Study on environmental impact assessment and sustainable management of construction projects in construction stage

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Abstract: This paper focuses on the construction stage, discusses the impact of construction projects on the environment, and puts forward sustainable management strategies based on BIM and Internet of Things technology. First, identify the key environmental impact factors in the construction stage, including resource consumption, pollution discharge and ecological interference, and establish a static and dynamic evaluation system to realize quantitative analysis and prediction of environmental impact. Secondly, a sustainable management strategy system covering three levels of technology, management and policy is constructed, and the green transformation in the construction stage is promoted through the "environment-cost" double-objective optimization platform, environmental management and control mechanism and hierarchical incentive and restraint mechanism. Finally, taking a financial innovation center project in a city as an example, the real-time environmental management model based on BIM and the Internet of Things has achieved remarkable results in reducing carbon emissions, dust and noise, and improved the economy and efficiency of construction management. This study provides theoretical support and practical tools for the sustainable development of the construction industry under the goal of "double carbon".

1. Introduction

With the acceleration of global urbanization, the construction industry not only promotes economic development, but also brings great environmental pressure. This industry consumes a lot of resources, produces serious pollution, and causes significant damage to the ecosystem. At the same time, its carbon emissions in the whole life cycle account for more than half of the national total, and its contribution in the construction stage is significant [1]. Facing the urgent requirements of China's "double carbon" goal and promoting the green transformation of construction industry, it is urgent to realize the coordinated development of high quality and low environmental impact through scientific environmental impact assessment and sustainable management [2]. This study takes the construction stage as the breakthrough point, breaks through the traditional static evaluation paradigm, puts forward a real-time prediction model of construction environmental impact based on BIM+ Internet of Things, and improves the theoretical system of sustainable development in the construction field. It provides the construction enterprises with a "cost-environment" decision-making tool, helps the government to formulate a phased carbon emission regulatory policy, and promotes the transformation of the construction industry from "end governance" to "source control".

2. Identification and assessment of environmental impact in construction stage

Based on the life cycle assessment framework and the characteristics of construction technology, the key environmental impact factors in the construction stage mainly include three aspects: resource consumption, such as the use of building materials, water and energy (electricity and fuel); Pollution emissions, including carbon emissions (CO_2, CH_4), dust ($PM_{2.5}$, PM_{10}), noise, sewage and construction waste; And ecological disturbance, such as land disturbance, vegetation destruction and soil erosion, these factors together constitute the core content of environmental impact

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assessment of construction activities [3].

In order to realize the accurate monitoring of the construction environmental impact, a sensor network is constructed through the Internet of Things technology, and key data such as energy consumption, mechanical operation status, dust and noise are collected in real time, and integrated with BIM model to form a digital twin environment with time-space linkage, which provides technical support for the visualization and collaborative management of dynamic data [4]. On this basis, a hierarchical environmental impact assessment and prediction system is established: on the one hand, BIM model combined with LCA database is used to calculate the static environmental impact; On the other hand, the real-time data of the Internet of Things and the 4D-BIM schedule are integrated, and a dynamic prediction model is constructed by using machine learning algorithm, so as to realize the forward-looking prediction of environmental impact trends and promote the transformation of environmental management from passive response to active early warning.

By constructing a multi-dimensional comprehensive evaluation index library covering carbon footprint, resource consumption intensity, pollution emission concentration and ecological restoration cost, and combining with AHP and other methods for weight distribution and normalization, a multi-index collaborative evaluation system is formed to realize quantitative comparison and scientific decision support for environmental impacts of different construction schemes [5-6].

3. Construction of sustainable management strategy system

Based on the results of environmental impact assessment, this study constructs a sustainable management strategy system from three levels: technology, management and policy (Figure 1). Break through the lag and static defects of traditional environmental management, provide theoretical support and practical tools for green transformation in construction stage, and help the construction industry achieve sustainable development under the goal of "double carbon".

