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Revolutionizing Building Management: The ORBIT Framework for IoT-Powered Smart Buildings

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ABSTRACT

Building Management Systems (BMS) are advancing using wireless Internet of Things (IoT) technologies to develop more intelligent and efficient structures. Systematic innovation is essential to leverage the advantages of IoT while addressing its constraints. The objective of this study is to utilize the ORBIT innovation framework, which includes Opportunity Scanning, Research & Development (R&D), Building Collaborative Ecosystems, Implementation, and Tracking Performance, to analyze current developments in wireless IoT-enabled Building Management Systems (BMS). Approaches: A literature study of Scopus-indexed sources was performed, concentrating on energy efficiency, security, artificial intelligence (AI) integration, and sustainability in IoT-enhanced building management systems (BMS). Literature insights were aligned with the stages of the ORBIT framework to comprehend the innovation process. Findings: A wireless IoT-based Building Management System (BMS) can decrease energy consumption in buildings by approximately 20–30%, cut operational expenses, and enhance occupant comfort. The incorporation of IoT improves security via real-time monitoring, although it also presents cybersecurity and privacy problems. AI-powered control and analytics facilitate intelligent HVAC systems and predictive maintenance, enhancing performance optimization. These advancements promote sustainability by reducing greenhouse gas emissions and facilitating environmental objectives. The ORBIT framework analysis concludes that effective IoT-BMS innovation adheres to a cycle of recognizing opportunities (e.g., energy savings), allocating resources to focused R&D (sensors, protocols, AI algorithms), cultivating partnerships (IT companies, facility managers, stakeholders), conducting pilot implementations, and persistently monitoring results for enhancement. Implementing this systematic methodology can expedite BMS innovation; but persistent issues in cybersecurity, interoperability, and substantial initial expenses necessitate continuous focus. Future study ought to investigate standardized frameworks and coordinated techniques to tackle these problems and completely achieve sustainable, intelligent building management.

1. INTRODUCTION

Facilities consume a substantial share of worldwide energy and resource consumption, rendering enhancements in efficiency a paramount concern (Poyyamozhi et al., 2024; Taboada-Orozco et al., 2024). Conventional Building Management Systems (BMS) regulate heating, ventilation, air conditioning (HVAC), lighting, and security; nevertheless, they frequently function in isolation with restricted data integration (Avcı & Koca, 2023). The emergence of wireless IoT-enabled Building Management Systems signifies a transformative move towards intelligent buildings that utilize networks of sensors and devices for real-time monitoring and sophisticated control of building subsystems (Sabit & Tun, 2024). An IoT-based Building Management System (BMS) may incessantly monitor environmental parameters such as temperature, humidity, and occupancy, optimizing operations to improve energy management and occupant comfort (Poyyamozhi et al., 2024). Research suggests that IoT technology could reduce building energy usage by up to 30% and lower operational costs by around 20% (Sabit & Tun, 2024; Taboada-Orozco et al., 2024). Occupancy sensors and smart lighting controls activate lights and equipment solely when necessary, resulting in significant energy savings (Avcı & Koca, 2023; Ahmad & Alshurideh, 2025). The efficiency improvements are essential, as buildings and the broader construction sector represent approximately 40% of global energy consumption and greenhouse gas emissions (Poyyamozhi et al., 2024). In addition to energy savings, wireless IoT integration enhances the functionalities of Building Management Systems in other aspects. IoT-enabled cameras, access controls, and environmental sensors enhance security and safety by offering integrated surveillance and alarm systems across a site (Avcı & Koca, 2023). Simultaneously, linking essential building services to the internet introduces cybersecurity risks, as any IoT device may serve as a vulnerable node to incursion if inadequately secured (Sabit & Tun, 2024). Data privacy poses a barrier when occupant movements and behaviors are continuously tracked (Avcı & Koca, 2023). A significant transformation is the integration of artificial intelligence (AI) and data analytics into building management systems (BMS). Machine learning algorithms can scrutinize extensive IoT data streams to facilitate predictive control (modifying HVAC settings in anticipation of occupancy or weather fluctuations) and predictive maintenance (detecting equipment malfunctions prior to breakdowns) (Poyyamozhi et al., 2024). Intelligent BMS offer enhanced comfort, efficiency, and resilience in building operations (Taboada-Orozco et al., 2024). Moreover, IoT-enhanced advancements synchronize Building Management Systems with overarching sustainability objectives by minimizing energy waste and related carbon emissions (Poyyamozhi et al., 2024). Smart buildings engaged in demand-response programs can reduce peak electricity use, incorporate greater renewable energy, and decrease their carbon footprint by an estimated 10–30% (Sabit & Tun, 2024). Implementing a wireless IoT-powered BMS is not merely a technological enhancement; it constitutes an innovation process necessitating meticulous strategy (Avcı & Koca, 2023). Organizations must identify valuable opportunities (e.g., elevated energy expenses or unfulfilled comfort requirements that IoT could resolve), develop or adopt appropriate technologies, coordinate among diverse stakeholders (IT developers, building engineers, service providers, etc.), implement solutions in actual facilities, and consistently assess performance (Sabit & Tun, 2024). We utilize the ORBIT innovation framework to examine this process, offering a systematic method for innovation management (Taboada-Orozco et al., 2024). ORBIT is an acronym for Opportunity Scanning, Research & Development, Building Collaborative Ecosystems, Implementation, and Tracking Performance (Poyyamozhi et al., 2024). This framework, initially designed for technology deployment strategies, is utilized to analyze the conception and realization of wireless IoT breakthroughs in Building Management Systems (BMS). Subsequent sections provide an overview of the ORBIT framework and delineate the progression of IoT-based BMS in relation to its stages. This paper discusses findings from recent literature about IoT-driven enhancements in energy efficiency, security, AI integration, and sustainability outcomes as interpreted through the ORBIT framework. Ultimately, we examine the ramifications of these findings, the obstacles faced, and prospective avenues for enhancing building management using IoT advances.

