by 18%. The proposed framework enriches the integration of low-carbon technologies and dynamic cost management, providing practical guidance for intelligent green buildings and electromagnetic-assisted infrastructure monitoring.

INDEX TERMS low-carbon technology, green building, dynamic cost control, system dynamics, electromagnetic sensing

I. INTRODUCTION

A. RESEARCH BACKGROUND AND SIGNIFICANCE

1) Research Background

THE global construction industry accounts for 30% to 40% of total energy consumption and as high as 34% of carbon emissions, far exceeding the transportation sector, making it one of the world’s major carbon emission sources [1]. To address climate change, countries worldwide have prioritized "dual carbon" goals, positioning energy conservation and carbon reduction within the construction and manufacturing sectors as critical breakthroughs for achieving systemic industrial decarbonization. China is in a stage of rapid urbanization. By the end of 2023, the cumulative constructed energy-saving building area had reached 32.68 billion square meters, accounting for over 64% of the total existing urban building area, and the scale of ultra-low energy consumption and near-zero energy consumption buildings exceeded 43.7 million square meters, achieving remarkable results in green building development [2,3]. As the core support for green buildings to achieve energy conservation and carbon reduction, low-carbon technology covers multiple fields such as energy-saving technology, renewable energy utilization technology, and low-carbon building material application technology. Its application can significantly improve the whole-life-cycle performance of buildings [4,5]. As a sustainable development direction of the construction industry, green buildings put forward new requirements for cost control, and traditional cost management methods are difficult to meet the refined whole-life-cycle management needs of green buildings [6]. In 2024, China issued the "Work Plan for Accelerating Energy Conservation and Carbon Reduction in the Construction Sector" [7], clearly proposing goals such as the full implementation of green building standards for new urban buildings by 2025. There is an urgent need to construct a scientific and efficient dynamic cost control system to address development bottlenecks.

2) Research Significance

(1) Theoretical Significance: This study analyzes the coupling relationship between low-carbon technology and green building costs, constructs a dynamic control model, enriches the integration theory of the two, improves the whole-life-cycle dynamic cost management framework, and provides a reference for subsequent research in related fields. (2) Practical Significance: The constructed model can realize real-time monitoring, early warning, and precise control of green building costs, providing enterprises with scientific cost management solutions. The supporting phased cost optimization strategy effectively alleviates the financial pressure of low-carbon technology application, enhancing project benefits to facilitate the large-scale integration of sustainable practices across both green building and manufacturing infrastructures to realize collective carbon reduction goals.

B. REVIEW OF DOMESTIC AND FOREIGN RESEARCH STATUS

In foreign research, Life Cycle Assessment (LCA) has been increasingly widely used in the construction field, especially in the evaluation of new building projects [8]. In terms of green building cost control, foreign countries have earlier adopted Life Cycle Cost Analysis (LCCA) to construct cost evaluation systems, focusing on the quantification of energy consumption and environmental costs [9,10]; domestic research focuses on the identification of cost components [11,12], but is dominated by static analysis, lacking dynamic adaptability. In the research on low-carbon technology application, both domestic and foreign studies focus on efficiency and applicability analysis, but fail to fully consider its dynamic impact on costs, nor form a technology selection plan coordinated with cost control. In terms of dynamic control models, foreign countries use system dynamics (SD), machine learning, and other methods to achieve cost prediction; although there are relevant applications in China, most focus on the construction stage, do not cover the whole life cycle, and ignore the empowering role of low-carbon technology.

C. RESEARCH CONTENT AND METHODS

1) Research Content

The core research content of this paper includes four parts: (1) Systematically analyze the core theories of green buildings empowered by low-carbon technology, and clarify the direct and indirect impact mechanisms of low-carbon technology on costs; (2) Construct a dynamic cost control model for green buildings empowered by low-carbon technology, design the model framework, select core algorithms, and determine key parameters; (3) Design a whole-life-cycle cost optimization strategy based on the control model, covering the design, construction, and operation stages as well as policy and market auxiliary measures; (4) Verify the feasibility of the model and the effectiveness of the optimization strategy through empirical analysis of typical cases.

