

The Development, Trends, and Challenges of Smart Mosque Research: A Systematic Literature Review 2021–2026

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Abstract: Smart Mosque research has expanded from energy efficiency and building automation toward wider digital services involving artificial intelligence, Internet of Things, data management, operational security, and inclusivity. Objective: This study maps the development, trends, and challenges of Smart Mosque research published between 2021 and 2026 using a Context-Technology-Impact framework. Methods: A PRISMA 2020-guided systematic literature review was conducted using reproducible PubMed and Crossref searches and second-reviewer validation. Records were screened against mosque/masjid or Hajj/Umrah technology relevance, assessed using an eight-item quality-appraisal instrument, and classified by evidence-access status. Results: The search produced 1,664 exported records and 870 records after deduplication. After staged screening, second-reviewer validation, and excluded-sample consensus, 72 records were retained, consisting of 10 full-text confirmed records and 62 limited-access/provisional records. The evidence shows four dominant directions: artificial intelligence for operational security and Hajj/Umrah crowd monitoring, energy and sustainability systems, Internet of Things and automation, and digital mosque-management platforms. Conclusion: Smart Mosque research is developing into a broader digital-operational ecosystem, but the evidence remains methodologically uneven because many records were available only at abstract or limited-access level and 2026 data were partial up to August 2026. Future studies should prioritize full-text-verifiable empirical research, multi-site evaluation, system reliability, user-centered assessment, privacy and data governance, and inclusive digital services.

Keywords: artificial intelligence; energy efficiency; inclusivity; Internet of Things; smart mosque

INTRODUCTION

Places of worship worldwide are undergoing rapid digital transformation, and mosques are no exception. Field evidence from 2025–2026 illustrates the pace of this shift globally. The Two Holy Mosques in Saudi Arabia deployed more than 40 multilingual smart screens for Ramadan 2026 (Gulf News, 2026), launched the AI robot "Manara" for multilingual fatwa services (Gulf News, 2025), and expanded sign-language provision for nearly 20 million deaf worshippers (Arab News, 2022). Masjid Istiqlal in Jakarta launched its own official AI chatbot in 2025 (Liputan6.com, 2025). These developments mark the maturation of the "Smart Mosque" concept. The concept has evolved from partial automation of lighting, sound systems, and air conditioning into a cyber-physical ecosystem that integrates congregant applications, management dashboards, IoT devices, data backends, and, increasingly, digital twins (Rosad et al., 2025a, 2025b). This trajectory is consistent with mosque-building studies showing that mosques have distinctive occupancy, thermal-comfort, and energy-management patterns compared with ordinary buildings (Azmi et al., 2024; Taufan et al., 2023; Yüksel et al. 2024).

Academic interest in this field has grown accordingly, yet systematic literature reviews (SLRs) that map Smart Mosque research remain scarce. The only closely related SLR identified to date (Sadiq et al., 2024) analyzed 43 Scopus-indexed articles published between 2005 and 2024 and identified two dominant thematic clusters: energy-

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efficient buildings and building automation and smart-building technology. While valuable, that review did not explicitly address economic transparency (the digital management of zakat, infaq, and waqf) or congregational inclusivity (accessibility for persons with disabilities, multilingual services, elderly worshippers) as measured impact dimensions. It predates the 2025–2026 surge in publications associated with generative AI (Fathoni et al., 2025) and blockchain-based digital fund governance (Mokodenseho et al., 2023).

This gap matters because Smart Mosque research increasingly spans technological, social, operational, and economic outcomes that a single-database, energy-focused review cannot capture. Methodologically, the gap is not only thematic but also evidential: emerging Smart Mosque studies vary widely in database visibility, full-text accessibility, empirical depth, and mosque-specific relevance. This review addresses that gap by using auditable PubMed and Crossref searches, bilingual inclusion where available, explicit mosque/masjid and Hajj/Umhrah technology eligibility rules, a Context-Technology-Impact framework, evidence-access classification, quality appraisal, and second-reviewer validation. This design allows the review to map the wider research landscape while still distinguishing full-text-confirmed evidence from provisional landscape evidence.