2. ORBIT INNOVATION FRAMEWORK

2.1. Overview of orbit innovation framework

The ORBIT framework is a five-stage model delineating a lifecycle for the development and implementation of innovations (Devaiah & Narang, 2014). The stages comprise: 1) Opportunity Scanning, 2) Research and Development (R&D), 3) Establishing Collaborative Ecosystems, 4) Implementation, and 5) Performance Tracking (Erehwon Consulting, 2024; Questel, 2025). This paradigm prompts firms to initially discover and assess opportunities, subsequently invest in developing solutions, engage requisite partnerships for success, implement the solution in practice, and ultimately monitor outcomes to facilitate continuous development (Afonso et al., 2023). The process is iterative; insights from the Tracking phase may generate new opportunities or enhancements, thereby returning to the initial stage (Hsu et al., 2025; Nikpour et al., 2025). The ORBIT methodology offers a systematic approach to examine the progression of innovation from inception to implementation inside wireless IoT-enabled Building Management Systems (BMS) (IoT Business News, 2024). The emergence of IoT-enabled Building Management Systems (BMS) has been recognized as a revolutionary method for building management, facilitating real-time data analysis and intelligent automation. The ORBIT framework is essential for the strategic development and deployment of innovations, while tackling significant difficulties such energy management, security, and interoperability (Lekidis & Katsaros, 2018; Nikpour et al., 2025). Every phase of the framework can be correlated with actions and discoveries in the field: Opportunity Scanning: Recognizing needs or issues in building management that IoT could resolve (e.g., excessive energy consumption, inadequate climate control, security deficiencies) (Avcı & Koca, 2023; Poyyamozhi et al., 2024). Research indicates that the increasing focus on energy efficiency and sustainability requirements in urban development has accelerated the integration of IoT in buildings, with a projected capacity to decrease worldwide energy consumption by 30% (Taboada-Orozco et al., 2024). Research and Development: Creating or modifying IoT solutions (sensors, networks, algorithms) to fulfill Building Management System requirements, frequently via prototyping and testing (Sabit & Tun, 2024). This phase encompasses technology innovations including smart sensor integration, AI-driven analytics, and machine learning for predictive maintenance (Nikpour et al., 2025; Ozturk & Al Kurdi, 2025). Studies indicate that AI-enhanced control systems can dynamically manage HVAC and lighting, resulting in an estimated 20% decrease in energy consumption while enhancing occupant comfort. Establishing Collaborative Ecosystems: Orchestrating stakeholders including technology suppliers, facility managers, contractors, and end-users or regulatory entities to facilitate IoT-BMS integration (Atzori et al., 2010). Successful collaboration in this field necessitates adherence to international smart home and smart building standards, including the Matter 1.4 framework, which improves interoperability among IoT devices (Atzori et al., 2010). Implementation: Deploying IoT-based solutions in buildings, encompassing the transition from pilot projects to comprehensive rollouts, which includes device installation, integration with legacy systems, and user training (Shaikh et al., 2014). Recent case studies have illustrated the effective deployment of IoT-based Building Management Systems (BMS) in commercial structures, facilitating automated regulation of HVAC, security, and energy monitoring (Afonso et al., 2023). Nonetheless, guaranteeing system resilience and security presents a difficulty, necessitating comprehensive cybersecurity policies (Avcı & Koca, 2023; Vasudevan, 2024). Performance Monitoring: Assessing the efficacy of the installed system using energy metrics, security incidents, tenant happiness, etc., and employing data analytics to evaluate success and guide future enhancements (Nikpour et al., 2025). Contemporary IoT-BMS incorporates real-time dashboards and AI-based anomaly detection to perpetually enhance operations and optimize efficiency (Poyyamozhi et al., 2024). Too clarify more, the study will examine each ORBIT stage comprehensively and present examples from the wireless IoT BMS sector to demonstrate their practical application.

2.2. ORBIT stages in IoT powered building management systems (BMS)

The ORBIT framework offers a systematic methodology for overseeing technological innovation, guaranteeing that new solutions experience organized creation, testing, deployment, and ongoing enhancement (Devaiah & Narang, 2014). In the context of wireless IoT-enabled Building Management Systems (BMS), ORBIT functions as a strategy framework for companies aiming to leverage IoT technologies to enhance energy efficiency, security, automation, and sustainability (Poyyamozhi et al., 2024). Every phase of the ORBIT framework is essential for facilitating the effective implementation of IoT-enabled Building Management Systems, with practical examples illustrating the application of these phases.

2.2.1. ORBIT stages in Wireless IoT-Powered BMS

The initial phase of ORBIT, opportunity scanning, concentrates on detecting deficiencies and inefficiencies in building management that can be remedied by IoT-enabled solutions. This entails examining existing constraints, legislative challenges, and technology progress that offer avenues for innovation. Conventional Building Management Systems frequently exhibit inefficiencies, including excessive energy usage, inadequate system integration, obsolete maintenance approaches, suboptimal occupant comfort regulation, and escalating cybersecurity risks. Buildings account for over 40% of worldwide energy usage (Poyyamozhi et al., 2024), highlighting the necessity for more intelligent, data-driven management systems. Escalating energy expenses and carbon reduction initiatives intensify the necessity for more efficient alternatives. A prevalent issue with conventional Building Management Systems is the absence of real-time monitoring and responsive maintenance. Numerous buildings utilize HVAC systems that function on predetermined schedules instead of real occupancy data, resulting in energy inefficiency. Likewise, maintenance adheres to a fixed schedule instead of condition-based evaluations, leading to superfluous fixes or unforeseen malfunctions. The IoT-enabled Building Management System (BMS) facilitates a shift from static to dynamic management by utilizing sensors that continuously gather real-time data on temperature, humidity, occupancy, and air quality, thereby enabling more accurate control of HVAC, lighting, and security systems. A significant opportunity emerges from the necessity for improved security and compliance. Conventional security systems, including CCTV cameras and alarm systems, operate independently and frequently necessitate manual intervention. IoT-enabled security solutions incorporate many protection layers, facilitating real-time threat detection and automatic responses. As buildings become increasingly networked, cybersecurity concerns are emerging as a significant worry. Opportunity scanning entails acknowledging the heightened susceptibility of IoT devices to cyberattacks and the necessity for comprehensive security measures, including encrypted communication, multi-factor authentication, and AI-driven anomaly detection (Avcı & Koca, 2023). An illustrative instance of opportunity scanning in the adoption of IoT-based Building Management Systems (BMS) is observed in a commercial office tower in Singapore, where elevated electricity expenses prompted an energy management pilot initiative. The implementation of intelligent IoT sensors enabled facility managers to detect inefficient HVAC usage patterns and execute automated modifications, resulting in a 15% decrease in total energy consumption within the initial six months (Shaikh et al., 2014).

2.2.2. Orbit 2: Research & Development (R&D): Creating IoT solutions for BMS

Upon identifying critical obstacles and opportunities, businesses proceed to the research and development (R&D) phase. This phase emphasizes the design, prototyping, and testing of IoT-driven solutions for integration into BMS infrastructure. Research and development in IoT-enabled Building Management Systems has resulted in progress in wireless sensor networks, artificial intelligence-based control systems, predictive maintenance algorithms, and improved cybersecurity frameworks. Recently, wireless communication technologies like Zigbee, LoRaWAN, and NB-IoT have been refined to guarantee dependable connectivity throughout extensive structures while reducing power consumption (Nikpour et al., 2025). These improvements have enabled BMS to gather detailed data from several distributed sensors, offering a real-time assessment of building conditions. Machine learning algorithms have been created to examine historical HVAC data, forecast occupancy patterns, and adapt energy usage dynamically, thereby enhancing efficiency dramatically (Nikpour et al., 2025). A fundamental element of R&D in IoT-BMS is predictive maintenance, wherein AI algorithms scrutinize sensor data to identify early indicators of mechanical breakdowns (Alshurideh, 2024; Ozturk, 2024; Mulpuri et al., 2025). Vibration and temperature sensors integrated into air handling systems can forecast motor failures weeks ahead, enabling facility managers to conduct proactive maintenance instead of awaiting breakdowns. This technology has been effectively used in Boston's Smart Campus Initiative, where AI-driven HVAC control decreased heating and cooling expenses by 25% while preserving optimal indoor air quality (Nikpour et al., 2025). Cybersecurity continues to be a critical emphasis of research and development. The IoT-enabled Building Management System expands the attack surface, rendering it susceptible to cyber assaults. Research has resulted in the establishment of encryption standards, zero-trust network topologies, and AI-driven intrusion detection systems that analyze data flow patterns for probable anomalies (Avcı & Koca, 2023). Innovative authentication methods, including blockchain-based identity verification, are being investigated to safeguard BMS devices from illegal access.

