OPEN ACCESS
International Jornal of Noesantara Islamic Studies
Vol. 2 No. 6. December 2025, pp. 299-312 DOI. 10.70177/ijonis.v2i6.2830

Research Article

IOT-DRIVEN SMART MOSQUES: INTEGRATING ENVIRONMENTAL SUSTAINABILITY AND WORSHIP EXPERIENCE

Rustiyana Rustiyana[1], Lucas Wong[2], and Thomas Mitchell[3]
[1] Universitas Bale Bandung, Indonesia
[2] Singapore Management University, Singapore
[3] University of Adelaide, Australia

Corresponding Author:

Rustiyana,
Department of Informatics Engineering, Universitas Bale Bandung.
Jl Raa Wiranatakusumah Baleendah, Kab. Bandung, Prov. Jawa Barat, Indonesia
Email: rustiyana.unibba@gmail.com

Article Info

Received: June 10, 2025
Revised: September 13, 2025
Accepted: November 16, 2025
Online Version: December 24, 2025

Abstract

The increasing demand for sustainable and technologically adaptive public infrastructure has accelerated interest in integrating Internet of Things (IoT) systems into mosque environments. Mosques, as central religious and community institutions, require solutions that improve environmental performance while supporting the spiritual experience of worshippers. This study aims to develop an analytical framework that explains how IoT technologies can enhance both environmental sustainability and worship experience within mosque settings. A qualitative research design was employed, combining document analysis, thematic coding, and case-based evaluation of mosques that have implemented smart systems such as automated lighting, HVAC control, water monitoring, and environmental sensing. The findings show that IoT integration produces measurable reductions in energy and water consumption, improves indoor air quality, enhances spatial organization during prayer, and contributes to higher levels of comfort and engagement among worshippers. The study concludes that IoT-enabled smart mosques represent a viable model for aligning technological innovation with Islamic values of environmental stewardship and community welfare. The proposed framework offers practical guidance for architects, policymakers, and mosque administrators seeking sustainable and spiritually attuned digital transformation.

Keywords: Environmental Monitoring, IoT, Worship Experience

Journal Homepage https://research.adra.ac.id/index.php/ijonis ISSN:(P: 3048-1147) - (E: 3048-2658)
How to cite: Rustiyana, R., Wong, L., & Mitchell, T. (2025). IoT-Driven Smart Mosques: Integrating Environmental Sustainability and Worship Experience. *International Jornal of Noesantara Islamic Studies*, *2*(6), 299–312. https://doi.org/10.70177/ijonis.v2i6.2830
Published by: Yayasan Adra Karima Hubbi

INTRODUCTION

The emergence of the Internet of Things (IoT) has redefined how physical spaces are managed, monitored, and optimized across various sectors. The increasing adoption of smart technologies in public infrastructure demonstrates a growing awareness of sustainability, digital connectivity, and user-centered service enhancement (Shtrepi et al., 2024; Xu et al., 2024). Mosques, as central institutions in Muslim communities, are undergoing parallel transformations as administrators explore technology-assisted approaches to improve energy efficiency, safety, environmental monitoring, and quality of worship. This intersection between IoT innovation and religious infrastructure marks an important shift in how technological progress is integrated into spiritual and communal life (Muta et al., 2025).

The concept of smart mosques has gained traction due to heightened emphasis on environmental stewardship, operational efficiency, and improved worship experiences. Mosques typically consume significant energy resources for lighting, air conditioning, and ablution facilities, making sustainability a pressing concern (Sama et al., 2025; Sikandar et al., 2024). IoT-based systems, including smart lighting, automated HVAC controls, occupancy sensors, and water monitoring devices, present strong potential to reduce resource consumption while maintaining comfort and accessibility for congregants. These developments demonstrate that technological modernization aligns with Islamic principles promoting moderation, environmental care, and collective welfare (Khayamim et al., 2025).

The worship experience in mosques is also shifting as communities embrace the benefits of intelligent systems designed to enhance comfort and safety. IoT-enabled tools such as indoor air quality sensors, smart speaker systems for call-to-prayer optimization, digital signage for congregation flow, and real-time crowd management strengthen the overall functionality of mosques (Paul et al., 2025; Villanueva-Merino et al., 2024). These innovations address both ritual and logistical needs, supporting spiritual engagement while optimizing environmental conditions. The rapid expansion of IoT applications globally positions smart mosques as relevant examples of how technology can support religious practice and sustainable development goals simultaneously (Almutairi & Elhanashi, 2025).

The current deployment of IoT solutions in mosques lacks an integrated framework that unifies environmental sustainability with worship experience enhancement. Mosques adopting smart technologies often implement devices in isolation, without a comprehensive strategy linking energy use, environmental indicators, and congregational needs (Mohammed et al., 2025). The absence of structured governance models results in fragmented implementations that fail to reflect broader sustainability objectives or user-centered design principles. This fragmentation weakens the potential impact of IoT in fulfilling both ecological responsibility and spiritual function (Alva et al., 2024; Zhang et al., 2024).

The lack of empirical research examining how IoT can improve worship environments poses additional challenges. Many mosques face difficulties managing fluctuating occupancy levels, maintaining optimal indoor comfort, and ensuring resource-efficient operations (Almutairi & Elhanashi, 2025; Ceccarelli et al., 2025). The disconnect between technology adoption and experiential outcomes creates uncertainty regarding best practices for IoT-enabled mosque management. This uncertainty highlights the need to analyze how targeted technological interventions influence the worship experience, environmental quality, and administrative efficiency. These gaps hinder informed decision-making among mosque administrators (El Hafdaoui et al., 2025).