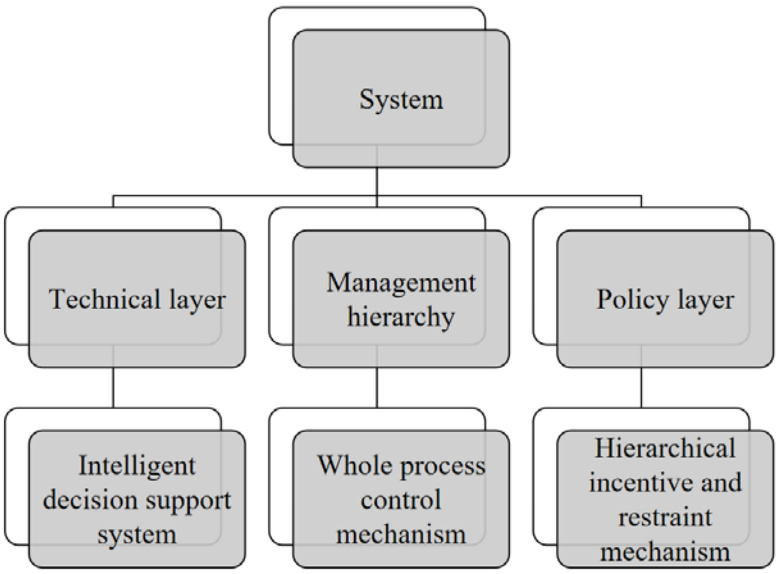

Figure 1 Sustainable management strategy system

The technical layer develops an "environment-cost" dual-objective optimization platform integrating BIM+IoT, simulates the environmental impact and economic cost of different construction schemes in real time, and recommends Pareto optimal solutions; Digital twinning technology is introduced to verify the feasibility of green construction scheme through virtual debugging [7].

Establish an environmental management and control mechanism covering the whole construction process at the management level. Clear the carbon emission limit and red line of resource consumption in the construction organization design in advance, and strengthen the source constraint; Real time monitoring and over limit warning can be achieved through environmental performance dashboards, triggering dynamic adjustment measures such as equipment replacement and logistics optimization; Afterwards, relying on big data analysis to trace the root cause of the problem, a green construction improvement report was formed and fed back to subsequent projects to achieve closed-loop management and continuous optimization.

Establish a hierarchical incentive and restraint mechanism at the policy level [8]. Introduce a "green construction certification" system for enterprises, connect real-time environmental data to the carbon trading market, and stimulate the endogenous power of low-carbon transformation; Build a "dynamic monitoring platform for construction carbon emissions" for the government, support the implementation of differentiated policies according to regions and project types, such as measures to limit production during the period of high pollution incidence or subsidies for low-carbon technologies, and promote the formation of a collaborative governance pattern with government guidance, market drive and enterprise participation.

4. Empirical research design

Select a financial innovation center project in a city as an empirical case. The project is a super high-rise building (45 floors above ground and 3 floors underground), with a total construction area of about 120,000 square meters and a construction period of about 28 months. The construction content is complex, involving earthwork, structure, curtain wall, electromechanical installation and other stages, and the environmental impact factors are comprehensive and representative.

For comparative study, the underground structure engineering stage (3rd to 8th month) of the project is divided into two areas:

(1) The control group (Zone A) adopts traditional construction management methods, relying on manual reports and regular inspections for environmental management.

(2) The experimental group (Zone B) applies the whole system proposed in this study, that is, deploying IoT sensor network, integrating BIM model, and running real-time prediction and decision optimization platform.

In the experimental group (Zone B), various types of IOT sensors are deployed, including smart meters installed in secondary distribution boxes to monitor power consumption, GPS and fuel consumption sensors on large machinery to monitor operation status, dust, noise and meteorological monitoring equipment arranged in the construction site, and AI cameras to intelligently identify environmental protection implementation such as bare soil coverage and vehicle washing. All data are transmitted to the cloud in real time through LoRa/5G network, and integrated with BIM model to build a dynamic perception and visualization management platform for the construction environment.

In order to comprehensively evaluate the effect, the core comparison indicators shown in Table 1 are set.