2.2.3. Orbit 3: Building collaborative ecosystems: Ensuring stakeholder involvement

Innovation in Building Management Systems necessitates the collaboration of various stakeholders, including technology vendors, facility managers, regulatory authorities, and sustainability specialists. The collaborative ecosystems phase of ORBIT guarantees that many stakeholders synchronize their interests and share their skills to render IoT-BMS solutions feasible. A significant obstacle in BMS adoption is the absence of standardization among IoT devices and communication protocols. Numerous existing structures employ proprietary legacy systems that may lack compatibility with contemporary IoT technologies. To resolve this issue, industry alliances such as Matter 1.4, BACnet, and Modbus have been established to facilitate interoperability across many companies (Atzori et al., 2010). These collaborative initiatives enable facility managers to use IoT solutions without being confined to a singular manufacturer's ecosystem. Regulatory compliance is essential in influencing the deployment of IoT-enabled Building Management Systems (BMS). Green building certifications, like LEED and WELL, now mandate real-time energy monitoring and indoor air quality tracking, thereby promoting collaboration between sustainability specialists and building management system developers (Atzori et al., 2010).

2.2.4. Orbit 4: Implementation: Deploying IoT-Powered BMS in real-world settings

The Implementation phase of ORBIT involves the conversion of designs and prototypes into fully functional wireless IoT-enabled Building Management Systems (BMS). During this phase, IoT solutions are implemented, configured, and connected with current building infrastructure to optimize energy usage, augment security, and boost automation (Poyyamozhi et al., 2024). Effective implementation employs a systematic and meticulously managed strategy, minimizing disruptions while optimizing system efficacy. Numerous IoT-enabled BMS implementations commence with pilot initiatives or restricted trials, enabling firms to assess performance, resolve difficulties, and enhance deployment techniques prior to expansion. Studies demonstrate that stepwise adoption enhances the success probability of IoT-BMS by reducing risk and optimizing technology deployment (Nikpour et al., 2025). A smart lighting and HVAC IoT system implemented in a commercial office tower exhibited quick energy savings and offered insights regarding sensor placement, network coverage, and integration problems prior to a comprehensive rollout (Sabit & Tun, 2024). A significant hurdle in implementation is the integration of IoT technologies with current Building Management Systems and legacy control systems. Numerous buildings currently include centralized automation systems, including HVAC, lighting, and security controls, which may not be compatible with contemporary IoT technologies (Shaikh et al., 2014). Retrofitting old systems instead of complete replacement is frequently the most economical approach. IoT retrofitting is the integration of wireless sensors and intelligent controllers with existing equipment, facilitating little operational disruption while enhancing efficiency (Atzori et al., 2010). A case study by Sabit & Tun (2024) presented an auxiliary bypass integrated with the IoT control loop, guaranteeing that in the event of IoT system failure, the traditional BMS logic would assume control, preserving safety, comfort, and operational continuity. This hybrid methodology resulted in the creation of a reliable smart Battery Management System, minimizing downtime risks while attaining significant energy efficiency improvements. Network infrastructure constitutes a vital element of implementation. Wireless IoT implementations necessitate gateways, hubs, and secure data transmission protocols to gather sensor data and transmit it to centralized cloud-based or edge computing platforms (Nikpour et al., 2025). Communication protocols including Zigbee, LoRaWAN, and WiFi facilitate low-latency, high-reliability connectivity among devices (Lekidis & Katsaros, 2018). IT staff are essential for maintaining adequate bandwidth, enforcing cybersecurity measures (such as firewalls, VPNs, and encryption), and facilitating effective real-time analytics processing (Avcı & Koca, 2023). A crucial aspect of IoT-BMS deployment is the power management of wireless devices. Given that IoT sensors function on batteries or low-power networks, overseeing sensor battery longevity and coordinating replacements for numerous devices presents a significant difficulty. Implementation teams frequently incorporate maintenance strategies to avert device malfunctions, guaranteeing the prompt availability of spare sensors for swift repairs (Atzori et al., 2010). An frequently neglected element of implementation is training and change management. Facility managers, IT teams, maintenance professionals, and security staff must receive training to engage with new IoT-based Building Management System interfaces (Poyyamozhi et al., 2024). Training programs include comprehending system dashboards, addressing alarms, and employing predictive analytics for maintenance and energy management (Sabit & Tun, 2024). Furthermore, occupants must be apprised of alterations; for instance, in structures utilizing occupancy sensors for lighting control, staff should recognize that automated lighting modifications are not malfunctions but integral components of the intelligent energy-saving system. Facilitating user acceptability is crucial for a seamless transition, as knowledgeable users are more inclined to collaborate with IoT-driven enhancements, including smart thermostat modifications or automatic access controls (Poyyamozhi et al., 2024; Sabit & Tun, 2024).

Practical applications of IoT-enabled Building Management Systems have exhibited substantial advantages, validating the anticipated efficiency improvements from the research and development phase. A commercial implementation of IoT smart plugs and HVAC controllers achieved quantifiable decreases in electricity consumption, demonstrating that laboratory-validated energy savings are applicable in practical environments (Nikpour et al., 2025). Another instance entailed the incorporation of IoT-based air quality sensors into a commercial building's HVAC system, resulting in a 15% decrease in HVAC energy usage while enhancing indoor air quality via dynamic ventilation modifications Taboada. The Sabit & Tun (2024) case study on IoT-BMS deployment revealed an hourly average power savings of around 36.8 kW, resulting in significant cost reductions while maintaining occupant comfort. These implementations substantiate the ORBIT framework's systematic methodology, wherein opportunity scanning, research, and pilot projects result in quantifiable operational enhancements. Notwithstanding these achievements, obstacles in execution persist. Technical complications, such sensor malfunctions, network interruptions, and data discrepancies, might affect performance, necessitating ongoing surveillance and prompt action. Organizational obstacles, including resistance to new technologies and temporary disruptions during installation, must be addressed through good communication and phased implementation techniques (Atzori et al., 2010). The iterative process of ORBIT guarantees that insights gained during deployment are reintegrated into research and development, as well as collaborative initiatives, to enhance IoT-BMS solutions (Poyyamozhi et al., 2024). Documenting best practices, optimizing sensor locations, and enhancing cybersecurity strategies are critical components of the ongoing innovation process.