2) Research Methods

This paper adopts a combination of multiple research methods: (1) Literature Research Method: Systematically sort out relevant research on green building cost control, low-carbon technology application, and dynamic control models to lay a theoretical foundation; (2) Questionnaire Survey Method: Collect opinions from experts in construction enterprises, design units, and consulting institutions to calibrate model parameters and optimization strategies; (3) Case Study Method: Select typical green building projects to verify the operability of the model and strategies; (4) System Dynamics Method: Construct a dynamic cost control model to realize dynamic simulation and prediction of costs; (5) Empirical Research Method: Verify the application effect of the model through comparative analysis of case data. (6) Objective Data Calibration Method: Supplement expert scoring with historical market data (e.g., 5-year material price fluctuation records) to improve the objectivity of parameter determination.

II. CORE THEORIES AND COST IMPACT MECHANISM OF GREEN BUILDINGS EMPOWERED BY LOW-CARBON TECHNOLOGY

A. DEFINITION OF CORE CONCEPTS

Low-carbon technology refers to a technology system that can reduce carbon emissions throughout the whole life cycle of buildings and improve energy utilization efficiency. It covers four categories: energy-saving technology (e.g., external wall insulation, energy-saving doors and windows) [13], renewable energy utilization technology (e.g., photovoltaic, ground-source heat pump) [14], low-carbon building material technology (e.g., recycled aggregate concrete) [15], and intelligent control technology (e.g., intelligent energy consumption monitoring system) [16]. Its core characteristics are "low emission, high energy efficiency, and high adaptability" [17]. Green building cost, based on the whole life cycle theory, covers the costs and benefits of buildings from planning and design, construction, operation and maintenance to demolition and recycling [18], including initial investment costs, operation costs, maintenance costs, carbon emission reduction benefits, and policy subsidy benefits. It is different from the limitation of traditional costs that only focus on the construction stage [19]. Dynamic cost control refers to a management model that collects cost-related data in real time from a whole-life-cycle perspective, realizes cost trend prediction, risk early warning, and dynamic adjustment through model analysis. Its core is to achieve a closed-loop management of "data-driven - real-time monitoring - precise regulation" to adapt to the dynamic cost changes brought by the application of low-carbon technology [20,21].

B. EMPOWERING ROLE OF LOW-CARBON TECHNOLOGY AND COST IMPACT MECHANISM

The empowering role of low-carbon technology in green buildings is mainly reflected in three aspects: (1) Energy conservation and carbon reduction: Reduce building energy consumption and carbon emissions through photovoltaic, insulation, and other technologies. Reports from the United Nations Environment Programme show that the rational application of low-carbon technology can reduce building carbon emissions by 20%-40%; (2) Performance improvement: Improve indoor comfort and durability of buildings, and enhance the value of building assets; (3) Benefit increment: Save operation costs through energy conservation and realize carbon benefit monetization with the help of carbon trading markets. The impact of low-carbon technology on green building costs presents a "two-way dynamic" characteristic, divided into direct impact and indirect impact. The specific influencing factors and action paths are shown in Table 1:

TABLE 1. Specific Influencing Factors and Action Paths

Impact Type	Core Influencing Factors	Action Path	Impact Characteristics
Direct Impact	Purchase cost of low-carbon technology, construction and installation cost, design adaptation cost	Increase initial investment and directly push up costs in the design and construction stages	Short-term, rigid, quantifiable
Indirect Impact	Operation energy saving, reduced maintenance costs, carbon benefits, policy subsidies, asset appreciation	Reduce long-term operation costs, improve whole-life-cycle benefits, and offset part of the initial costs	Long-term, dynamic, correlative
Key Regulatory Factors	Technology selection, design scheme, policy support, carbon market price	Regulate the balance between direct and indirect impacts and determine the overall cost level	Controllable, guiding

III. CONSTRUCTION OF DYNAMIC COST CONTROL MODEL FOR GREEN BUILDINGS EMPOWERED BY LOW-CARBON TECHNOLOGY

A. PREMISES AND OBJECTIVES OF MODEL CONSTRUCTION

1) Construction Premises

The model is constructed based on three core theories: (1) Whole Life Cycle Theory: Cover all stages from building planning to demolition, and comprehensively consider costs and benefits at each stage; (2) System Dynamics Theory: Analyze the coupling relationship between low-carbon technology and cost factors, and construct a dynamic feedback mechanism; (3) Cost-Benefit Theory: Realize the balanced optimization of low-carbon benefits and cost input. At the same time, two premise assumptions are clarified: (1) Data Accessibility: Low-carbon technology application data and cost data at each stage of green buildings can be accurately collected; (2) Parameter Dynamic Stability: Core parameters remain relatively stable within short-to-medium cycles (3-5 years) and are dynamically adjusted based on market fluctuations and policy changes to adapt to different projects.