Table 1 Core comparison index

Indicator category	specific indicators	Data source
Environmental index	Carbon emissions per unit area ($kgCO_2$ eq/m^2)	Energy consumption data conversion
	Average dust concentration (μ g/m^3)	Dust sensor
	Daytime noise peak (dB(A))	Noise sensor
Economic indicator	Input cost of environmental protection measures (ten thousand yuan)	Project financial data
	Loss caused by rectification/shutdown due to environmental problems (ten thousand yuan)	Project log
Management	Response time of environmental	System journal

index	problems (hours)	
	Scheme simulation and decision-making efficiency (hours/time)	Management record

The research is carried out according to the process of baseline measurement, intervention implementation and data collection and analysis. Firstly, the experimental group (Zone B) and the control group (Zone A) were monitored synchronously for two weeks to ensure that the initial conditions were consistent. Then the intelligent management system was activated in the experimental group, while the control group maintained the traditional management. In the construction stage of underground structure, the data of the two areas are continuously collected synchronously. Finally, the differences between the two groups in various indexes are evaluated by statistical methods such as comparative analysis and t-test, so as to verify the effectiveness of the intelligent management system.

Through empirical research, the results are shown in Table 2 and Figure 2. The experimental results showed that the experimental group (Zone B) using an intelligent management system was significantly better than the control group (Zone A) maintaining traditional management in core environmental indicators. The carbon emissions per unit area decreased from 215 $kgCO_2$ eq/m^2 to 185 $kgCO_2$ eq/m^2 (a decrease of 14.0%), the average concentration of PM2.5 decreased from 89 μ g/m^3 to 65 μ g/m^3 (a decrease of 27.0%), and the number of times noise exceeded the standard decreased from 28 times to 9 times (a decrease of 67.9%). The carbon emission trend chart also showed that the experimental group achieved real-time optimization of mechanical scheduling and energy consumption, and the emission growth became more stable and the overall level was lower, confirming the significant improvement effect of intelligent management on the construction environment.

Table 2 Comparison table of main environmental indicators

Environmental index	Control group (Zone A)	Experimental group (Zone B)	Decline
Carbon emission per unit area	215 $kgCO_2eq/m^2$	185 $kgCO_2eq/m^2$	14.0%
Average concentration of PM2.5	89 $\mu g/m^3$	65 $\mu g/m^3$	27.0%
Noise exceeding standard times	28 times	9 times	67.9%

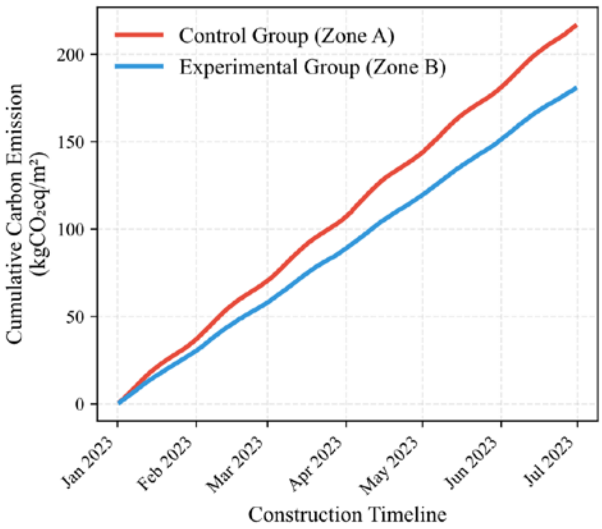

Figure 2 Comparison of carbon emission trends

As shown in Table 3, the application of intelligent management system significantly improved the economy and efficiency of construction management. The environmental management cost of the experimental group (Zone B) was reduced to 125000 yuan, a decrease of 20.9% compared to the control group (Zone A) of 158000 yuan; The shutdown loss has significantly decreased from 45000 yuan to 12000 yuan, a decrease of 73.3%; At the same time, the problem response time was shortened from 4.5 hours to 0.5 hours, with an efficiency improvement of 89%, indicating that the system effectively reduced resource waste and management delays through advance prediction and dynamic optimization, achieving a dual improvement in cost savings and response capabilities.

