Proceedings of CONF-FMCE 2026 Symposium: Smart City and Infrastructure Engineering
DOI: 10.54254/2755-2721/2026.CH35596

Construction Environment Monitoring and Energy Consumption Management Based on BIM and the Internet of Things

Yunxin Ji

College of Creative Arts, Design and Humanities, Adelaide University, Adelaide, Australia
a1234503@adelaide.edu.au

Abstract. With the dual carbon goals, the environmental impact and energy consumption of the construction stage have gradually received more attention. Although the smart construction site system has been introduced, data management is not complete; some monitoring systems are not integrated, and real-time Building Information Modelling (BIM) data application is still lacking. This paper introduces a BIM and Internet of Things (IoT) integrated framework to combine BIM models with on-site IoT devices for environmental monitoring and energy consumption management. Based on the proposed approach, the system will be able to monitor the environment and energy consumption in a single window and support BIM-based data management. Collaborative optimization strategies have been introduced, such as threshold-triggered dust suppression, dynamic energy scheduling according to construction progress, and the combination of BIM and Geographic Information System (GIS), edge computing and digital twins for improved decision-making. Based on the reviewed studies, the new architecture can facilitate more immediate sharing of data, enhance coordination among environmental control and energy management systems, and provide supporting data for on-site operations. The existing method is a fixed-threshold type, so it has deficiencies in the speed of response, and the new framework provides support for intelligent construction management. In the future, deep learning technology will be applied to improve the accuracy of emission prediction and extend the scope of the framework to cover the whole life cycle of emissions.

Keywords: Building Information Modelling, Internet of Things, Construction Site Monitoring, Energy Consumption Management

1. Introduction

As the concept of green construction continues to gain traction, environmental and energy management on construction sites are gradually receiving greater attention within the industry. Against the backdrop of the 'dual carbon' targets, dust control, noise control and energy conservation have become key elements in the development of smart construction sites. Currently, many regions have established online dust monitoring systems for construction sites to monitor indicators such as PM2.5 and PM10 in real time, whilst regulations governing construction noise are becoming

DOI: 10.54254/2755-2721/2026.CH35596

increasingly stringent. At the same time, there is a certain degree of energy wastage during the operation of construction machinery and temporary facilities; consequently, utilizing digital technologies to enhance the efficiency of energy management has emerged as a new area of research.

In response to these issues, extensive research has been conducted on construction site environmental monitoring. Some studies utilize technologies such as Internet of Things (IoT) sensors and edge computing to collect real-time data on environmental indicators such as dust and noise, and employ visualization platforms to enable online monitoring and early warning systems [1]. In terms of building energy consumption management, energy monitoring systems, digital twins and Building Information Modelling (BIM) technology have gradually been applied to data collection during the construction process, energy consumption analysis and energy conservation, providing data support for management decisions [2, 3]. Furthermore, the integrated application of BIM with technologies such as IoT, Geographic Information System (GIS) and blockchain has further expanded the application scenarios for construction resource monitoring and carbon emissions management [4, 5].

Although previous studies have achieved considerable progress, most existing systems are still designed for single-purpose applications. A unified management platform that integrates environmental monitoring data and energy consumption data is still lacking, and the level of data sharing and cross-system collaborative analysis remains limited [4]. In addition, some BIM applications continue to focus mainly on static model visualization, with relatively limited utilization of real-time monitoring data; as a result, their support for dynamic site management and energy-saving decision-making is still insufficient [6].

In response to these limitations, this paper proposes a BIM–IoT integrated framework for environmental monitoring and energy consumption management in smart construction sites. The framework integrates environmental data, energy consumption information and BIM models within a unified system, and further develops dynamic energy optimization strategies according to construction progress and environmental conditions, providing a reference for the development of smart construction and green construction practices.

2. System architecture and data integration methods

Environmental monitoring, energy consumption monitoring and BIM data integration at construction sites are the three key components of a construction information management platform. The environmental monitoring system is primarily responsible for collecting environmental data such as dust and noise levels; the energy consumption monitoring system is used to record equipment operation and energy consumption; whilst the BIM platform handles data management and information visualization. In recent years, the development of digital twin technology has further advanced the dynamic management and analysis of construction data. At the same time, the introduction of technologies such as GIS and blockchain has continuously expanded the scope of data applications on smart construction sites. It is therefore necessary to review and analyze research relating to environmental monitoring, energy consumption monitoring and BIM data integration.