2) Construction Objectives

The core objectives of the model include four points: (1) Realize real-time dynamic monitoring of costs and accurately capture cost fluctuations caused by the application of low-carbon technology; (2) Establish a risk early warning mechanism to identify risks such as cost overruns and insufficient technology adaptability in advance; (3) Provide precise control schemes to support decision-making for low-carbon technology selection and cost adjustment; (4) Balance low-carbon benefits and cost input to achieve minimum whole-life-cycle costs and maximum low-carbon benefits.

B. OVERALL FRAMEWORK DESIGN OF THE MODEL

1) Division of Core Modules

The model adopts a modular design, including five core modules. The functions and positioning of each module are shown in Table 2:

TABLE 2. Functions and Positioning of Core Modules

Core Modules	Core Functions	Input Content	Output Content
Low-Carbon Technology Selection Module	Screen suitable low-carbon technologies based on project characteristics and quantify technology costs and benefits	Project type, climate conditions, low-carbon goals, budget constraints	Technology selection list, cost-benefit estimation data
Cost Data Collection Module	Collect cost and technology application data in real time throughout the whole life cycle	Design drawings, construction records, energy consumption data, carbon trading data	Standardized cost database, data quality evaluation report
Dynamic Control Module	Realize dynamic simulation, prediction, and regulation of costs based on algorithms	Standardized data, technical parameters, policy data	Dynamic cost trends, control adjustment schemes
Risk Early Warning Module	Identify risks such as cost overruns and technology failure, and issue early warning signals	Cost deviation data, technology operation data, market fluctuation data	Risk level assessment, early warning report, response suggestions
Feedback Adjustment Module	Adjust technology selection and cost schemes according to control and early warning results	Control schemes, early warning reports, actual project feedback	Optimized technology list, cost adjustment schemes

2) Logical Relationship Between Modules

Each module forms a closed-loop logic through "data flow - logical correlation - feedback optimization": First, the low-carbon technology selection module outputs a technology list, which is input into the cost data collection module together with basic project data to form a standardized database; The dynamic control module calls database data to realize cost prediction and control through core algorithms; The risk early warning module identifies potential risks based on control results and real-time data and outputs early warning reports; The feedback adjustment module adjusts technology selection and cost schemes according to control schemes and early warning reports, forming a complete closed loop of "data collection $\rightarrow$ analysis and control $\rightarrow$ early warning and feedback $\rightarrow$ optimization and adjustment" to ensure the dynamic adaptability of the model.

C. CORE ALGORITHMS AND PARAMETER SETTINGS OF THE MODEL

1) Selection and Adaptation of Core Algorithms

This paper selects system dynamics (SD) as the core algorithm to construct a dynamic simulation model for the following reasons: (1) System dynamics is good at analyzing complex systems with multiple variables and multiple feedbacks, and can accurately depict the coupling relationship between low-carbon technology and cost factors; (2) It supports long-term dynamic simulation, adapting to the time span of the whole life cycle of green buildings; (3) The model structure is flexible, and can be adapted to different types of green building projects through parameter adjustment. The model takes "low-carbon technology input - dynamic cost change - benefit output" as the core feedback loop, constructs a system flow diagram, covering three subsystems: technology input subsystem, cost subsystem, and benefit subsystem, and realizes dynamic simulation of costs through the causal relationship and feedback mechanism between variables. To address the integration gap between SD and BP neural network, this study clarifies the explicit interaction mechanism: The SD model outputs dynamic cost trends (e.g., 5-year cost fluctuation curves) and key feedback loop results (e.g., the impact intensity of technology investment on cost), which serve as the training input data for the BP neural network; The BP neural network optimizes the prediction of short-term cost fluctuations (e.g., quarterly material price-driven cost changes) through weight adjustment, and outputs the prediction error and optimized parameter suggestions; The SD model dynamically calibrates core parameters (e.g., material price fluctuation coefficient) based on the BP neural network's output, realizing iterative optimization of the integrated model. This integrated mechanism breaks the "black box" limitation, ensuring the scientific rigor of the model.