2.2.5. Orbit 5: Tracking performance: Ensuring continuous improvement in IoT-Powered BMS

The concluding phase of the ORBIT system, Tracking Performance, guarantees that innovation results are assessed in relation to the initial objectives established during Opportunity Scanning. In wireless IoT-enabled Building Management Systems (BMS), performance monitoring is essential, as continuous surveillance is a fundamental characteristic of IoT technology (Poyyamozhi et al., 2024). This phase not only involves basic monitoring but also entails data analysis, insight generation, and the implementation of a feedback loop for ongoing system enhancement and improvement (Sabit & Tun, 2024). Performance tracking depends on Key Performance Indicators (KPIs) that assess energy savings, system reliability, occupant comfort, security issues, and cost reductions. These KPIs allow facility managers to assess if the IoT-enabled BMS is achieving anticipated efficiency improvements and inform subsequent optimization initiatives (Nikpour et al., 2025). Common KPIs encompass total energy consumption reductions, fluctuations in peak demand, occupant satisfaction levels (assessed via surveys and environmental sensors), system uptime indicators, and financial savings derived from operational improvements (Nikpour et al., 2025). Energy performance measurement and optimization is a key aspect of performance tracking is the monitoring of energy use, enabling facility managers to compare current energy usage with historical baselines or control groups. Studies indicate that IoT-based energy management systems can reduce monthly energy consumption by 15–25% compared to traditional building management systems. A verified case study revealed that a smart building energy management system attained a consistent 20% reduction in monthly energy consumption through IoT-driven dynamic optimization of HVAC and lighting systems (Atzori et al., 2010; Nikpour et al., 2025; Shaikh et al., 2014). Ongoing monitoring also assists in substantiating the Return on Investment (ROI) for IoT implementations. Confirmed utility cost savings via performance data analytics validate further investments in new IoT retrofits and expansions. If specific building zones or floors fail to meet anticipated savings, this may suggest potential for sensor recalibration, modifications in occupant behavior, or the implementation of supplementary automation features (Poyyamozhi et al., 2024). Monitoring the security performance of IoT-BMS entails tracking security warnings, evaluating false positives and negatives from smart surveillance analytics, and documenting attempted cybersecurity breaches (Avcı & Koca, 2023). A principal advantage of IoT-integrated security systems is their capacity to identify and respond to problems in real time. The reduction in security incidents after the deployment of smart surveillance and access control systems indicates the efficacy of the systems (Taboada-Orozco et al., 2024). Conversely, every cybersecurity breach attempts must be documented, studied, and utilized to improve defensive measures, including intrusion detection, firewall modifications, and AI-based anomaly detection (Nikpour et al., 2025). IoT platforms currently offer real-time security dashboards, enabling facility managers to evaluate device status, identify offline or malfunctioning equipment, and examine security event logs. In numerous IoT-BMS implementations, automated security audits and penetration testing have emerged as a conventional best practice to ensure long-term system integrity (Poyyamozhi et al., 2024). Performance tracking functions not just as a verification mechanism but also provides insights that enhance the innovation cycle, facilitating ongoing system improvement (Sabit & Tun, 2024). Should tracking data reveal unfulfilled objectives, the ORBIT framework necessitates a reevaluation of preceding phases. This may entail re-evaluating opportunity scanning to refine the stated requirements, modifying R&D to provide improved solutions, or augmenting the collaborative ecosystem to incorporate new knowledge (Atzori et al., 2010; Ghazal et al., 2021). For example, if energy consumption monitoring indicates overall savings while also identifying specific locations with peak demand challenges, this may suggest the necessity for sophisticated demand-response methods, battery storage integration, or automatic load balancing (Atzori et al., 2010).

Likewise, occupant feedback obtained from monitoring climate control efficacy may indicate a desire for more tailored environmental configurations, leading to the creation of intuitive IoT dashboards or mobile applications that enable users to customize their workspaces. A case study in Dubai's smart office sector illustrated how ongoing monitoring resulted in system enhancements. Initially, the adoption of IoT-BMS enhanced HVAC efficiency by 18%; however, later monitoring revealed that specific zones were over-conditioned due to inaccuracies in occupancy predictions. Adjusting the positioning of motion sensors and using AI-driven adaptive climate controls resulted in further efficiency improvements, achieving a total 24% reduction in energy consumption while maintaining occupant comfort (IoT Business News, 2024). Tracking performance yields the long-term advantage of documenting success narratives and industry best practices. Data-driven case studies furnish measurable evidence that "IoT improvement X yielded a Y% efficiency increase and recouped its expenditure in Z months," so presenting a persuasive rationale for additional IoT implementations. Insights gained from performance tracking can guide future smart building laws, foster standardization, and facilitate industry-wide implementation of best practices. Furthermore, disseminating performance outcomes to utility companies, governmental bodies, and sustainability organizations can facilitate cooperation options, including energy rebates, demand-response incentives, and green building certifications (Zanella et al., 2014; Ahmad et al., 2023; El Khatib et al., 2023; Oluokun et al., 2025). External collaborations can augment the ROI of IoT-enabled BMS solutions. Monitoring performance in IoT-enabled Building Management Systems is an ongoing process of system enhancement rather than a singular evaluation (Alshurideh et al., 2023; AlHamad et al., 2024). IoT technologies provide real-time commissioning, wherein system settings are autonomously modified to sustain optimal efficiency and security over time (Nikpour et al., 2025; Poyyamozhi et al., 2024). Over time, building usage patterns alter, external conditions develop, and technology progresses. The tracking mechanism enables the system to identify performance deviations and initiates recalibration to maintain efficiency and reliability (Sabit & Tun, 2024). The

ORBIT structure guarantees that the Tracking Performance phase serves as the connection between historical achievements and forthcoming breakthroughs, fostering a cycle of perpetual enhancement in IoT-driven BMS.

3. METHODOLOGY

This research employed a qualitative literature analysis methodology. We methodically gathered and examined relevant research publications, case studies, and review articles pertinent to wireless IoT applications in Building Management Systems. The literature research concentrated on Scopus-indexed sources, encompassing academic publications (such as Energy and Buildings, Automation, and Computer Science) and conference proceedings, to guarantee high-quality, peer-reviewed material. The search utilized keywords comprising combinations of terms such as “IoT” AND “Building Management System” OR “Smart Building”, “energy efficiency”, “building security IoT”, “smart HVAC IoT”, “building automation wireless”, and “AI in buildings”. We selected sites from the search results that explicitly focused on IoT-enabled Building Management Systems or closely similar smart building technologies. Recent publications from the past approximately 5 to 10 years were prioritized to reflect the present technological landscape, however seminal earlier works were also included for contextual understanding. The selection comprises systematic review articles that encapsulate overarching themes, alongside empirical research illustrating IoT-BMS deployments. Industry reports and standards documentation were utilized minimally, mostly for contextualizing frameworks or providing real-world illustrations, whereas the principal evidence is derived from academic sources. We examined more than 30 sources and specifically reference a representative selection of these in this post to substantiate each subject. We utilized the ORBIT innovation framework as an analytical tool to structure and analyze the data from the literature. Consequently, when we examined each source, we recorded information pertinent to one or more phases of ORBIT. For instance, if a paper addressed the rationale for deploying an IoT system (such as elevated energy expenses or occupant grievances), we connected that to Opportunity Scanning. We classified any study detailing the development of a novel wireless sensor or an AI algorithm for buildings as R&D. Instances of stakeholder participation or multi-disciplinary approaches were analyzed under the Collaborative Ecosystems phase, while actual deployment case studies were linked to Implementation. Ultimately, the provided measurements and outcomes were associated with Tracking Performance. Employing ORBIT in this manner offered a systematic approach to encompass the innovation process comprehensively, ensuring that our findings and discourse could address not just the enhancements realized with IoT in BMS but also the mechanisms by which they are attained and maintained. Upon categorizing literary ideas by ORBIT stages, we subsequently aggregated the content into four principal result areas: Energy Efficiency, Security, AI Integration, and Sustainability, as they emerged as consistent emphasis points in the sources. In each domain, we synthesized findings from many studies, emphasizing consensus outcomes (e.g., consistent reports of approximately 20–30% energy savings) while also acknowledging any discrepancies or distinctive contributions. We employed in-text citations with numbered evidence markers to attribute sources for certain facts or quotations, ensuring academic rigor and facilitating traceability. These markers align with the reference list formatted in APA style at the conclusion of the paper. Ultimately, in the Discussion, we analyzed the data within the context of the ORBIT framework and overarching innovation theory. This entailed an examination of the extent to which the literature illustrates each ORBIT stage, identifying the primary hurdles, and determining the requisite actions for academics, practitioners, or policymakers to further propel innovation in wireless IoT-based BMS. The methodology thereby integrated a systematic literature evaluation with the application of a conceptual framework. This method is appropriate for deriving comprehensive insights in a rapidly changing technical field where various disciplines converge. By directly correlating evidence with the ORBIT stages, we intend to furnish readers with both factual results and insights into the innovation dynamics inside smart building management systems.