Table 3 Comparison of economic and management indicators

Index	Control group (Zone A)	Experimental group (Zone B)	Effect
Environmental management cost	158000 yuan	125000 yuan	Reduce by 20.9%
factory shutdown losses	45000 yuan	12000 yuan	Reduce by 73.3%
Problem response time	4.5 hours	0.5 hours	Shorten by 89%

The study quantitatively verified the significant effectiveness of the real-time environmental management model integrating BIM and IoT in reducing carbon emissions, dust, and noise through empirical analysis. It revealed that "source control" and "real-time optimization" have both environmental benefits and economic value, which helps to reverse the inherent perception of "environmental protection increases costs"; The research has developed a replicable and verifiable green construction intelligent management paradigm, providing strong support for enterprise practice and government dynamic supervision. Future discussions will focus on key issues such as the universality of the model, adaptability to different project scales, cost-effectiveness of sensor deployment, and data security and privacy protection.

5. Conclusion

Taking the construction stage as the breakthrough point, this paper puts forward a real-time prediction model of construction environmental impact based on BIM+ Internet of Things, and constructs a sustainable management strategy system covering three levels: technology, management and policy. Through empirical research, the project of a financial innovation center in a city is selected as a case, and the effects of adopting traditional construction management methods and intelligent management systems are compared and analyzed. The results showed that the experimental group (Zone B) was significantly better than the control group (Zone A) in core environmental indicators such as carbon emissions per unit area, average dust concentration, and frequency of noise exceeding standards, with reductions of 14.0%, 27.0%, and 67.9%, respectively. At the same time, the application of intelligent management systems has significantly improved the economy and efficiency of construction management. The environmental management cost of the experimental group has been reduced by 20.9%, the downtime loss has been reduced by 73.3%, and the problem response time has been shortened by 89%. These results verify that the real-time environmental management model of BIM and IoT has achieved remarkable results in reducing carbon emissions, dust and noise, and reveal that "source control" and "real-time optimization" have both environmental benefits and economic values. The research has formed a set of replicable and verifiable green construction intelligent management paradigm, which provides strong support for enterprise practice and government dynamic supervision. In the future, the key issues such as the universality of the model, the adaptability of different project scales, the cost-effectiveness of sensor deployment, and data security and privacy protection will be further discussed.

References

[1] Lu Jing, Hao Shuhan. Discussion on the Impact of Farmland Water Conservancy Engineering Construction on the Ecological Environment and Protection Strategies[J]. New Farmers, 2025, (22): 28-30.

[2] Chen Hongyu. Research on the Impact of Rural Water Conservancy Project Construction on the Water Environment and Protective Measures[J]. Water Safety, 2025, (13): 85-87.

[3] Zhan Dingbing. Discussion on the Impact of Water Conservancy and Hydropower Engineering Construction on the Ecological Environment[J]. China Industry and Economy, 2025, (12): 35-37.

[4] Zhu Jincheng, Shen Feng, Xu Xiao. Research on Environmental Impact Assessment Methods for the Water Environment Improvement Project of Houqiao Street, Wuxi, Jiangsu[J]. Water Safety, 2025, (12): 103-105.

[5] Ma Lele, Guo Yuntong. Ecological Environment Impact Analysis of the Continued Construction and Renovation Project of Qingyi River Irrigation District[J]. Haihe Water Conservancy, 2025, (06): 20-24.

[6] Hu Chuanbao. Research on the Effect Evaluation of Environmental Protection Measures in Municipal Road Construction[J]. Engineering and Construction, 2025, 39(03): 511-513.

[7] Zhao Keli, Wang Weikang. Environmental Impact Assessment of Green Construction of Railway Bridges and Its Application[J]. Value Engineering, 2024, 43(35): 124-127.

[8] Niu Jiaan, Jiang Guipeng. Research on the Impact of Building Construction on the Environment and Its Solutions[J]. Cleaning World, 2024, 40(10): 163-168.