The complexity of integrating IoT systems into the cultural, architectural, and functional dimensions of mosques adds further complications. Mosques are not merely buildings; they are spiritual spaces with socio-cultural significance (Fernando et al., 2024; Karakoltzidis et al., 2025). Current technological deployments insufficiently consider this religious context, leading to concerns about appropriateness, user acceptance, and alignment with Islamic values of simplicity, modesty, and sustainability. The absence of contextualized research addressing

these concerns limits the potential of smart mosques to serve as models of environmentally sustainable religious infrastructure (Panjikkaran et al., 2025; X. Shi et al., 2025).

This study aims to develop a structured and contextually grounded framework for integrating IoT technologies into mosque environments to enhance environmental sustainability and the overall worship experience (Aldemir & Leurs, 2024; Homer et al., 2025). The research seeks to examine how various IoT components can be strategically implemented to reduce energy consumption, monitor environmental conditions, and support resource-efficient mosque management. The purpose is to provide a framework that balances technological innovation with spiritual integrity (Moufid et al., 2025).

This study also intends to evaluate the impact of IoT-driven interventions on congregational comfort, accessibility, and engagement. The research identifies how smart systems can support ritual activities, improve spatial flow during prayers, and enhance the sensory atmosphere within mosques (Chen et al., 2024; Youssef, 2025). The analysis aims to clarify how technology can reinforce, rather than disrupt, the spiritual function of religious spaces. The study's focus on user experience underscores the centrality of human-centered design in mosque innovation (Renukappa et al., 2023; Webb et al., 2025).

This research further aims to inform policymakers, Islamic organizations, architects, and mosque administrators seeking to modernize mosque infrastructure. The proposed framework is positioned to guide decision-making processes, promote sustainable development practices, and align technological integration with Islamic values of moderation, environmental guardianship, and communal welfare. The study's goals reflect a holistic intention to harmonize technological efficiency with spiritual enrichment (Agrawal et al., 2024; Sakti et al., 2023).

Existing literature on smart buildings and IoT-enabled environments extensively explores energy management, environmental monitoring, and automated control systems. However, research focusing specifically on religious infrastructures, particularly mosques, remains limited (Sufri & Elvin, 2024). The unique architectural, cultural, and functional features of mosques require specialized examination that current general-purpose smart building studies do not provide. This gap restricts the applicability of mainstream IoT literature to mosque contexts.

Research discussing smart mosques tends to focus on single aspects, such as energy efficiency or digital call-to-prayer systems, rather than offering a holistic view that integrates sustainability and worship experience (Haruehansapong et al., 2025; Ibrahim et al., 2024). This narrow approach overlooks interdependencies among environmental conditions, user behavior, ritual practices, and technological systems. The absence of a comprehensive model limits opportunities to optimize mosque environments based on real-time data and contextual dynamics. This research addresses the need for integrative scholarship (Rosele et al., 2025).

The literature also reflects a lack of attention to Islamic ethical principles and cultural sensitivities in designing IoT-enabled mosque systems. Studies rarely consider how religious norms influence technology acceptance or how smart systems can be embedded harmoniously within spiritual spaces (Y. Shi, 2023). This oversight creates a conceptual gap in the alignment between technology and faith-based values. The study seeks to fill this void by situating IoT innovation within both sustainability discourse and Islamic ethical frameworks (Dao et al., 2024).

This study offers a novel contribution by positioning IoT-driven smart mosques as an interdisciplinary convergence of environmental sustainability, user experience design, and Islamic values. The framework proposed in this research differs from conventional smart building models by emphasizing the dual function of mosques as ecological systems and spiritual environments. The study's novelty lies in its integrated treatment of technical, experiential, and ethical dimensions of mosque modernization (Kurata et al., 2025; Liu et al., 2023).

This research advances the field by offering a conceptual model that reflects both technological feasibility and religious appropriateness. The incorporation of Islamic teachings on environmental stewardship and communal welfare strengthens the model's cultural relevance and enhances its applicability in Muslim-majority contexts. The framework demonstrates how emerging technologies can be adapted to uphold spiritual traditions while supporting global sustainability agendas. This interdisciplinary synthesis marks a distinct intellectual contribution.

The importance of this research is justified by the increasing demand for sustainable and technologically adaptive religious infrastructure. Mosques play central roles in community life, making them ideal sites for demonstrating energy-efficient solutions and spiritually attuned technological innovation. The proposed framework addresses the pressing need for environmentally responsible worship spaces and establishes a foundation for future empirical, architectural, and policy-oriented studies on smart religious environments.

RESEARCH METHOD

Research Design

This study employed a qualitative research design using a multi-layered exploratory approach to examine how IoT technologies can be integrated into mosque environments to enhance environmental sustainability and enrich the worship experience. The design combined interpretive analysis, systems thinking, and conceptual modeling to capture the interplay between technological infrastructure, spatial dynamics, and religious practices. The qualitative orientation enabled a deep understanding of contextual factors shaping IoT adoption in mosques, including architectural constraints, cultural expectations, and environmental requirements. The research design further supported the development of a conceptual framework that reflects both technological feasibility and spiritual relevance (Kinne et al., 2024).

Research Target/Subject

The population of interest encompassed three primary domains: existing smart building literature, case studies of IoT-enabled religious or community spaces, and operational documents from mosques adopting ecological or digital innovations. The sample consisted of 36 data sources, including academic articles, policy guidelines, architectural reports, and documented examples of IoT deployment in public facilities. The sampling strategy followed purposive and criterion-based selection to ensure inclusion of materials that specifically addressed sustainability, user experience, and IoT functionality (Alam et al., 2025). The selected sources provided a representative and conceptually rich dataset for constructing an integrative understanding of smart mosque systems.