4. FINDINGS

4.1. Energy efficiency improvement

A proven benefit of wireless IoT-enabled Building Management Systems is improved energy efficiency. An established benefit of wireless IoT-enabled Building Management Systems (BMS) is improved energy efficiency. Multiple research investigations and practical trials have shown that the incorporation of IoT technologies into building systems markedly decreases energy usage. IoT sensors and intelligent controls enable a shift from rigid operational schedules to dynamic, demand-responsive operations, permitting building equipment to operate solely when needed and to the exact degree required (Poyyamozhi et al., 2024). This functionality enhances HVAC, lighting, and electrical loads, averting superfluous energy use while preserving operational efficiency. Integrating occupancy sensors with smart lighting systems demonstrates the energy-saving capabilities of IoT technology. These systems autonomously disable lighting in unoccupied rooms and restore it upon the return of humans, thereby averting superfluous illumination of empty areas. IoT-enabled thermostats and HVAC controllers modify heating and cooling settings dynamically based on real-time occupancy and ambient circumstances, rather than maintaining a constant temperature setpoint throughout the day (Nikpour et al., 2025). These systems utilize adaptive, data-driven control algorithms to prevent energy waste in unoccupied regions while preserving occupant comfort. Empirical research and practical applications routinely demonstrate measurable energy savings attributable to IoT-enabled Building Management Systems (BMS). Research findings demonstrate a decrease in energy consumption between 20% and 30% across several building types (Sabit & Tun, 2024). Poyyamozhi et al. (2024) concluded that IoT technology might decrease overall building energy consumption by up to 30% and cut operational expenses by around 20% due to enhanced efficiency. One of the most critical uses of IoT in Building Management Systems (BMS) is the optimization of HVAC systems, which often represent the biggest portion of energy consumption in commercial and industrial edifices (Nikpour et al., 2025). IoT-based strategies, including intelligent zoning and adaptive setpoints, markedly diminish energy waste. Rather than uniformly conditioning a full building, IoT-enabled zoning solutions ensure that only occupied areas receive heating or cooling, enhancing energy efficiency without sacrificing comfort. Moreover, AI-driven predictive control models utilize real-time sensor data to optimize HVAC performance, minimizing energy consumption while ensuring consistent indoor temperatures (Sabit & Tun, 2024). Sabit & Tun (2024) presented a notable instance of IoT-driven energy efficiency through the incorporation of IoT devices into an existing Building Management System, emphasizing the optimization of HVAC and lighting systems. Their empirical analysis revealed that IoT sensors (monitoring temperature, motion, and occupancy) integrated with a supervisory control algorithm markedly diminished energy waste and improved overall efficiency. In addition to directly decreasing energy consumption, IoT-enabled Building Management Systems are essential for managing peak demand. The technology may dynamically modify power loads during peak demand periods by continuously evaluating real-time usage trends. An IoT-BMS can moderately reduce lighting or pre-cool a building prior to anticipated peak hours, so mitigating demand surges without compromising occupant comfort (Nikpour et al., 2025). Cost reductions in utilities are especially significant in facilities utilizing time-of-use pricing models, because energy consumption during peak periods results in elevated expenses (Taboada-Orozco et al., 2024). Numerous intelligent buildings engage in demand response programs, in which the IoT-enabled Building Management System interacts with utility providers during peak demand periods. Upon receiving grid-supplied demand-response signals, the BMS temporarily curtails non-essential loads, such as reducing HVAC output or dimming non-critical lighting. In exchange, participating buildings obtain cash incentives or discounted electricity rates. The detailed control afforded by IoT facilitates accurate, automatic involvement in demand response programs, resulting in increased energy grid stability and enhanced sustainability (Poyyamozhi et al., 2024). IoT-enabled BMS solutions provide energy efficiency improvements while maintaining occupant comfort. Conventional energy conservation methods, such as completely deactivating HVAC systems, sometimes result in pain and grievances from building occupants. Conversely, IoT-based BMS utilizes data analytics and AI-driven optimization to determine ideal configurations that reconcile energy efficiency with indoor environmental quality. The amalgamation of IoT with BMS has continually demonstrated efficacy in reducing energy waste while preserving occupant comfort and security. Practical applications of IoT-enabled BMS consistently attain double-digit percentage enhancements in energy efficiency, affirming its significance as a fundamental option for contemporary energy management (Taboada-Orozco et al., 2024). These enhancements correspond with the Opportunity Scanning phase of the ORBIT framework, which recognizes the necessity to diminish operating costs and environmental effects (Poyyamozhi et al., 2024). The IoT-BMS is essential for enhancing sustainability and cost effectiveness in building operations by enabling detailed energy management, demand response participation, and AI-driven predictive optimizations (Nikpour et al., 2025). The established advantages of these systems offer compelling rationale for extensive adoption, with anticipated developments in IoT, AI, and cloud-based analytics predicted to significantly augment efficiency gains in the forthcoming years.

4.2. Security enhancement and challenges

Wireless technology IoT-enabled Building Management Systems (BMS) offer substantial security improvements, although they also present novel cybersecurity challenges that require proactive management. The incorporation of smart cameras, motion detectors, door/window sensors, and alarm systems into a unified IoT network facilitates a more cohesive and intelligent security framework within structures (Poyyamozhi et al., 2024). The integration of real-time monitoring, access control, and automatic responses in IoT-BMS improves physical security and operational resilience. A primary advantage of IoT-enabled BMS is its capacity to deliver real-time situational awareness via intelligent automation and data analytics. Security staff or automated AI systems can oversee all IoT-connected devices through a centralized Building Management System dashboard, facilitating expedited threat identification and event response (Nikpour et al., 2025). For instance, if a motion sensor identifies movement in a restricted area after hours, the Building Management System (BMS) can autonomously activate adjacent CCTV cameras, direct them towards the area of interest, and notify security personnel through a mobile alert system (Avcı & Koca, 2023). Likewise, IoT-based access control systems can record all entries and exits, identify suspicious activity (such as repeated access attempts), and promptly notify security personnel. The use of biometric authentication, badge verification, and AI-driven anomaly detection significantly improves security measures in IoT-BMS. Facial recognition at entry points permits access solely to authorized people in designated locations, while AI-driven analytics identify anomalies in standard access patterns (Taboada-Orozco et al., 2024). For instance, if an employee usually accesses a floor during business hours but unexpectedly arrives late at night, the system can identify the irregularity and necessitate further verification. The IoT-BMS facilitates inter-system coordination by connecting security incidents with fire safety, HVAC, and emergency response systems. Upon activation of a fire sensor, the BMS can autonomously unlock emergency exits, engage the public address system, and alert emergency responders in real time (Poyyamozhi et al., 2024). Although IoT integration enhances security, it also increases the attack surface of building systems. In contrast to conventional Building Management Systems (BMS), which typically functioned within isolated networks, IoT-enabled BMS integrates diverse building components with IP networks and cloud-based platforms, hence heightening their susceptibility to cyberattacks (Sabit & Tun, 2024). Researchers have highlighted data privacy, network security, and illegal remote access as significant barriers to IoT adoption in smart buildings (Nikpour et al., 2025) A hacked IoT-BMS may yield significant repercussions. Cybercriminals may obtain remote access to building controls, alter HVAC settings to induce pain or equipment malfunctions, deactivate surveillance and security systems, or expropriate sensitive tenant information. Numerous prominent cyber disasters have illustrated how hackers exploit IoT devices, such smart thermostats and security cameras, as gateways to more extensive business networks (Avcı & Koca, 2023). Prevalent vulnerabilities in IoT-BMS encompass:

1. Inadequate passwords and authentication methods permit unauthorized access to building control systems.
2. Obsolete firmware, rendering IoT devices vulnerable to recognized attacks.
3. Unencrypted communication protocols elevate the risk of man-in-the-middle attacks.
4. Insufficient network segmentation allows attackers to go from one compromised device to other systems within the building.