The significance of this review is threefold. Academically, it extends Smart Mosque research beyond a single energy-centric lens by operationalizing a multidimensional Context-Technology-Impact framework that makes economic transparency and congregational inclusivity explicit and testable synthesis categories rather than incidental observations. Practically, it gives mosque administrators and technology developers an evidence base of what has already been attempted, at what quality, and with what measured outcomes, reducing duplication of low-maturity prototypes, such as single-site IoT deployments, that are rarely replicated or reliability-tested. For policy, the review identifies areas where religious-affairs authorities, mosque administrators, and research funders can prioritize investment, particularly in disability-inclusive AI, data governance, reliable operational systems, and full-text-verifiable empirical evaluation. This priority is also supported by recent peer-reviewed mosque-energy and holy-site technology studies that report occupancy sensing, photovoltaic feasibility, cooling-load prediction, and AI-based pilgrimage crowd-management models (Abdallah et al., 2025; Alaboodi & Alharbi, 2024; Alharbi & Alsehami, 2025; Shah, 2024).

This study addresses that need through a PRISMA 2020-guided systematic literature review (Page et al., 2021) grounded in an explicit Context-Technology-Impact framework spanning energy efficiency, sustainability, economic transparency, and congregational inclusivity. The review extends the search window to 2021–2026 to capture the most recent trends, includes English and Indonesian literature where available, and expands the corpus through a two-round search covering digital twins, structural health monitoring, crowd-management robotics, and broader geographic diversity, while maintaining strict mosque-specific eligibility criteria. Its methodological contribution is the combination of multidimensional coding, evidence-status separation, conservative appraisal of limited-access records, and second-reviewer validation of retained and excluded records. Specifically, the study addresses six research questions concerning the smart technologies most widely adopted and studied in Smart Mosques between 2021 and 2026. These include the annual trend, the contribution of these technologies to mosque energy efficiency and operational sustainability, the role of data and AI technology in the economic transparency of zakat, infaq, and waqf management, the impact of Smart Mosque implementation on congregational inclusivity and experience, the methodologies and system architectures most commonly used and their methodological quality, and the research gaps and future development directions projected toward 2030.

METHOD

This study follows the PRISMA 2020 guidelines (Page et al., 2021) for reporting systematic reviews. The review is organized using a Context-Technology-Impact framework. The context domain covers mosque, masjid, Smart Mosque, and Hajj/Umhrah holy-site management when the object of study is directly related to mosque or holy-site operation. The technology domain covers artificial intelligence (AI), machine learning, Internet of Things (IoT), automation, renewable and energy systems, digital platforms, data management, blockchain, accessibility technology, crowd monitoring, and safety/security systems. The impact domain consists of five dimensions: Energy Efficiency, Sustainability, Economic Transparency/Data Management, Congregational Inclusivity, and Operational Efficiency/Security. Operational Efficiency/Security was included as a distinct dimension because several studies in this field address crowd monitoring, mosque security, operational readiness, smart-door systems, surveillance, and Hajj/Umhrah safety technologies.

The literature search was conducted through auditable bibliographic sources accessible to the authors. PubMed and Crossref were used as the main reproducible sources. PubMed was used to capture records related to mosque, masjid, Hajj, Umrah, crowd management, safety, accessibility, AI, IoT, and holy-site management. Crossref title-based searches were used to identify mosque/masjid and technology-focused publications across the 2021–2026 publication window. Google Scholar was checked through Publish or Perish, but automated retrieval was temporarily restricted by Google Scholar's unusual-traffic protection; therefore, Google Scholar was not used as the primary reproducible source. Institutional Scopus access was not available to the authors and was therefore not

reported as a searched database. For each searchable source, the query, search date, year limit, reported result count, exported record count, and evidence file were documented in the search log.

The complete identification, deduplication, screening, and inclusion flow is summarized in Table 1. The PubMed search yielded 64 exported records. Crossref title-based searches across sixteen predefined query groups yielded 1,600 exported records, with a maximum of 100 exported records per query. After deduplication by DOI where available and by normalized title where DOI was unavailable, 870 records remained in the screening template. Title and metadata screening were used to identify records with explicit mosque, masjid, Hajj, or Umrah relevance and a technology-related object of study. Records without a clear mosque or holy-site technology object were excluded at this stage. Candidate records were then grouped into three screening batches: high-priority records for immediate full-text or evidence appraisal, records requiring abstract screening, and low-priority records for exclusion unless strong relevance could be verified.