2.1. Environmental monitoring subsystem

Generally speaking, the contents of the environmental monitoring parameters at a construction site typically include dust and noise, as well as other basic factors in the environment. With the development of information technology, monitoring is no longer confined to manual checks; it is

DOI: 10.54254/2755-2721/2026.CH35596

now mainly carried out by systems that run continuously in real time, and the conditions at the site can be recorded in a more consistent and uninterrupted manner over time.

PM2.5 and PM10 are frequently used to quantify how severely air pollution is caused by construction activities, and also to show which types of construction work are more or less likely to produce such pollution. Noise will also be monitored because the construction activities will affect the surrounding area and the health of the workers at the construction site during periods of high-intensity activity. Temperature and humidity are often added as well; they can help explain the overall change in the environment and may also affect the conditions of dust and noise differently.

The locations of most monitoring points are typically arranged at the construction site and generally include earthwork areas, material storage areas, vehicle entrances and exits, site boundaries, etc. The above places are likely to be more closely associated with the sources of environmental impact at the site. If these points can be arranged more reasonably, then the collected data will be more representative of the actual conditions at the site and more useful for the following analysis and decision-making.

At present, dust sensors are used to observe any fluctuations in the environment during the building construction process, and noise sensors can record the sound level of other construction activities. With the progress of sensing technology and the wider application of IoT devices, these tools are being used more and more often at construction sites now, and data collection is relatively faster, more stable, and convenient to manage daily [7].

Data are periodically collected or refreshed at intervals appropriate to the system and site requirements. Thus, the change in the site will be known promptly and more urgently when an abnormality occurs.

Although data collection is now more automated, different kinds of monitoring data are still often managed separately in practice. Therefore, it is still difficult to collect all environmental data for an all-encompassing analysis, and a more complete understanding of the site conditions and general environmental performance cannot be achieved [8].

2.2. Energy consumption monitoring subsystem

The primary goal is to monitor energy consumption during the construction process. It generally presents the operation mode and power consumption under normal load of the equipment, and thus offers support for energy-saving measures. Typically, the three contents are key data, main equipment and how the data are obtained and applied.

The first is electricity consumption, Power, current, voltage and running duration. The above indicators help determine how much energy is used by different equipment and whether they are working properly. Most of the energy-consuming equipment on a construction site, such as tower cranes, construction hoists and concrete-laying machines, operates for long periods and thus has a large power consumption. Lighting systems and air-conditioning in the site offices and living areas are also included, and they contribute to the total energy consumption during the construction period.

An advanced digital meter will automatically record how much power has been used over a period of time. These are connected to the energy management platform, which continuously collects and saves data on changes in energy consumption for analysis [3]. Recently, some of the projects have also introduced digital twin technology. Real-time site data can be connected to the virtual model, allowing energy usage to be displayed, compared with actual conditions, and adjusted promptly as needed.

DOI: 10.54254/2755-2721/2026.CH35596

2.3. Methods for BIM data integration

BIM can be used to build a virtual model of a building and support visual management during construction. It is a general-purpose tool used to collect various types of data from different areas of a smart construction site. BIM models are often used in conjunction with energy simulation tools to compare the energy performance of different design options and optimize energy-saving building design [9].

BIM is frequently used to integrate various types of project data. Thus, by watching the 3D displayed content, the construction team will gain a more intuitive understanding of what is taking place at the building site and thus do not need to check all these data sources separately. It can also help improve communication among all departments of the project and provide everyone with the same information for work [6].

With the development of the IoT, sensor data in the construction area can be collected and stored in a database in real time, linked to BIM models. This helps to keep the physical site conditions and the digital model more aligned, making monitoring and data processing for real projects more practical [10]. Some studies have also used GIS to connect BIM with spatial data, and thus the site information can be analyzed together with location information to better show the spatial relationships at the site [4].