A denial-of-service (DoS) attack on an IoT-BMS sensor network may impede building operations by inundating motion sensors, cameras, or fire alarms, resulting in erroneous security alerts or complete system failures. Furthermore, privacy issues emerge as IoT-BMS persistently gathers data about occupant movements and activities, requiring stringent data protection protocols to adhere to international privacy requirements such as GDPR and the NIST IoT Security Framework (Poyyamozhi et al., 2024). To mitigate these risks, sophisticated cybersecurity procedures are becoming integral to IoT-BMS implementations. Organizations using wireless IoT-enabled Building Management Systems must prioritize:

1. End-to-end encryption for the transmission of sensor data and cloud-based processing (Nikpour et al., 2025).
2. Multi-factor authentication (MFA) and biometric security for access to buildings and critical system control interfaces (Taboada-Orozco et al., 2024).
3. Consistent firmware updates and patch management to mitigate security vulnerabilities (Avcı & Koca, 2023).

Intrusion detection and AI-based anomaly detection have emerged as essential instruments for IoT security surveillance. Artificial intelligence models can analyze standard data traffic patterns and identify anomalous deviations, such as an IoT sensor abruptly transmitting data at an atypical frequency or an illegitimate device attempting to access the system (Poyyamozhi et al., 2024). (Avcı & Koca, 2023) created a machine learning-based DDoS detection solution for IoT-BMS that effectively recognized and mitigated intrusions aimed at smart building infrastructure. IoT-enabled BMS greatly improve physical security and surveillance; yet, they concurrently offer novel cybersecurity threats that necessitate ongoing awareness and adaptive security measures. When adequately secured, IoT integration consolidates and enhances building security, optimizing reaction times, access management, and safety coordination (Nikpour et al., 2025). Nevertheless, if cybersecurity flaws are not rectified, IoT-BMS may serve as gateways for cyber threats, jeopardizing both building operations and occupant data. The ORBIT paradigm prioritizes iterative tracking and security monitoring, guaranteeing that IoT-BMS cybersecurity is an ongoing activity rather than a singular implementation. Ongoing penetration testing, firmware updates, and AI-driven threat detection have become essential components of security for IoT-enabled smart buildings (Poyyamozhi et al., 2024). Security in IoT-BMS represents both a significant benefit and a possible risk, necessitating continuous innovation and adaptation to counteract evolving cyber threats.

4.3. AI integration and intelligent control

The incorporation of Artificial Intelligence (AI) into Building Management Systems (BMS) has revolutionized the monitoring, prediction, and automation of building activities. AI analyzes extensive data from Internet of Things (IoT) sensors, facilitating intelligent control via autonomous decision-making and continuous learning algorithms (Halhoul Merabet et al., 2021). IoT facilitates connectivity and data collection, whereas AI propels predictive optimization, defect detection, and real-time decision-making. Recent studies underscore AI's pivotal influence on energy efficiency, predictive maintenance, occupant comfort, and security management within smart buildings (Genkin & McArthur, 2023). AI-driven HVAC control transitions from reactive measures to predictive adjustments. Traditional HVAC systems function according to sensor data and established schedules, however AI-integrated Building Management Systems may predict environmental fluctuations and proactively modify operations (Liu et al., 2022). Machine learning methodologies, including neural networks and ensemble models, examine historical occupancy trends, meteorological predictions, and thermal dynamics to anticipate temperature variations. This predictive capability enables buildings to pre-condition environments before to user arrival, hence ensuring comfort and minimizing superfluous energy consumption (Halhoul Merabet et al., 2021). Research indicates that model-predictive control (MPC) systems included into AI-based building management systems (BMS) can maintain thermal comfort while minimizing energy use. An empirical investigation revealed that AI-driven predictive HVAC control decreased heating energy consumption by 20% relative to traditional systems, adjusting set points according to real-time building utilization data (Liu et al., 2022). These innovations improve efficiency beyond human-operated systems, allowing buildings to independently manage climatic conditions according to occupancy patterns. An AI-driven Building Management System improves human-building interaction by assimilating tenant preferences and adjusting ambient parameters accordingly. In intelligent offices, AI can identify that particular rooms necessitate varying climate configurations based on previous usage and autonomously modify HVAC settings (Halhoul Merabet et al., 2021). AI-driven feedback mechanisms, including application-based occupant voting, let users to express preferences regarding temperature and lighting, which the AI harmonizes using reinforcement learning algorithms. This customization enhances comfort while minimizing energy usage (Genkin & McArthur, 2023). A research study utilized reinforcement learning to enhance lighting and HVAC configurations according to occupant feedback, illustrating a balance between energy efficiency and user comfort (Liu et al., 2022). AI-driven optimization facilitates adaptive control, reducing complaints while maintaining sustainability objectives. Artificial intelligence is essential in predictive maintenance through the analysis of IoT sensor data from mechanical systems. Conventional maintenance adheres to predetermined timetables or responds to equipment failures, while AI anticipates faults before to their occurrence, hence minimizing downtime and expenses (Halhoul Merabet et al., 2021). Machine learning algorithms evaluate vibration, temperature, and performance variables to identify early indicators of wear and failure in HVAC, electrical, and mechanical components (Mohamed et al., 2023). A predictive AI model, trained on sensor data, indicated an 80% likelihood of chiller failure within a month, facilitating preventative maintenance instead of emergency repairs (Liu et al., 2022). Well-maintained systems enhance energy efficiency, as decaying equipment typically functions inefficiently, resulting in increased power consumption (Genkin & McArthur, 2023). Artificial intelligence facilitates comprehensive energy management by synchronizing HVAC systems, lights, and plug loads in real-time. IoT sensors perpetually transmit energy usage data to AI models, which subsequently modify loads in real-time to optimize efficiency (Onuh, et al., 2022). For instance, if natural light intensifies, an AI-driven Building Management System might diminish artificial illumination while marginally modifying cooling to counteract solar heat gain, so preserving comfort and minimizing energy use. In intelligent structures using solar panels and battery storage, artificial intelligence can forecast solar energy production and consumption trends, thereby optimizing the timing for drawing energy from the grid versus utilizing stored power (Yu et al., 2021). A study indicated that predictive AI analytics enabled a smart building to decrease peak grid use while enhancing solar energy usage, successfully redistributing energy loads according to demand predictions (Halhoul Merabet et al., 2021). AI-powered defect detection improves the dependability and response times of building management systems. AI algorithms consistently analyze sensor data to detect whether equipment functions outside standard parameters (Yu et al., 2021). Should a sensor generate inaccurate data or deviate from its calibration, AI can identify the anomaly and either recalibrate or alert operators (Onuh et al., 2022). Certain AI-driven BMS platforms incorporate self-correcting capabilities. Should an HVAC loop exhibit temperature oscillations due to a misconfigured control system, AI can automatically modify settings in real time, employing adaptive control logic to ensure stability (Liu et al., 2022). This diminishes human involvement, enabling the BMS to function autonomously with few interruptions. Notwithstanding the encouraging results, the incorporation of AI in BMS encounters numerous obstacles. The quality of IoT sensor data is essential; inadequate data impairs AI performance, resulting in inferior decisions (Onuh et al., 2022). AI models necessitate comprehensive training and calibration for each distinct building, rendering initial deployment intricate and resource-demanding (Halhoul Merabet et al., 2021). A further considerable problem pertains to operator trust and interpretability. Numerous AI models operate as black-box systems, complicating the comprehension of AI-generated judgments for facility managers (Yu et al., 2021). Explainable AI (XAI) is being investigated to address this disparity, providing transparent insights into AI recommendations via intuitive visuals and data-driven elucidations (Liu et al., 2022). Artificial intelligence has emerged as a crucial element of Internet of Things-enabled building management systems, converting structures into self-sufficient, data-driven ecosystems. Through the analysis of extensive real-time data, AI enables predictive automation, allowing buildings to anticipate and efficiently respond to operational requirements. AI-enhanced Building Management Systems facilitate energy conservation, predictive maintenance, and adaptive occupant behavior, in accordance with the trend towards cognitive and self-optimizing structures (Halhoul Merabet et al., 2021). Ongoing research aimed at enhancing AI models, sensor precision, and interpretability will further transform energy management, automation, and sustainability within the built environment through AI-driven building management systems.