2) Determination of Key Parameters

The key parameters of the model are divided into four categories. To improve objectivity, a hybrid calibration method combining expert scoring and objective data verification is adopted. Specific parameters and calibration methods are shown in Table 3:

TABLE 3. Key Parameters and Calibration Methods

Parameter Category	Core Parameters	Parameter Meaning	Calibration Method
Low-Carbon Technology Cost Parameters	Technology unit price, installation rate, adaptation and transformation rate	Purchase, installation, and adaptation design costs of various low-carbon technologies	Market research method + case data calibration + 3-year historical price verification
Energy Consumption and Carbon Emission Reduction Parameters	Unit energy consumption coefficient, carbon emission reduction coefficient, energy consumption reduction rate	Energy consumption level and carbon emission reduction effect after technology application	Experimental test method + industry standard reference + project operation data feedback
Policy and Market Parameters	Policy subsidy rate, carbon trading unit price, discount rate	Policy support intensity and market benefit level	Policy document sorting + market data tracking + dynamic adjustment based on policy updates
Risk and Fluctuation Parameters	Material price fluctuation coefficient, technology failure risk probability	Uncertain factors of cost	Statistical analysis of 5-year market fluctuation data + expert scoring (weight ratio: 7:3)

Parameter values are determined through the hybrid calibration method to ensure rationality and adaptability.

D. FEASIBILITY VERIFICATION OF THE MODEL

(1) Theoretical Verification: The rationality of the model is verified through logical deduction. The model is constructed based on three core theories, and the module division conforms to the management logic of "data - analysis - decision - feedback". The closed-loop mechanism can achieve the goal of dynamic control; the selection of core algorithms and parameters is supported by both theory and practice, and it is feasible in terms of logic. (2) Small-Scale Case Verification: A small green residential project is selected for preliminary verification. Data on the application of photovoltaic technology and external wall insulation technology as well as cost data at each stage of the project are collected and input into the model for simulation. The results show that the deviation rate between the cost trend predicted by the model and the actual project cost is controlled within 5%, and the risk early warning accuracy rate is over 85%, indicating that the model runs stably and has initial operability. (3) Policy Sensitivity Analysis: To make up for the lack of policy impact analysis, this study adds a sensitivity verification scenario: simulating the termination of policy subsidies and a 30% fluctuation in carbon trading prices. The results show that the model's cost prediction deviation rate increases by only 2.1% and 1.8% respectively, indicating strong robustness to policy changes.

IV. DESIGN OF GREEN BUILDING COST OPTIMIZATION STRATEGY BASED ON THE CONTROL MODEL

A. CORE PRINCIPLES OF COST OPTIMIZATION

Cost optimization follows four core principles: (1) Dynamic Adaptation Principle: Taking carbon emission reduction targets (meeting national/industry standards) as the rigid constraint, and optimizing whole-life-cycle costs within the feasible region to achieve Pareto optimality; (2) Low-Carbon Benefit Priority Principle: Ensure that the optimization strategy does not reduce the low-carbon performance of buildings and give priority to ensuring the realization of carbon emission reduction goals; (3) Whole-Life-Cycle Cost Minimization Principle: Comprehensively consider initial investment and long-term operation costs to avoid short-term cost orientation; (4) Dynamic Adaptation Principle: Dynamically adjust optimization strategies in combination with project stage characteristics, market changes, and policy updates. The mathematical expression of the Pareto optimal solution is: Minimize C (whole-life-cycle cost) subject to E $\leq E_0$ (E is the actual carbon emission, E_0 is the target carbon emission), ensuring that cost optimization does not violate low-carbon goals.

B. PHASED COST OPTIMIZATION STRATEGY

From the whole-life-cycle perspective of the model, differentiated optimization strategies are designed according to the design, construction, and operation stages, as shown in Table 4:

TABLE 4. Phased Cost Optimization Strategies

Project Stage	Core Optimization Direction	Specific Optimization Measures	Model Support Role
Design Stage	Low-carbon technology selection and scheme optimization	1. Select highly adaptable technology combinations based on the technology cost-benefit data output by the model; 2. Adopt modular design to reduce technology adaptation and transformation costs; 3. Conduct multi-scheme comparison to balance costs and low-carbon benefits	Provide decision support for technology selection and quantify the cost and benefit differences of different schemes
Construction Stage	Low-carbon construction technology application and cost control	1. Adopt low-carbon processes such as prefabricated construction and green concrete to reduce energy consumption and waste costs; 2. Real-time monitor construction costs based on the model and adjust resource allocation in a timely manner; 3. Optimize construction processes to reduce technology rework costs	Real-time feedback of cost fluctuations, early warning of overrun risks, and provision of resource adjustment schemes
Operation Stage	Energy consumption control and low-carbon transformation optimization	1. Optimize the operation strategy of air conditioning, lighting, and other systems based on model energy consumption early warning; 2. Introduce a dynamic discount rate (adjusted annually based on GDP growth rate and inflation rate) and a technology obsolescence coefficient (e.g., BIPV system efficiency decay rate of 0.5% per year) to evaluate long-term costs; 3. Reasonably select the timing of low-carbon transformation to reduce transformation costs; 4. Participate in carbon trading to maximize carbon benefits	Dynamically monitor energy consumption and operation costs, predict transformation benefits, and assist in deciding the timing of transformation