The inclusion criteria were as follows: publication year between 2021 and 2026; publication as a journal article, conference paper, or book chapter; English or Indonesian language; explicit mosque, masjid, Smart Mosque, or Hajj/Umrah holy-site context; and substantive engagement with at least one technology pillar. Hajj/Umrah records were included only when they addressed operational technology, crowd monitoring, safety/security systems, AI/ML, sensing, digital management, or related holy-site operational issues. Studies on Hajj/Umrah public health, psychology, theology, law, heritage, or general social issues were excluded unless they included a clear technology system or digital-management object. Community-service, training, installation, or socialization articles were excluded from the core corpus unless the full text showed an original research design, data, and evaluation.

Evidence access was recorded for each retained record. Records with locally available full-text PDFs were marked as full-text confirmed. Records available only through abstracts, screenshots, or metadata were marked as limited-access or provisional evidence. This distinction was used to avoid overstating the strength of records for which full texts were not accessible. As shown in Table 1, the final screening and validation process retained 72 records, consisting of 10 full-text PDF-confirmed studies and 62 limited-access or provisional records. Thirteen of these provisional records were recovered through second-reviewer validation of the excluded-sample set and consensus discussion. These records were retained only for landscape mapping because their abstracts or metadata showed clear mosque/masjid or Hajj/Umrah technology relevance, but they were flagged separately from full-text confirmed studies.

Quality appraisal used an eight-item instrument adapted from (Kitchenham & Charters, 2007). The items assessed clarity of research objective, mosque or holy-site specificity, clarity of technology pillar, methodological description, presence of data or evaluation, support for results, clarity of context or limitations, and peer-reviewed source status. Each item was scored 0, 0.5, or 1, giving a maximum score of 8. The minimum inclusion threshold was set at 4.8 out of 8 for full synthesis. For abstract-only or limited-access records, unverifiable items were scored conservatively as 0 or 0.5, and the records were flagged as provisional landscape-mapping evidence rather than full synthesis evidence.

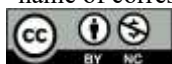
Screening and appraisal were organized using structured forms with separate fields for reviewer decisions, evidence-access status, quality scores, threshold decisions, and exclusion reasons. A second reviewer independently validated all 59 initially retained records and a 30-record sample of excluded records. Agreement on the initially retained corpus was 57 of 59 records (96.6%); two disagreements concerned evidence-strength classification rather than topical relevance. Excluded-sample validation identified 17 records for consensus discussion, after which 13 were added as provisional landscape-mapping evidence and 4 remained excluded. AI assistance was used only for formatting, organization, and preliminary record management; inclusion, exclusion, quality-appraisal, and consensus decisions were assigned to human review.

Table 1 presents the revised PRISMA 2020 selection flow and explicitly separates full-text confirmed records from limited-access provisional records. This distinction is important for interpreting the evidence base: the synthesis treats the 10 full-text confirmed studies as the strongest evidence and uses the 62 limited-access records as provisional landscape-mapping evidence where appropriate. The complete selection process is summarized numerically in Table 1 and visualized in Figure 1. The flow distinguishes records excluded during title and metadata screening, records assessed in prioritized appraisal batches, second-reviewer validation of retained and excluded records, full-text confirmed records, and limited-access provisional records.

Table 1. Summary of the PRISMA 2020 selection flow.

Stage	n
PubMed records exported	64
Crossref records exported	1,600
Records after deduplication	870
Records not advanced at title/metadata screening	730
Candidate records advanced to prioritized screening	140
Batch 1 retained	12
Batch 1 excluded	1

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Other Batch 1 not retained	10
Batch 2 provisional included	47
Batch 2 excluded	2
Batch 2 not advanced	16
Batch 3 excluded	52
Reviewer 2 excluded-sample records checked	30
Additional provisional records recovered after consensus	13
Records remaining excluded after excluded-sample consensus	17
Full-text PDF-confirmed retained records	10
Abstract-only/provisional retained records	62
Total retained/provisionally retained	72