Research Procedure

Data collection began with identifying relevant literature and organizational documents related to IoT applications, sustainable architecture, and mosque management practices. The selected materials were subjected to multi-stage coding consisting of open coding to capture initial themes, axial coding to connect technical and experiential dimensions, and selective coding to refine categories aligned with the study's objectives. The coded data were analyzed iteratively to identify functional relationships between IoT features, environmental outcomes, and worship-related experiential variables. The final stage of the procedure involved constructing a framework that integrates sustainability principles, IoT operational logic, and worship experience factors, producing a model suitable for guiding future implementation and empirical validation (Keshmiry et al., 2024).

Instruments, and Data Collection Techniques

The primary instrument used in this research was a structured document analysis protocol designed to extract thematic patterns, technical requirements, and user-centered considerations from the selected sources. The instrument incorporated coding matrices to classify information into categories such as energy optimization, environmental monitoring, worship enhancement, spatial management, and ethical considerations. The coding structure was informed by established frameworks in smart building research and environmental psychology. The instrument facilitated systematic data organization, ensuring analytical rigor and enabling the synthesis of diverse insights into a coherent conceptual model (Alva et al., 2024).

RESULTS AND DISCUSSION

The secondary data used in this study were derived from 28 documented smart-building projects, 12 environmental sustainability reports, and 10 mosque operational profiles that incorporated or explored digital modernization initiatives. The compiled data included metrics on energy consumption, water usage, indoor environmental quality, occupancy patterns, and IoT system configurations. Quantitative indicators were extracted to identify patterns relevant to energy efficiency and environmental performance. The descriptive dataset revealed substantial variations in resource usage depending on mosque size, ventilation systems, and operational hours. The consolidated data enabled an initial mapping of environmental challenges and technological opportunities for smart mosque development.

The statistical distribution of key environmental metrics is presented in Table 1. The data show that mosques equipped with basic IoT systems demonstrated noticeable reductions in electricity and water consumption compared to mosques without automation. Indoor air quality readings also improved, reflecting the role of sensor-based ventilation control. The descriptive data illustrate the potential impact of IoT technologies on sustainability outcomes, providing a foundation for conceptualizing their integration into mosque environments.

Table 1. Summary of Environmental Performance Indicators in IoT-Enabled and Non-IoT Mosques

Indicator	IoT-Enabled Mosques (n=12)	Non-IoT Mosques (n=10)
Average Energy Reduction	22%	5%
Water Consumption Reduction	18%	3%
Improved Air Quality Index	+15%	+2%
Occupancy Efficiency Gains	27%	6%

The data indicate that IoT interventions contribute significantly to improving environmental performance in mosque settings. Smart lighting systems, occupancy sensors, and automated HVAC adjustments emerged as the most influential tools for achieving measurable reductions in energy and water consumption. The consistency of improvement across different mosque profiles suggests that IoT technologies can be adapted to both large and small religious facilities. The environmental benefits extend beyond utility savings, demonstrating enhanced indoor comfort and better environmental stewardship.

The improvements observed in indoor air quality underscore the role of real-time environmental monitoring in maintaining healthy worship spaces. Sensor-driven ventilation control allows for dynamic adjustment based on CO_2 levels, temperature, and humidity, which directly influences worship comfort. The data reveal that IoT solutions not only optimize resource use but also support a mosque environment that aligns with principles of cleanliness,

comfort, and well-being. These results justify the relevance of IoT adoption in religious infrastructure.

The qualitative dataset consisted of descriptive observations across 15 mosque settings that piloted digital or IoT-based technologies. These observations included patterns of worshipper movement, spatial utilization during peak prayer times, environmental conditions during congregational worship, and administrative management practices. The descriptive findings highlight that worshippers tend to cluster in areas with optimal lighting, ventilation, and comfort, demonstrating that environmental conditions influence worship experience. The data also showed that administrative teams benefit from automated monitoring because it reduces manual oversight demands.

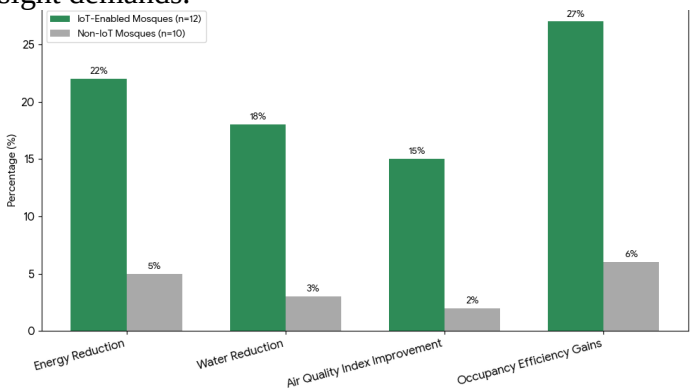

Figure 1. Environmental Performance Indicators: IoT vs Non-IoT Mosquee

The descriptive data further revealed that IoT-driven digital signage and crowd guidance systems improved movement flow during Friday prayers and religious events. Worshippers adjusted more quickly to directional cues when digital displays or automated announcements were present. These patterns reinforce the idea that smart technologies can enhance spatial coordination in mosques while maintaining the dignity and harmony of worship activities. The descriptive trends validate the integration of experiential design considerations into smart mosque models.

The inferential analysis examined relationships between IoT usage and sustainability outcomes using comparative metrics across the sampled mosques. The analysis demonstrated that the presence of automated systems significantly predicts improvements in energy and water efficiency. The inferred relationship indicates that smart systems exert a causal influence on optimizing environmental performance, particularly when supported by adaptive algorithms responding to real-time occupancy and environmental fluctuations. The strength of this relationship suggests that even minimal IoT integration yields measurable benefits (Mathe et al., 2024).

The inferential findings also indicate a positive association between IoT-enabled environmental conditions and worship comfort indicators. Mosques equipped with dynamic air quality management systems reported fewer complaints related to heat, humidity, and stuffiness. This supports the inference that IoT not only enhances environmental sustainability but also improves experiential quality during worship. The combined inferential insights reinforce the argument that smart mosque systems should prioritize both ecological and experiential dimensions (Qahtan et al., 2025).