C. AUXILIARY OPTIMIZATION MEASURES AT THE POLICY AND MARKET LEVELS

To enhance the optimization effect, three auxiliary measures are designed in combination with the policy and market environment: (1) Make full use of policy dividends, accurately connect with local green building subsidies and special subsidies for low-carbon technology to reduce initial technology investment costs, and apply for tax reductions and exemptions to reduce financial pressure; (2) Rely on the carbon trading market, establish a carbon benefit accounting mechanism, predict carbon emission reduction through the model, and reasonably select the timing of carbon trading to improve additional project benefits; (3) Construct a supply chain collaborative mechanism, establish long-term cooperation with low-carbon building material suppliers and technology service providers, reduce technology and material costs through bulk purchasing and joint R&D, and realize supply chain cost sharing and benefit sharing.

V. EMPIRICAL ANALYSIS

A. CASE SELECTION AND BACKGROUND INTRODUCTION

A university student cultural and sports center is selected as an empirical case. As a public green building with a total construction area of 28,000 square meters, it is designed as a two-star green building. The core low-carbon technologies applied include Building-Integrated Photovoltaics (BIPV), ground-source heat pump system, external wall insulation system, and intelligent energy consumption monitoring system. In the early stage of the project, there were problems such as high investment in low-carbon technology and extensive cost control. The traditional static control model led to a high risk of cost overrun in the early stage, and the energy consumption control in the operation stage lacked precision. The basic information of the project is as follows: (1) The total investment budget is 120 million yuan, of which the investment in low-carbon technology accounts for 18%; (2) The construction period is 2 years, and the operation period is calculated as 50 years (with dynamic discount rate and technology obsolescence coefficient applied); (3) It is located in a temperate monsoon climate with an average annual sunshine duration of 2,600 hours, which has advantages for photovoltaic technology application.

B. DATA COLLECTION AND PROCESSING

Core data from the design, construction, and operation stages of the project are collected through field investigations, project file reviews, and enterprise interviews, including purchase and installation costs of low-carbon technologies, construction progress data, energy consumption monitoring data, and policy subsidy documents. Data are standardized according to the model requirements: abnormal data are eliminated, missing data are supplemented, and key parameters such as technology costs and energy consumption coefficients are calibrated. Finally, a standardized database containing 12 types of core indicators and more than 300 valid data is formed, laying a data foundation for model application.

C. APPLICATION AND EFFECT ANALYSIS OF THE DYNAMIC CONTROL MODEL

The standardized data are input into the dynamic cost control model constructed in this paper for 18 months of dynamic monitoring and simulation analysis. To intuitively reflect the model's advantages, a comparison with the traditional static control model is conducted from the core performance dimensions, and the specific differences are shown in Table 5:

TABLE 5. Model Performance Comparison

Comparison Dimension	Traditional Static Control Model	Dynamic Control Model in This Paper	Advantage Improvement Range
Cost prediction deviation rate in the design stage	8.2% (industry average + case measurement)	3.5% (case measurement)	57.3% (reduction in deviation rate)
Risk early warning advance rate in the construction stage	No active early warning (obvious lag)	90% (1-3 early warning cycles in advance)	Transformation from "passive response" to "active early warning"
Reduction rate of management time cost	$\leq$5% (dominated by manual accounting, limited efficiency improvement)	40% (automated data processing and analysis)	7 times (relative improvement range)
Reduction rate of risk loss	$\leq$20% (dominated by post-event remediation)	$\geq$60% (pre-event early warning + in-event regulation)	2 times (relative improvement range)
Applicability of application scenarios	Only suitable for conventional buildings, difficult to cope with dynamic cost changes of low-carbon technology	Accurately adapt to the whole-life-cycle control of low-carbon technology-empowered green buildings	Realize exclusive adaptation to low-carbon building scenarios
Core algorithm characteristics	Linear accounting logic, no feedback adjustment mechanism	System dynamics + BP neural network, supporting dynamic feedback and iterative optimization	Break through the limitation of linear thinking and adapt to complex system control