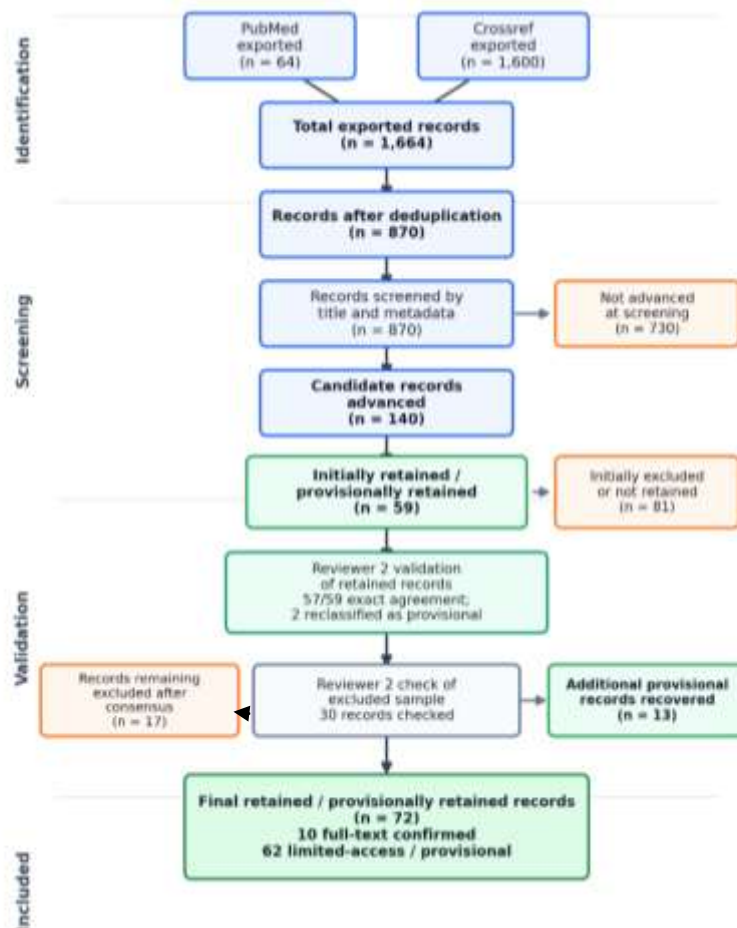


Fig. 1. PRISMA 2020 selection flow for the Smart Mosque systematic literature review.

PubMed and Crossref searches yielded 1,664 exported records. After deduplication, 870 records were screened. The final evidence base consisted of 10 full-text confirmed records and 62 limited-access/provisional records, resulting in 72 retained or provisionally retained records.

RESULT

As shown in Table 1 and Fig. 1, the screening and validation process retained 72 records for synthesis or provisional landscape mapping. This evidence base consisted of 10 full-text PDF-confirmed records and 62 limited-access or provisional records. The distinction between these two evidence-access categories is important because the full-text confirmed records provide the strongest basis for interpretive synthesis, whereas the limited-access records are used as provisional landscape-mapping evidence where appropriate. Table 2 summarizes the characteristics of the retained evidence base.

Table 2. Characteristics of the retained evidence base.

Characteristic	score	Notes
Total retained/provisionally retained records	72	Final corpus after second-reviewer validation and excluded-sample consensus
Full-text PDF-confirmed records	10	Strongest evidence base for synthesis
Abstract-only/provisional records	62	Includes 47 abstract-only records, 2 screenshot/abstract-only records, and 13 additional provisional records recovered from excluded-sample validation

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Additional provisional records recovered from excluded-sample validation	13	Used only for provisional landscape mapping
Quality score range, full-text confirmed	7-8	Mean 7.8 of 8
Quality score range, abstract-only/provisional	4-8	Reviewer 2 scored limited-access records conservatively; used for landscape mapping
Overall quality score range	4.0-8.0	Range after conservative Reviewer 2 validation

The retained records were distributed across the 2021-2026 publication window as follows: 9 records in 2021, 7 in 2022, 9 in 2023, 16 in 2024, 17 in 2025, and 14 in 2026. This distribution is visualized in Fig. 2. Publication activity increased after 2023, with the largest number of retained and provisionally retained records appearing in 2025. The 2026 records should be interpreted cautiously because the year was still incomplete at the time of search and appraisal. Therefore, the 2026 count is reported descriptively and is not used as the basis for a direct full-year comparison or a definitive trend claim.