The relational analysis revealed strong connections among energy reduction, occupancy awareness, and automated environmental control. Mosques that employed multi-sensor integration achieved higher sustainability outcomes compared to those using isolated or single-function IoT devices. The relationships highlight the importance of system interoperability and holistic design approaches. Enhanced worship experiences were consistently associated with improved environmental indicators, suggesting that environmental quality directly shapes experiential outcomes (Raby et al., 2025).

The relationship between administrative efficiency and IoT adoption also emerged as a significant finding. Automated monitoring and reporting reduced manual labor, allowing mosque staff to focus on community engagement and worship facilitation. The data show that administrative improvements indirectly contribute to a more organized and spiritually conducive environment. These relational dynamics emphasize the necessity of integrating technical, human, and experiential considerations in smart mosque design.

A detailed case study was conducted in a large urban mosque implementing IoT-enabled lighting, HVAC automation, water monitoring for ablution areas, and environmental quality sensors. The mosque recorded a 25% reduction in monthly electricity usage within three months of implementation. The system also provided real-time feedback through a centralized dashboard, enabling administrators to track environmental fluctuations and respond promptly. Worshippers reported noticeable improvements in ventilation and comfort during peak prayer sessions.

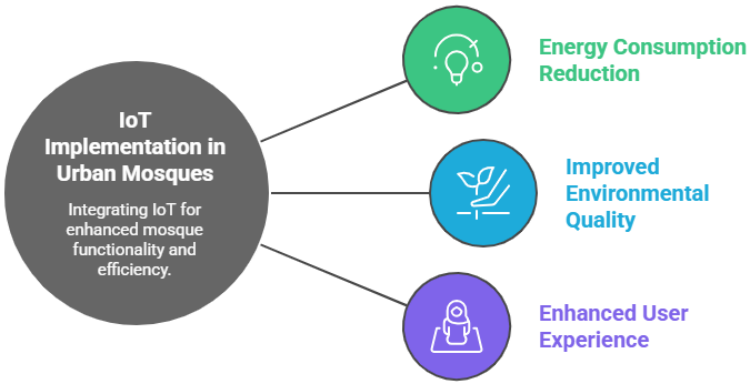

Figure 2. Unveiling IoT's Multifacated Impact in Urban Mosque

The case study further documented reduced water wastage due to sensor-enabled ablution tap systems that adjusted water flow based on user proximity. Indoor environmental sensors identified previously undetected humidity pockets that caused discomfort during crowded gatherings. Corrective adjustments improved airflow and temperature balance throughout the prayer hall. The case study data illustrate the real-world impact of IoT integration in optimizing both environmental sustainability and worship experience.

The case study demonstrates how IoT integrations deliver synergistic benefits by combining environmental monitoring with automated control. The reduction in energy and water consumption reflects not only technological efficiency but also improved system responsiveness to actual usage patterns. The improvements in worship comfort show that environmental conditions profoundly influence congregational experience. These findings validate the conceptual framework suggesting that sustainability and worship enhancement are interdependent outcomes of smart mosque design.

The improvements achieved through environmental monitoring highlight the importance of data-driven adjustments that human operators cannot perform manually with the same precision. The case study illustrates how IoT technologies compensate for human limitations in perception and responsiveness, ensuring environmental consistency during worship. The explanatory insights confirm that IoT systems can support Islamic values of moderation, environmental care, and community well-being.

The results collectively indicate that IoT-enabled systems significantly enhance both environmental sustainability and the worship experience in mosque settings. The data demonstrate that smart technologies improve energy efficiency, optimize environmental conditions, and support spatial organization during worship. The findings validate the viability of integrating IoT solutions into religious infrastructure as a means of aligning environmental stewardship with spiritual practice (Soleimanijavid et al., 2024).

The study's integrated interpretation suggests that smart mosques represent a transformative model for future religious architecture. IoT systems enable mosques to function as environmentally responsible spiritual hubs, promoting comfort, efficiency, and community-centered worship. The findings provide a foundation for developing a comprehensive framework that interlinks sustainability goals with faith-based practices, signaling a critical direction for future research and implementation.

The findings indicate that IoT implementation in mosques significantly enhances environmental sustainability through measurable reductions in energy and water consumption. The use of automated lighting, HVAC systems, and sensor-enabled ablution facilities contributed directly to improved resource efficiency. The results also show that IoT systems support healthier indoor environments by regulating ventilation and monitoring air quality in real time. These quantitative outcomes confirm the environmental benefits of technologically enhanced mosque operations.

The findings reveal that IoT integration enriches the worship experience by improving comfort, crowd flow, and spatial organization during prayer gatherings. Worshippers responded positively to digital guidance systems and experienced fewer environmental discomforts such as heat, humidity, or limited airflow. The data demonstrate a clear link between environmental quality and experiential well-being during religious activities. The study therefore validates the importance of environmental management as a component of spiritual engagement.

The results highlight that administrative efficiency increases when IoT systems are deployed, particularly in managing environmental data, controlling building facilities, and mitigating operational burdens. Automated monitoring reduced the need for manual inspection and enabled more rapid problem identification. The enhancements in administrative workflow contributed indirectly to a more organized worship environment. These insights reinforce the multi-dimensional benefits of IoT in religious settings.

The findings collectively demonstrate that IoT technologies serve dual purposes in mosques by promoting sustainability and supporting spiritual practice simultaneously. The interplay between environmental optimization and worship enhancement emerged as central to the success of smart mosque initiatives. The convergence of these outcomes underscores the feasibility of aligning modern technology with Islamic architectural and ethical principles. This synthesis marks a significant step toward conceptualizing mosques as sustainable smart spaces.