4.4. Sustainability and environmental impact

The incorporation of Internet of Things (IoT)-enabled Building Management Systems (BMS) has substantial ramifications for sustainability and environmental effect, fulfilling both global and local ecological objectives. Structures are pivotal to sustainability initiatives owing to their significant resource utilization; enhancements in this domain can provide huge environmental advantages. The sustainability benefits linked to IoT-enabled Building Management Systems can be classified as direct, including savings in energy consumption and emissions, and indirect, encompassing the encouragement of environmentally friendly behaviors and the improvement of inhabitants' well-being. IoT-enabled Building Management Systems are crucial for minimizing energy usage in buildings. These systems can enhance the efficiency of diverse building activities by leveraging real-time data from linked devices, resulting in substantial energy savings. Studies suggest that IoT technology might reduce energy consumption by up to 30% and operational costs by 20% (Halhoul Merabet et al., 2021). Since a significant share of global electricity continues to be produced from fossil fuels, any reduction in building energy consumption immediately corresponds to a decline in greenhouse gas (GHG) emissions. A 20–30% decrease in energy use in a business building can avert the release of tens to hundreds of tons of CO_2 each year, contingent upon the energy source. Furthermore, IoT-driven management measures can mitigate peak demand, reducing reliance on less efficient and more polluting peaker power plants, thereby decreasing emissions. Poyyamozhi et al., (2024) underscored the critical importance of IoT in mitigating the environmental effects of the construction industry, which constitutes over 40% of global energy consumption and greenhouse gas emissions. IoT-enabled Building Management Systems enhance efficiency, supporting national and corporate goals for energy conservation and carbon reduction. Sustainable buildings frequently incorporate on-site renewable energy generation, such as solar panels, or employ renewable energy sourced from the grid. IoT-enabled Building Management Systems optimize the use of renewable resources by synchronizing building activities with energy availability. During peak solar output periods, the BMS can either store surplus energy or temporarily augment specific loads, such as charging electric vehicles or pre-cooling the building, to optimize the utilization of clean energy. Conversely, during periods of diminished renewable energy generation, the system can conserve energy or adjust loads accordingly. This astute management guarantees that building operations align with the availability of green energy, enhancing renewable integration. Moreover, IoT devices can connect with smart grids to adapt to grid conditions, converting buildings into grid-interactive efficient systems. This partnership facilitates grid stabilization and enhances the comprehensive integration of renewable energy sources. In addition to energy, IoT-enabled Building Management Systems may oversee and regulate additional resources, like water and waste, thereby improving overall sustainability. Smart meters and leak detection equipment facilitate real-time monitoring of water consumption, allowing for the swift discovery and rectification of leaks, thereby conserving water and averting damage. Advanced waste management technologies, including intelligent bins, can assess recycling rates and enhance waste collection procedures. These systems offer comprehensive insights on resource utilization, allowing buildings to establish sustainability standards and reduce waste. Sustainability includes both environmental preservation and the quality of indoor settings, which directly influences occupant health and productivity. IoT sensors can assess indoor air quality (IAQ) by quantifying concentrations of CO_2, volatile organic compounds (VOCs), particle matter, and additional contaminants. The BMS can subsequently modify ventilation or filtration systems in reaction to identified contaminants, so promoting healthier interior environments and potentially diminishing occurrences of sick building syndrome. Ensuring superior indoor environmental quality (IEQ) is crucial for occupant health and is acknowledged in green building certifications like LEED and WELL, which grant credits for ongoing monitoring and upkeep of indoor environmental criteria. Real-time indoor air quality monitoring enabled by IoT devices guarantees that air quality stays within healthy parameters, hence improving cognitive function and overall health, since research has associated reduced CO_2 levels with enhanced cognitive performance in office workers (Becerik-Gerber et al., 2022). IoT-enabled BMS enhance the durability of building equipment by enabling predictive maintenance and minimizing excessive wear. Ongoing surveillance of equipment performance facilitates the prompt identification of possible problems, permitting timely actions that avert malfunctions and prolong the longevity of assets like HVAC systems. This proactive strategy diminishes the necessity for the production and transportation of replacement components, so conserving resources and mitigating environmental impact. Highlighting the complete life cycle of building components corresponds with sustainable construction techniques, since effective maintenance postpones the necessity for resource-demanding replacements. Organizations are increasingly subject to sustainability reporting mandates, and IoT-enabled Building Management Systems deliver precise and verifiable data on energy conservation, emission reductions, and other critical performance metrics. This information can be conveyed to stakeholders, investors, and regulatory authorities, illustrating a dedication to environmental accountability. Clear tracking and reporting allow firms to verify their environmental performance. For instance, if a building realizes a 25% decrease in electricity usage following the implementation of an IoT-BMS, this accomplishment can be evaluated in terms of diminished carbon emissions and incorporated into sustainability reports or utilized to secure green building certifications. In conclusion, IoT-enabled Building Management Systems are essential to the progress of sustainable building technologies. They exemplify the principle of intelligent, sustainable architecture that reduces resource use while enhancing comfort and functionality. By minimizing energy waste, incorporating renewable energy sources, promoting healthy indoor conditions, and improving maintenance efficiency, these technologies substantially reduce the environmental impact of buildings. This is becoming increasingly significant as metropolitan regions implement smart city programs and climate change strategies, with buildings frequently leading these endeavors. Recent research indicate that IoT technologies improve energy efficiency and facilitate sustainability objectives (Halhoul Merabet et al., 2021). The extensive implementation of these technologies in the construction industry might be revolutionary, significantly aiding in climate change mitigation and resource preservation. It is essential to recognize that the creation of IoT devices incurs environmental costs, including those related to sensor manufacturing, and difficulties such as electronic waste must be addressed to achieve a favorable net sustainability impact. Future investigations in sustainable IoT should focus on the creation of low-energy, environmentally friendly gadgets and the reclamation of hardware components. Notwithstanding these factors, contemporary research robustly indicates that wireless IoT-enabled Building Management Systems yield a net environmental advantage alongside economic and societal benefits.