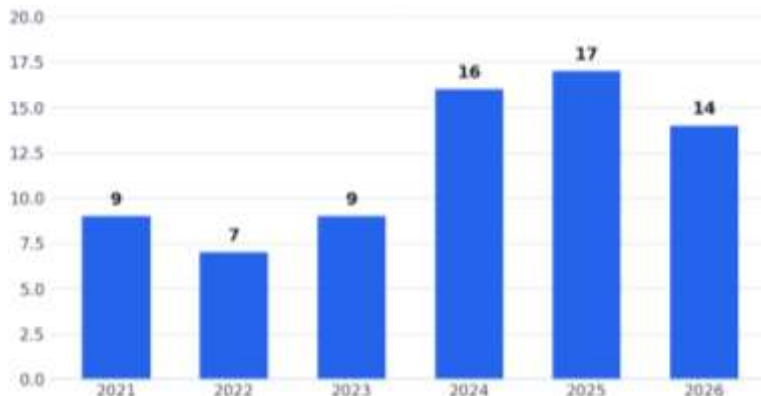


Fig. 2. Publication distribution by year for retained and provisionally retained records. The 2026 count is partial and is not projected to year-end.

Evidence-access status is shown in Fig. 3. Of the 72 retained or provisionally retained records, 10 were full-text PDF-confirmed and 62 were limited-access or provisional records. The provisional group includes 47 abstract-only records, 2 abstract/screenshot-supported records, and 13 additional records recovered through second-reviewer excluded-sample validation and consensus. These records remain flagged as limited-access evidence and are not treated as equivalent to full-text-confirmed studies.

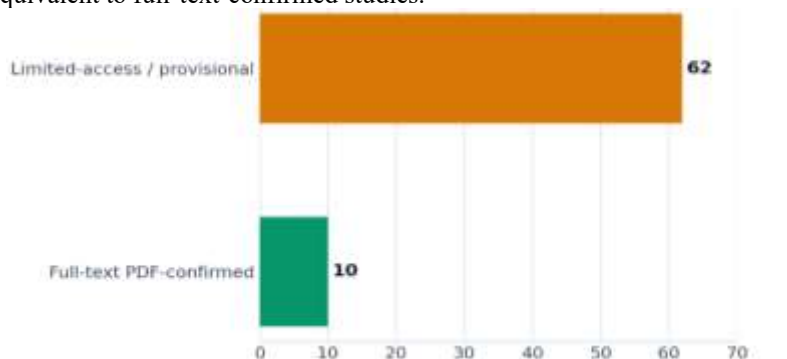


Fig. 3. Evidence-access status of retained records. Limited-access records are flagged as provisional evidence and are not described as fully full-text-appraised studies.

Quality appraisal was interpreted conservatively after second-reviewer validation. The 10 full-text confirmed records had scores ranging from 7.0 to 8.0 and provide the strongest evidence for synthesis. Many limited-access records received lower conservative Reviewer 2 scores because methods, data, evaluation, and result-support details could not be fully verified from abstracts, screenshots, or metadata alone. Therefore, limited-access records were retained for landscape mapping and topic identification rather than for strong claims about effectiveness or methodological maturity.

A dominant topic grouping was used to describe the thematic profile of the retained evidence. Because several studies could plausibly contribute to more than one technology or impact category, this grouping should be read as a descriptive overview rather than an exhaustive multi-label coding. As shown in Fig. 4, the dominant technology groupings were AI/Machine Learning (27 records), Energy/Renewable Systems (24 records), IoT/Automation (15 records), and Data Management/Digital Platform (6 records). The increase in AI/Machine Learning records mainly reflects additional provisional Hajj/Umrah crowd-management technologies recovered during second-reviewer excluded-sample validation. Energy and renewable-system studies remain a major cluster

around mosque cooling load, smart occupancy sensors, solar lighting, photovoltaic systems, and energy-efficient mosque buildings (Abdallah et al., 2025; Alaboodi & Alharbi, 2024; Alharbi & Alsehaimi, 2025; Alrashidi, 2023; Azmi et al., 2021; Taufan et al., 2023; Yüksel et al., 2024). IoT and automation studies continue to reflect practical mosque facility-control and monitoring systems.