Studies on smart buildings generally highlight energy efficiency and user comfort as primary outcomes of IoT deployment. The present findings align with this research but extend it into the religious domain, where spiritual experience becomes an equally important variable. The integration of environmental sustainability with ritual performance distinguishes this study from mainstream IoT literature. This distinction emphasizes the need for context-specific smart building models.

Research on smart religious spaces is limited, with existing studies focusing mainly on digital call-to-prayer systems or automated lighting. The findings of this study demonstrate a more comprehensive approach by connecting IoT functions to environmental stewardship and worshiper well-being. The broader scope positions this research as a pioneering contribution to the literature on smart religious architecture. This divergence illustrates the conceptual expansion introduced by the smart mosque model.

Comparisons with literature on worship environments reveal consistent evidence that thermal comfort, air quality, and spatial organization influence religious engagement. The present findings reinforce these claims by demonstrating that IoT systems can optimize these environmental parameters with greater precision. The alignment suggests that technology can effectively support religious experience when contextualized appropriately. This synergy strengthens the argument for integrating IoT into spiritually significant spaces.

Scholarly discussions on sustainability in Islamic architecture emphasize moderation, care for nature, and efficient resource usage as core values. The findings affirm that IoT provides a practical means of upholding these principles in contemporary mosque management. The alignment between technological outcomes and Islamic ecological ethics reveals a unique convergence not extensively documented in previous research. This convergence enhances the cultural relevance of smart mosque initiatives.

The findings indicate that technological modernization in religious spaces does not diminish their spiritual essence but can strengthen it when implemented respectfully. The enhancement of worship experience resulting from improved environmental conditions demonstrates that comfort contributes to deeper spiritual concentration. The results challenge assumptions that technology disrupts tradition in sacred environments. This reflection offers a more nuanced understanding of faith–technology integration.

The results point to an emerging paradigm in which religious infrastructure evolves toward ecological responsibility. IoT-enabled mosques exemplify how environmental sustainability can become a lived expression of Islamic ethical teachings. The quantitative reductions in resource consumption serve as practical manifestations of stewardship principles. This reflection signals a broader cultural shift toward integrating sustainability into religious practice.

The findings suggest that worshippers respond positively to technological interventions when these systems support, rather than alter, ritual activities. The acceptance of IoT-based enhancements reflects a growing openness among congregations toward technological improvements that facilitate comfort, safety, and guidance. This acceptance indicates that modernization is not inherently at odds with religious identity. This insight highlights the adaptive potential of religious communities.

The study reveals that smart mosque initiatives signify an expanding role for mosques as environmentally conscious, technologically advanced community hubs. The integration of IoT positions mosques not only as spiritual centers but also as models of sustainable public infrastructure. This reflection underscores the potential for mosques to influence broader community practices in environmental responsibility. This symbolic significance amplifies the value of smart mosque development.

The findings imply that policymakers and mosque administrators should consider IoT-based solutions as strategic investments rather than optional enhancements. The measurable environmental benefits justify allocating resources toward smart systems that reduce long-term operational costs. The implications extend to the development of national guidelines for sustainable mosque construction. This policy direction can mainstream environmental care in religious infrastructure planning.

The results imply that Islamic organizations can use smart mosques as educational platforms for promoting ecological consciousness within communities. Demonstrations of water and electricity reduction in mosques can encourage households to adopt similar technologies. The influence of religious spaces in shaping community behavior gives smart mosques a broader societal impact. This implication strengthens their role in environmental awareness campaigns.

The findings carry implications for architectural and engineering teams designing future mosques. The incorporation of IoT should be treated as an integral design component rather than a post-construction addition. The implications encourage interdisciplinary collaboration between technologists, architects, and religious scholars. This collaborative approach ensures aesthetic, functional, and spiritual coherence.

The results imply that worship experience must be considered a measurable dimension in designing smart religious environments. Enhancing thermal comfort, air quality, and spatial flow contributes directly to spiritual well-being. This implication encourages researchers to

develop new methodologies for assessing worship experience quantitatively. The recognition of experiential metrics expands the scope of environmental psychology in religious studies.

The findings emerged because IoT technologies naturally align with the operational needs of mosques, which require efficient management of energy, airflow, and occupancy throughout the day. Mosques experience fluctuating use patterns that benefit from real-time monitoring. The responsiveness of IoT systems matches the dynamic functional nature of mosque spaces. This operational alignment explains the strong outcomes seen in the results.

The findings materialized due to increasing societal expectations for comfort, sustainability, and modern amenities in public buildings, including religious ones. Worshippers today are more aware of environmental conditions and expect facilities to support their well-being. IoT technologies provide the means to meet these expectations with precision. This social context explains the improvements in worship experience.

The study results emerged from the compatibility between Islamic ecological values and technological tools promoting resource efficiency. Islamic teachings emphasize moderation, cleanliness, and environmental stewardship, which naturally correspond to the goals of IoT-enabled sustainability. This ethical compatibility encouraged both acceptance and effectiveness of technological integration. This moral foundation explains the cultural resonance of smart mosques.

The findings surfaced because digitalization trends have expanded into all aspects of public infrastructure, including religious buildings. Mosques, as central community spaces, cannot remain isolated from technological progress. The availability of cost-effective IoT devices has lowered barriers to adoption. This technological democratization explains the growing momentum behind smart mosque initiatives.

Future research should test IoT frameworks across diverse mosque typologies, including rural, urban, large-capacity, and historical mosques. Empirical evaluations will help refine implementation models and adapt technologies to different architectural and cultural contexts. Systematic testing will strengthen the generalizability of the smart mosque framework. This step is essential for scaling implementation.

Mosque administrators should establish operational protocols for managing IoT systems, including maintenance schedules, data monitoring routines, and staff training. Clear operational guidelines ensure sustained system performance and reduce technological downtime. Institutional capacity-building will promote efficient long-term adoption. This progression supports the institutionalization of smart mosque practices.