It can be seen from the above table that the dynamic control model constructed in this paper is comprehensively superior to the traditional static model in core performance. The specific effect analysis is as follows: (1) Significant improvement in cost accuracy: Before the model application, the Cost prediction deviation rate in the project design stage was 8.2%, and the early warning of actual overrun risks in the construction stage was lagging; after the model application, the Cost prediction deviation rate in the design stage was reduced to 3.5%, and the model can real-time capture cost fluctuations in the construction stage with a risk early warning advance rate of 90%, realizing precise control. (2) Enhanced risk control capability: The model identified 3 types of core risks, such as insufficient adaptability of photovoltaic module installation and cost overrun of ground-source heat pump construction, and output targeted response suggestions. After rectification, the relevant risk losses were reduced by more than 60%. (3) Improved management efficiency: Through automated data processing and analysis of the model, the time cost of cost management was reduced by 40%, and manual accounting errors were reduced. (4) Strong policy robustness: The sensitivity analysis shows that even if the 8 million yuan policy subsidy is terminated, the project's whole-life-cycle cost only increases by 3.2%, and the carbon emission reduction target is still achievable, verifying the model's adaptability to policy changes.

D. IMPLEMENTATION AND VERIFICATION OF COST OPTIMIZATION STRATEGIES

(1) Based on the model analysis results, a phased optimization strategy is formulated for the case project: In the design stage, optimize the selection of photovoltaic modules, replace some high-priced modules with more cost-effective high-efficiency modules to reduce technology investment costs; In the construction stage, adopt prefabricated construction technology and optimize the construction process to reduce rework costs; In the operation stage, adjust the linked operation strategy of the ground-source heat pump and air conditioning system based on the model energy consumption early warning, and apply the dynamic discount rate and BIPV technology obsolescence coefficient to opti-

mize long-term cost accounting. At the same time, apply for 8 million yuan of local special subsidies for green buildings and realize 1.2 million yuan of carbon benefits through participating in the local carbon trading market. The effect verification after the implementation of the strategy shows that: The whole-life-cycle cost of the project is reduced by 9.8% compared with that before optimization, among which the initial investment cost of low-carbon technology is reduced by 12%, and the average annual energy consumption cost in the operation stage is reduced by 15%; The carbon emission reduction is increased by 18% compared with that before optimization, reducing carbon emissions by about 280 tons per year; The project investment payback period is shortened by 2.3 years, realizing the dual improvement of economic and environmental benefits, which verifies the effectiveness of the optimization strategy.

VI. CONCLUSIONS AND PROSPECTS

A. RESEARCH CONCLUSIONS

This paper systematically researches the construction of dynamic cost control models and cost optimization for green buildings and low-carbon production facilities empowered by advanced technologies, yielding the following core conclusions: (1) The impact of low-carbon technology on green building costs presents a two-way dynamic characteristic of "increased direct investment and increased indirect benefits", and technology selection and design schemes are the core nodes to regulate the balance between the two; (2) The constructed dynamic control model includes five core modules and adopts a combined algorithm of

"system dynamics + BP neural network", which can realize real-time monitoring, risk early warning, and precise control of costs, and has feasibility and stability verified by theory and cases; (3) The designed whole-life-cycle phased optimization strategy and policy-market auxiliary measures can effectively reduce the whole-life-cycle cost of green buildings and improve low-carbon benefits, which is strongly proved by the 9.8% cost reduction and 18% carbon emission reduction of the case project; (4) The deep integration of low-carbon technology and dynamic cost control is the key path to solve the high cost of green buildings and promote their large-scale development.

B. FUTURE PROSPECTS

Future research can be carried out from three aspects: (1) Expand the scope of case samples to cover different types and regions of green building projects, and optimize model parameters to improve adaptability; (2) Deepen the application of AI technology in the model, introduce big data analysis and deep learning algorithms to improve the accuracy of cost prediction and risk early warning; (3) Future research should investigate cost optimization under special scenarios, such as extreme climates and severe fluctuations in the carbon market, to improve the strategy system for green building operations and energy-intensive processing; (4) Explore the quantitative method of the synergistic effect of low-carbon technology combinations and construct a more accurate cost impact assessment system.

AUTHOR CONTRIBUTIONS

Conceptualization – Xiaoye Xu, Shengnan Sun and Xiaoguang Zhao; methodology – Xiaoye Xu, Shengnan Sun and Xiaoguang Zhao; investigation – Xiaoye Xu, Shengnan Sun and Xiaoguang Zhao; writing-original draft preparation – Xiaoye Xu, Shengnan Sun and Xiaoguang Zhao. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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