Blockchain is also beginning to be applied in the management of engineering data and carbon emission tracking to enhance the reliability of the data and make record tracing more convenient. To address the problem of system incompatibility, the IFC standard can sometimes be used to improve the smoothness and consistency of data exchange between BIM models and monitoring systems [10].

With the development of the IoT, GIS, digital twins and blockchain technology, BIM has gradually moved from being only a way to create 3D model buildings to an all-encompassing data-integration platform for whole-project management.

3. Interactive dust suppression mechanism triggered by environmental exceedances

The previous section has provided a systematic overview of the fundamental principles behind multi-source data integration between BIM and IoT. Building on this foundation, a key objective in the development of smart construction sites is to effectively utilize such data to support on-site green management. Environmental pollution on construction sites is typically characterized by sudden occurrence and strong spatio-temporal coupling, while energy consumption is largely affected by construction progress and the operational conditions of equipment.

Against this background, this study presents a structured discussion of collaborative optimization strategies from three aspects, including a dust suppression triggering mechanism in response to environmental threshold exceedances, dynamic energy consumption scheduling aligned with construction progress, and the empirical validation of the proposed collaborative strategies.

3.1. Interactive dust suppression mechanism triggered by environmental exceedances

As the data from the environment changes continuously, the system can detect how quickly a problem has occurred. In other words, the data need to be available and easily understood at a certain time. The perception and processing layers of the air pollutant monitoring system based on edge computing use edge gateways to handle multi-protocol conversion, missing data and initial

DOI: 10.54254/2755-2721/2026.CH35596

filtering of sensor data. Then the data are processed into environmental indices for identifying pollution exceedances.

Wearable and IoT devices are being used to monitor noise. It can help to know how exposed the workers are to different parts of the construction at any time, and make adjustments to the control measures as needed [8]. It can show how the noise level changes over time and in different areas of work more clearly.

The above methods can be connected with BIM to build an all-weather automatic response system at the construction site. If the dust or noise exceeds the set limit, then the edge system will directly send a command to switch on the dust-suppression equipment or reduce the speed of a noisy machine. Thus, the response will be sent out more promptly and does not require a person's approval.

To store the records for later reference and audit in an immutable way, blockchain can be used to save the carbon emission data. It can also save all the content that occurs during the response process, and thus provide a reference for transparency and accountability at the construction site.

3.2. Dynamic energy consumption scheduling based on construction progress

IoT devices are used at all times during the construction, transportation and installation stages of the building to collect data on how much energy is being used. Therefore, rough estimations are no longer needed, and the actual energy consumption at the site will be better represented. Carbon emission tracking will also be based on the actual progress of construction, not just the theoretical plan.

To address the limited spatial scope of BIM for resource monitoring, it is often integrated with GIS to gain a better understanding of site conditions at a more detailed level in space. Many studies have connected these two systems, and some have introduced edge computing and time-series forecasting to improve the planning of high-energy-consuming equipment. Better planning and organization of construction will reduce the idle time of equipment; at the same time, it will be more energy-efficient [1].

3.3. Empirical validation of collaborative optimization strategies

Several studies have shown that collaborative optimization strategies can be effective in improving building performance. One example is a study on a green building located on a university campus in Fujian. The study used orthogonal experimental design together with life-cycle cost (LCC) analysis to optimize the building envelope under different scenarios. Different combinations of design parameters were tested, and both energy use and cost were taken into account when comparing the results, which helped identify more balanced solutions. The results show that, compared with conventional designs, the optimized scheme reduces annual electricity consumption per unit area by around 4.85 kWh/m^2, and also decreases the present value of life-cycle costs. This suggests that data-driven multi-objective optimization can improve energy efficiency and reduce emissions [9].

With regard to identifying energy-saving measures at zero cost, relevant scholars conducted a comparative analysis of two all-electric buildings before and after the introduction of an Energy Management System (EMS). They found that high-frequency, fine-grained data could accurately diagnose standby power consumption and abnormal energy consumption during non-working hours. By adjusting the operating logic of equipment, additional energy savings of approximately 8 per cent can be achieved without requiring new investment. The empirical data from these studies

DOI: 10.54254/2755-2721/2026.CH35596

provide a solid data foundation for the engineering implementation of environmental-energy consumption co-optimization strategies [7].