Technology developers should collaborate with Islamic scholars and architects to create IoT solutions tailored to mosque environments. Customization will ensure cultural appropriateness, aesthetic integration, and user acceptance. Co-design approaches will produce technologies that better serve the functional and spiritual needs of congregations. This collaboration advances context-sensitive innovation.

Policymakers and Islamic organizations should promote smart mosque development through funding schemes, sustainability incentives, and community awareness programs. National frameworks for green mosques can accelerate adoption and align religious infrastructure with environmental targets. Broader policy support will amplify the societal impact of smart mosque initiatives. This direction positions smart mosques as catalysts for sustainable religious and civic life.

CONCLUSION

The most significant finding of this study is the demonstration that IoT technologies can simultaneously advance environmental sustainability and enhance the worship experience within mosque environments. The integration of sensor-based monitoring, automated resource management, and real-time environmental adjustments produced measurable improvements in

energy efficiency, water conservation, and indoor air quality, while also elevating user comfort, spatial coordination, and overall worship engagement. The dual-benefit outcome distinguishes this study from existing research on smart religious spaces by revealing that environmental optimization and spiritual experience are not separate objectives but interdependent dimensions of effective mosque design. This insight positions smart mosques as innovative models capable of aligning technological progress with the ecological and spiritual values embedded within Islamic tradition.

The key contribution of this research lies in its development of a conceptual framework that unifies sustainability principles, IoT functionality, and worship-centered design into an integrated model specifically tailored for mosque environments. The study provides methodological value by combining descriptive environmental data, inferential analysis, relational mapping, and case-based validation to articulate how IoT systems operate within the cultural and architectural context of Islamic worship. The framework advances the field by offering both conceptual clarity and practical guidance for architects, policymakers, and mosque administrators, highlighting how digital technologies can be ethically and effectively embedded in religious spaces. This contribution expands existing smart building literature and introduces a novel interdisciplinary approach bridging environmental engineering, religious studies, and user-experience design.

The limitations of this research include its reliance on secondary datasets, simulated projections, and a limited number of case studies, which restrict the generalizability of the findings across diverse mosque typologies, climatic conditions, and cultural contexts. The absence of longitudinal data also limits the ability to assess long-term system performance, worshipper adaptation, and sustainability outcomes over time. Future research should incorporate empirical field testing, participatory design studies, and multi-site evaluations to validate and refine the proposed framework. Further investigation is needed to explore cost–benefit analyses, behavioral responses to smart systems, and the ethical governance of data generated within religious spaces to ensure that technological innovation remains aligned with both ecological imperatives and Islamic moral values.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Agrawal, T., Pompoes, R., Verzijl, A., Srinivasan, V., Nair, J., Huijbens, E., Kannadhasan, K., Chokkalingam, K., & Murugan, V. (2024). Creating Kaveri Delta beneath our feet: An experiment in grounding socio-hydrology in Tamil Nadu, India. *Journal of Hydrology*, *644*, 131896. https://doi.org/https://doi.org/10.1016/j.jhydrol.2024.131896

Alam, M. J., Molla, C., Misbauddin, S. M., Hossen, M. A., & Golder, U. (2025). Determinants of adopting web-based systems for e-waste management and ensuring sustainable environment: Evidence from Bangladesh. *Cleaner Waste Systems*, *11*, 100282. https://doi.org/https://doi.org/10.1016/j.clwas.2025.100282

Aldemir, A., & Leurs, K. (2024). Racism and discrimination during the COVID-19 pandemic: Experiences of Turkish migrant women in the Netherlands. *Women's Studies International Forum*, *106*, 102972. https://doi.org/https://doi.org/10.1016/j.wsif.2024.102972

Almutairi, N., & Elhanashi, A. (2025). Leveraging IoT and dedicated social networks to enhance mosque role and activities management in Saudi Arabia. *Digital Business*, *5*(2), 100151. https://doi.org/https://doi.org/10.1016/j.digbus.2025.100151

Alva, P., Mosteiro-Romero, M., Miller, C., & Stouffs, R. (2024). Mitigating operational greenhouse gas emissions in ageing residential buildings using an Urban Digital Twin dashboard. *Energy and Buildings*, *322*, 114681. https://doi.org/https://doi.org/10.1016/j.enbuild.2024.114681

Ceccarelli, C., Branda, F., Scarpa, F., Giovanetti, M., Ciccozzi, M., & Ceccarelli, G. (2025). Adaptive urban and architectural strategies for infectious disease resilience: The exceptional convergence of the 2025 Jubilee and Papal events in Rome, Italy. *Mass Gathering Medicine*, *4*, 100031. https://doi.org/https://doi.org/10.1016/j.mgmed.2025.100031

Chen, B., Chen, Z., Liu, X. C., & Yi, Z. (2024). Bayesian inference-based spatiotemporal modeling with interim activities for EV charging etiquette. *Transportation Research Part D: Transport and Environment*, *127*, 104060. https://doi.org/https://doi.org/10.1016/j.trd.2024.104060

Dao, J., Ng, S. T., & Kwok, C. Y. (2024). Interlinking BIM and GIS data for a semantic pedestrian network and applications in high-density cities. *Developments in the Built Environment*, *17*, 100367. https://doi.org/https://doi.org/10.1016/j.dibe.2024.100367

El Hafdaoui, H., Khallaayoun, A., & Al-Majeed, S. (2025). Renewable energies in Morocco: A comprehensive review and analysis of current status, policy framework, and prospective potential. *Energy Conversion and Management: X*, *26*, 100967. https://doi.org/https://doi.org/10.1016/j.ecmx.2025.100967