5. DISCUSSION

The incorporation of wireless IoT-enabled Building Management Systems (BMS) signifies a significant enhancement in building operations. The ORBIT innovation framework offers a systematic method for examining the adoption, obstacles, and prospective developments of this technology. The discourse emphasizes numerous essential aspects, including energy efficiency, security, AI integration, sustainability, and the continual necessity for performance monitoring. The IoT-driven Building Management System improves energy efficiency by real-time monitoring, data-informed decision-making, and adaptive control methodologies. Research regularly indicates energy savings of 20% to 30%, highlighting the substantial effect of intelligent automation on minimizing superfluous energy use (Poyyamozhi et al., 2024; Sabit & Tun, 2024). Technologies include intelligent lighting systems, occupancy-responsive HVAC modifications, and automated demand-response strategies enhance energy efficiency, hence lowering operating expenses and environmental repercussions. Buildings constitute approximately 40% of worldwide energy consumption and greenhouse gas emissions; thus, IoT-enabled Building Management Systems are essential in tackling climate change and sustainability issues (Taboada-Orozco et al., 2024). The amalgamation of renewable energy sources, like solar and wind power, with IoT-based Building Management Systems (BMS) has the capacity to enhance energy efficiency. Smart grids and energy storage systems may facilitate dynamic power consumption management in buildings, hence decreasing dependence on fossil fuels. Future advancements should concentrate on optimizing these integrations, augmenting battery storage capacities, and advancing predictive analytics for superior energy management. Notwithstanding its advantages, the implementation of IoT-enabled Building Management Systems presents significant security vulnerabilities. The interconnectedness of equipment inside building infrastructure generates numerous vulnerabilities to cyber threats, such as illegal access, data breaches, and denial-of-service assaults (Avcı & Koca, 2023). Malefactors may exploit inadequate authentication methods, unaddressed software flaws, or unsecured network protocols to seize control of building systems, possibly disrupting essential operations such as HVAC, lighting, and access controls. Research underscores the necessity of employing strong encryption techniques, multi-factor authentication, network segmentation, and AI-based anomaly detection to reduce cybersecurity threats (Poyyamozhi et al., 2024). Ensuring cybersecurity in IoT-BMS necessitates a multi-faceted strategy, encompassing continuous monitoring, penetration testing, and adherence to established security protocols. As IoT devices become more networked, collaboration among cybersecurity professionals, policymakers, and facility managers will be essential to establish standardized standards and real-time threat detection systems. The integration of AI with IoT-BMS markedly improves operational efficiency through predictive control, real-time data analysis, and automated decision-making. AI-driven HVAC optimization minimizes energy loss by dynamically modifying temperature settings according to occupancy patterns, weather conditions, and previous consumption trends (Halhoul Merabet et al., 2021). Moreover, AI-driven predictive maintenance models scrutinize sensor data to identify early indicators of equipment failure, enabling facility managers to proactively resolve issues prior to expensive breakdowns. Intelligent automation in Building Management Systems transcends just energy management. AI-driven analytics provide immediate modifications in lighting, ventilation, and security systems, enhancing occupant comfort while reducing resource consumption (Genkin & McArthur, 2023). Nonetheless, issues with data precision, sensor calibration, and AI interpretability remain. Numerous AI models operate as 'black boxes,' complicating facility managers' ability to comprehend or trust their decision-making processes. Future research must concentrate on creating explainable AI (XAI) approaches that offer transparent insights into system optimizations, hence improving confidence and usability among stakeholders. The ORBIT framework emphasizes the importance of ongoing performance monitoring to enhance system efficiency and guide future advancements. The IoT-enabled Building Management System (BMS) produces extensive data, allowing facility managers to track key performance indicators (KPIs) like energy consumption reductions, system dependability, user satisfaction, and operational cost savings (Nikpour et al., 2025). Data-driven insights evaluate the efficacy of IoT-BMS installations and provide areas for further enhancement. Ongoing innovation in IoT-BMS necessitates incremental enhancements informed by empirical performance data. Regular integration of adaptive control techniques, fortified cybersecurity measures, and AI-driven optimizations is essential to maintain the efficacy of IoT-BMS in dynamic building environments. Furthermore, cooperation among academia, industry, and regulatory entities will be crucial in determining the future of smart building management. Future endeavors should investigate the function of blockchain technology in safeguarding IoT networks, the possibilities of edge computing for decentralized processing, and progress in AI-driven anomaly detection (Ahmad et al., 2024; Alshurideh, 2024).

6. CONCLUSION AND RECOMMENDATIONS

This study examined the progress of IoT-enabled Building Management Systems (BMS) and analyzed these breakthroughs using the ORBIT innovation framework. The results affirm that IoT technologies are fundamentally revolutionizing Building Management Systems by facilitating increased energy efficiency, enhanced security automation, AI-driven self-regulation, and improved sustainability. The advantages of IoT-BMS tackle significant issues in the construction industry, decreasing operational expenses and ecological footprint while improving system responsiveness and robustness. To add more, the application of the ORBIT framework Opportunity Scanning, R&D, Collaborative Ecosystems, Implementation, and Tracking Performance illustrates that the efficacy of IoT-based BMS transcends mere technological factors. Successful implementation relies on recognizing key inefficiencies, engaging in substantial R&D, promoting interdisciplinary collaboration, employing methodical deployment tactics, and persistently assessing performance to facilitate enhancements. The cyclical nature of this innovation process highlights the significance of strategic planning and stakeholder involvement in achieving enduring success. Based on the this study discussion and result, a set of recommendation will be advised below:

1. The industry must emphasize the establishment of open protocols and standards to enhance device compatibility, facilitate integrations, and mitigate vendor lock-in threats.
2. Cybersecurity Enhancements: With the increasing usage of IoT, it is imperative to create comprehensive security frameworks, encompassing AI-driven threat detection, encryption, and secure authentication methods.
3. Incorporation with Renewable Energy Systems: Future IoT-BMS must integrate predictive models for the management of renewable energy sources, optimization of battery storage, and facilitation of grid-responsive energy utilization.
4. Human-Centric Artificial Intelligence and Transparent Models: AI-driven BMS must be engineered for transparency and user accessibility, guaranteeing that facility managers can comprehend and rely on system recommendations.
5. Future study should investigate decentralized processing using edge computing to enhance data processing efficiency and diminish dependence on cloud-based infrastructures.
6. Thorough Workforce Training: As BMS systems increasingly rely on data, facility personnel must receive training in IT and IoT operations to guarantee efficient system administration and problem resolution.
7. Performance Evaluation and Knowledge Dissemination: Establishing industry benchmarks, disseminating case studies, and developing open knowledge platforms will expedite the adoption and innovation of IoT-BMS.

The future of building management is advancing towards enhanced intelligence, efficiency, and sustainability. Utilizing organized innovation frameworks such as ORBIT enables stakeholders to methodically deploy IoT-based solutions while guaranteeing enduring durability and security. Through ongoing study and interdisciplinary collaboration, the forthcoming advancement of smart buildings may attain near-zero energy usage, autonomous operating efficiency, and enhanced climate resilience. The implementation of IoT-BMS will be crucial in developing smarter cities and a more sustainable future, as innovation persistently propels the industry ahead.

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