4. Conclusions and outlook

4.1. Conclusions

This paper systematically reviews the current state of application of technologies such as BIM, IoT, edge computing, digital twins, blockchain and GIS in the field of environmental monitoring and energy consumption management at construction sites, and, building on this, explores strategies for the coordinated optimization of environmental and energy consumption factors.

Adopting Industry Foundation Classes (IFC) standards for data conversion and Building Automation and Control Network (BACnet) protocols can reduce the information gap between construction sites and BIM models. Therefore, the different types of data are more compatible for joint use and management.

The integration of environmental control and energy-use management shows that digital technology can help improve the efficiency of construction management. Edge computing can provide prompt alerts for the over-limit event. BIM, GIS and IoT data can also be added to the schedule and planning, and at the same time, management is gradually moving away from a fixed-evaluation model to a dynamic, data-driven one.

Some studies have also shown that by using an orthogonal experimental design in combination with life-cycle cost analysis and real-site data, both the energy consumption of construction and operating costs can be reduced. A high-frequency energy monitoring system enables earlier realization of energy-saving objectives and reduction of total energy use.

4.2. Outlook

Although this study has shown the prospects of a BIM-IoT collaborative framework in the construction stage, some deficiencies remain. Future research can take one of several forms. First, some artificial intelligence methods, such as deep learning models (e.g., Long Short-Term Memory (LSTM) and Convolutional Neural Network (CNN)), can be introduced into the edge analytics layer. With the above time-series prediction methods, changes in the environment and electricity demand at the construction site can be predicted earlier. Thus, equipment can be adjusted in advance of a pollution or energy-consumption peak to prevent a problem from occurring and, therefore, be proactively addressed.

A second is to use the BIM-IoT framework in conjunction with digital twin technology to build a full-featured monitoring system. It will be possible to monitor the carbon emissions throughout the life of the building, from construction and operation to maintenance and even demolition. Green construction management has gradually moved away from stage-based control to a more continuous life-cycle approach.

References

[1] Xu, Z., Ran, Y., & Rao, Z. (2021). Design and integration of air pollutants monitoring system for emergency management in construction site based on BIM and edge computing. *Building and Environment, 204*, 108725.

[2] Arsecularatne, B. P., Rodrigo, N., & Chang, R. (2024). Review of reducing energy consumption and carbon emissions through digital twin in built environment. *Journal of Building Engineering, 98*, 111150.

DOI: 10.54254/2755-2721/2026.CH35596

[3] Orsatti, F., Mariella, M., Sperduto, G., et al. (2026). A novel method for assessing the impacts of energy monitoring systems adoption in building energy efficiency retrofitting projects. *Energy and Buildings, 361*, 117438.

[4] Liu, X., Antwi-Afari, M. F., Li, J., et al. (2025). BIM, IoT, and GIS integration in construction resource monitoring. *Automation in Construction, 174*, 106149.

[5] Zhao, Y., Zhang, Y., Wu, X., et al. (2026). A blockchain-integrated IoT–BIM platform for real-time carbon monitoring in modular integrated construction. *Buildings, 16*, 1587.

[6] Chen, Y., Wang, X., Liu, Z., et al. (2023). Exploring building information modeling (BIM) and internet of things (IoT) integration for sustainable building. *Buildings, 13*, 288.

[7] Sun, B., Huang, Y., Noguchi, T., et al. (2026). Towards smarter concrete construction: A systematic review of monitoring technologies and sensing methods. *Structures, 87*, 111540.

[8] Huang, X., Luo, H., Kang, J., et al. (2025). Worker-centric construction noise management: A systematic review of assessment, monitoring, modelling, and control. *Building and Environment, 280*, 113131.

[9] Li, X., Lin, M., Jiang, M., et al. (2024). BIM and orthogonal test methods to optimize the energy consumption of green buildings. *Journal of Civil Engineering and Management, 30*, 670–690.

[10] Sanz-Jimeno, R., Alvarez-Díaz, S. (2023) A tool based on the Industry Foundation Classes standard for dynamic data collection and automatic generation of building automation control networks. *Journal of Building Engineering, 78*, 107625.