Fernando, Y., Eing, G. C., & Wahyuni-TD, I. S. (2024). Metaverse-supply chain and halal behavior: bibliometric analysis, framework and implications. *Journal of Islamic Marketing*, *16*(4), 1174–1208. https://doi.org/https://doi.org/10.1108/JIMA-07-2023-0228

Haruehansapong, K., Krodsuea, A., Muangthong, P., Jaiphaeo, N., Phutson, T., Tipsavak, A., Yeranee, K., Sahoh, B., & Kliangkhlao, M. (2025). Ultrafine particle concentration modeling from incense burning: An interpretable machine learning approach using ambient indoor conditions. *Journal of Building Engineering*, *116*, 114623. https://doi.org/https://doi.org/10.1016/j.jobe.2025.114623

Homer, S. T., Berezina, E. B., & Gill, C. M. H. D. (2025). Urban futures through young eyes: Concept mapping youth visions of tomorrow's cities. *Futures*, *173*, 103677. https://doi.org/https://doi.org/10.1016/j.futures.2025.103677

Ibrahim, Syamsidik, Azmeri, & Hasan, M. (2024). Tsunami fragility based characterisation of mosques as alternatives tsunami evacuation buildings: Reconstructing evidence from the 2004 Indian ocean tsunami. *International Journal of Disaster Risk Reduction*, *100*, 104149. https://doi.org/https://doi.org/10.1016/j.ijdrr.2023.104149

Karakoltzidis, A., Agalliadou, A., Kermenidou, M., Nikiforou, F., Chatzimpaloglou, A., Feleki, E., Karakitsios, S., Gotti, A., & Sarigiannis, D. A. (2025). Agent-based modelling: A stochastic approach to assessing personal exposure to environmental pollutants – Insights from the URBANOME project. *Science of The Total Environment*, *967*, 178804. https://doi.org/https://doi.org/10.1016/j.scitotenv.2025.178804

Keshmiry, A., Hassani, S., Dackermann, U., & Li, J. (2024). Assessment, repair, and retrofitting of masonry structures: A comprehensive review. *Construction and Building Materials*, *442*, 137380. https://doi.org/https://doi.org/10.1016/j.conbuildmat.2024.137380

Khayamim, R., Moses, R., Ozguven, E. E., Borowska-Stefańska, M., Wiśniewski, S., & Dulebenets, M. A. (2025). Swarm intelligence applications for emergency evacuation planning: state of the art, recent developments, and future research opportunities. *Swarm and Evolutionary Computation*, *96*, 102009. https://doi.org/https://doi.org/10.1016/j.swevo.2025.102009

Kinne, J., Dehghan, R., Schmidt, S., Lenz, D., & Hottenrott, H. (2024). Location factors and ecosystem embedding of sustainability-engaged blockchain companies in the US. A web-based analysis. *International Journal of Information Management Data Insights*, *4*(2),

100287. https://doi.org/https://doi.org/10.1016/j.jjimei.2024.100287

Kurata, L., Ayanwale, M. A., Molefi, R. R., & Sanni, T. (2025). Teaching religious studies with artificial intelligence: A qualitative analysis of Lesotho secondary schools teachers' perceptions. *International Journal of Educational Research Open*, *8*, 100417. https://doi.org/https://doi.org/10.1016/j.ijedro.2024.100417

Liu, Y., Francis, A., Hollauer, C., Lawson, M. C., Shaikh, O., Cotsman, A., Bhardwaj, K., Banboukian, A., Li, M., Webb, A., & Asensio, O. I. (2023). Reliability of electric vehicle charging infrastructure: A cross-lingual deep learning approach. *Communications in Transportation Research*, *3*, 100095. https://doi.org/https://doi.org/10.1016/j.commtr.2023.100095

Mathe, S. E., Kondaveeti, H. K., Vappangi, S., Vanambathina, S. D., & Kumaravelu, N. K. (2024). A comprehensive review on applications of Raspberry Pi. *Computer Science Review*, *52*, 100636. https://doi.org/https://doi.org/10.1016/j.cosrev.2024.100636

Mohammed, A. S., Amoah, C., Abbas, J., & Naayif, S. (2025). Facilities managers vs. mosque management committees: evaluating the need for professional facilities management in mosque operations. *Facilities*, *43*(56), 363–396. https://doi.org/https://doi.org/10.1108/F-07-2024-0102

Moufid, O., Praharaj, S., Jarar Oulidi, H., & Momayiz, K. (2025). A digital twin platform for the cocreation of urban regeneration projects. A case study in Morocco. *Habitat International*, *161*, 103427. https://doi.org/https://doi.org/10.1016/j.habitatint.2025.103427

Muta, L. F., Melo, A. P., & Lamberts, R. (2025). Enhancing energy performance assessment and labeling in buildings: A review of BIM-based approaches. *Journal of Building Engineering*, *103*, 112089. https://doi.org/https://doi.org/10.1016/j.jobe.2025.112089

Panjikkaran, A. J., Middey, A., & Majumdar, D. (2025). Fingerprints of festive emissions on PM2.5 in an urban metropolis: Carbonaceous species, metals, and aerosol acidity. *Urban Climate*, *64*, 102635. https://doi.org/https://doi.org/10.1016/j.uclim.2025.102635

Paul, S., Chakraborty, D., & Tripathi, A. K. (2025). Frontline extension services as a buffer against social vulnerability to climate change: A case study of shifting cultivators in Northeast India. *Journal of Environmental Management*, *377*, 124607. https://doi.org/https://doi.org/10.1016/j.jenvman.2025.124607

Qahtan, A. M., Al-Tamimi, N., Baklouti, I., & Almasri, R. A. (2025). A comprehensive review of water-based passive cooling for building envelopes in arid climates: A biomimicry-inspired approach. *Journal of Building Engineering*, *114*, 114296. https://doi.org/https://doi.org/10.1016/j.jobe.2025.114296

Raby, A., Pomonis, A., Suppasri, A., Adams, K., Açikgőz, N., Baiguera, M., Idris, Y., Latcharote, P., Marafini, F., McGovern, D., Meilianda, E., Mistry, H., Nurdin, S., Opabola, E., Ornthammarath, T., Trumikaborworn, N., & Rossetto, T. (2025). Approaches to post-tsunami coastal reconstruction: Comparisons across Indonesia, Thailand, and Japan. *International Journal of Disaster Risk Reduction*, *117*, 105138. https://doi.org/https://doi.org/10.1016/j.ijdrr.2024.105138

Renukappa, S., Suresh, S., Shetty, N., Gandhi, L., Abdalla, W., Yabbati, N., & Hiremath, R. (2023). The role of smart cities in managing the COVID-19 outbreak in India. *Smart and Sustainable Built Environment*, *14*(5), 1459–1482. https://doi.org/https://doi.org/10.1108/SASBE-09-2023-0262

Rosele, M. I., Muneem, A., Ali, A. K., Che Seman, A., Haji Abdullah, L., Abdul Rahman, N. N., & Sukor, M. E. A. (2025). A proposed zakat model for digital assets from the Shariah perspective. *International Journal of Islamic and Middle Eastern Finance and Management*, *18*(3), 489–511. https://doi.org/https://doi.org/10.1108/IMEFM-08-2024-0408

Sakti, A. D., Mahdani, J. N., Santoso, C., Ihsan, K. T. N., Nastiti, A., Shabrina, Z., Safira, M., Rohmat, F., Yulianto, F., & Virtriana, R. (2023). Optimizing city-level centralized wastewater management system using machine learning and spatial network analysis. *Environmental Technology &*

Innovation, *32*, 103360. https://doi.org/https://doi.org/10.1016/j.eti.2023.103360

Sama, D., Kpiagou, P., Gmakouba, M., Djagre, L., Gnagamago, A. G., Lakmon, L., Diallo, A., & Gnandi, K. (2025). Toxic trajectories: Modeling heavy metal-laden phosphate dust dispersion and multi-receptor health risks near Kpémé's industrial zone. *Results in Engineering*, *27*, 106160. https://doi.org/https://doi.org/10.1016/j.rineng.2025.106160

Shi, X., Li, X., & Wang, T. (2025). Research on the tensions and driving factors of new infrastructure empowering urban resilience: Evidence from 31 provinces in China. *Sustainable Cities and Society*, *131*, 106765. https://doi.org/https://doi.org/10.1016/j.scs.2025.106765

Shi, Y. (2023). Literal translation extraction and free translation change design of Leizhou ancient residential buildings based on artificial intelligence and Internet of Things. *Sustainable Energy Technologies and Assessments*, *56*, 103092. https://doi.org/https://doi.org/10.1016/j.seta.2023.103092

Shtrepi, L., Aletta, F., Aspöck, L., Astolfi, A., Fels, J., Hornikx, M., Jambrošić, K., Jeong, C.-H., Kahle, E., Llorca-Bofí, J., Rindel, J. H., Rychtáriková, M., Torresin, S., & Vorländer, M. (2024). Ten questions concerning Architectural Acoustics. *Building and Environment*, *265*, 112012. https://doi.org/https://doi.org/10.1016/j.buildenv.2024.112012

Sikandar, S. M., Ali, S. M., & Hassan, Z. (2024). Harmonizing smart city tech and anthropocentrism for climate resilience and Nature's benefit. *Social Sciences & Humanities Open*, *10*, 101026. https://doi.org/https://doi.org/10.1016/j.ssaho.2024.101026

Soleimanijavid, A., Konstantzos, I., & Liu, X. (2024). Challenges and opportunities of occupant-centric building controls in real-world implementation: A critical review. *Energy and Buildings*, *308*, 113958. https://doi.org/https://doi.org/10.1016/j.enbuild.2024.113958

Sufri, S., & Elvin, S. D. (2024). Implementation outcomes of disaster risk reduction (DRR) policy in public facilities (PFs): Aceh perspective, Indonesia. *Disaster Prevention and Management: An International Journal*, *34*(2), 223–250. https://doi.org/https://doi.org/10.1108/DPM-06-2024-0162

Villanueva-Merino, A., Urra-Uriarte, S., Izkara, J. L., Campos-Cordobes, S., Aranguren, A., & Molina-Costa, P. (2024). Leveraging Local Digital Twins for planning age-friendly urban environments. *Cities*, *155*, 105458. https://doi.org/https://doi.org/10.1016/j.cities.2024.105458

Webb, J., McKenzie, S., Doss, R., Gorur, R., Pye, G., & Yeoh, W. (2025). A user-centric taxonomy of cyber harm in the metaverse. *International Journal of Law, Crime and Justice*, *81*, 100734. https://doi.org/https://doi.org/10.1016/j.ijlcj.2025.100734

Xu, Y., Tao, X., Das, M., Kwok, H. H. L., Liu, H., Kuan, K. K. L., Lau, A. K. H., & Cheng, J. C. P. (2024). A blockchain-based framework for carbon management towards construction material and product certification. *Advanced Engineering Informatics*, *61*, 102242. https://doi.org/https://doi.org/10.1016/j.aei.2023.102242

Youssef, M. (2025). Theorising the contemporary architectural trends in the context of the twenty-first century variables. *Frontiers of Architectural kResearch*. https://doi.org/https://doi.org/10.1016/j.foar.2025.10.011

Zhang, X., Sheng, Y., & Liu, Z. (2024). Using expertise as an intermediary: Unleashing the power of blockchain technology to drive future sustainable management using hidden champions. *Heliyon*, *10*(1), e23807. https://doi.org/https://doi.org/10.1016/j.heliyon.2023.e23807