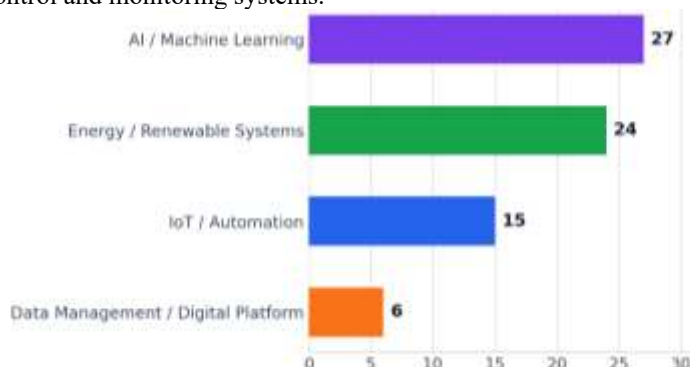


Fig. 4. Dominant technology grouping of retained and provisionally retained records. The grouping is descriptive and based on the dominant technology focus of each record.

The dominant impact or topic groupings are shown in Fig. 5. Operational Efficiency/Security was the largest grouping (27 records), followed by Energy Efficiency/Sustainability (24 records), IoT/Automation/Data Management (17 records), and Congregational Inclusivity (4 records). Operational Efficiency/Security captures Hajj/Umrah crowd monitoring, holy-site safety, anomaly detection, RFID, AI-enabled vision systems, and smart operational readiness (Al-Nabhan et al., 2021; Alharbey et al., 2022; Halboob et al., 2024; Shah, 2024). Energy Efficiency/Sustainability reflects mosque energy, ventilation, cooling, solar, and occupancy-sensing studies. IoT/Automation/Data Management captures mosque information systems, smart facility operations, digital services, and connected mosque-management platforms. Congregational Inclusivity appears less frequently, suggesting that accessibility-oriented Smart Mosque technologies remain a smaller but important area for future research.



Fig. 5. Dominant impact or topic grouping of retained and provisionally retained records. Records may contribute to more than one theme in detailed synthesis, but the figure shows the dominant grouping assigned for descriptive reporting.

Table 3 provides representative retained studies across the main dominant technology and impact groupings. The table intentionally identifies evidence status so that full-text confirmed studies and limited-access provisional studies are not treated as equivalent. Full-text confirmed studies provide stronger support for synthesis, while limited-access records are used to map emerging topics and guide future verification.

Table 3. Representative retained studies by dominant technology and impact grouping.

Year	Representative study	Dominant technology	Dominant impact / topic	Evidence status	Quality score
2025	Smart Mosque: An Iot-Based Control System For Managing Energy Consumption And Facility Operations	Energy / Renewable Systems	Energy Efficiency / Sustainability	full_text_pdf	8
2022	Improvement on I-Devices Using L-GCNN Classifier for Smart Mosque Simulation	AI / Machine Learning	IoT/Automation / Data Management	full_text_pdf	8
2025	Internet of Things (IoT) Based Smart Masjid System using Wi-Fi Smart Switch and IP Camera	IoT/Automation	IoT/Automation / Data Management	full_text_pdf	7
2023	Hajj pilgrimage abnormal crowd movement monitoring using optical flow and FCNN	AI / Machine Learning	Operational Efficiency/Security	full_text_pdf	7
2025	Assessing Mosque Energy Efficiency Using Smart Occupancy Sensors to Mitigate Climate Change in Hot Regions	Energy / Renewable Systems	Energy Efficiency / Sustainability	full_text_pdf	8

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2025	Leveraging IoT and dedicated social networks to enhance mosque role and activities management in Saudi Arabia	IoT/Automation	IoT/Automation / Data Management	full_text_pdf	8
2024	Machine learning model to predict the cooling load of mosque buildings during the design stage	Energy / Renewable Systems	Energy Efficiency / Sustainability	full_text_pdf	8
2021	A Fuzzy-based smart HVAC controller for mosque buildings-A design procedure under Dubai climate	Energy / Renewable Systems	Energy Efficiency / Sustainability	abstract_only	6.5
2023	Facilitating Solar Lighting Technology for Public Mosque in Rural Malaysia: A Conceptual Paper	Energy / Renewable Systems	Energy Efficiency / Sustainability	abstract_only	6
2025	Harnessing Artificial Intelligence for Mosque Management and Development: Opportunities, Challenges, and Strategic Approaches	AI / Machine Learning	IoT/Automation / Data Management	abstract_only	6

The Hajj/Umrah-related records are especially relevant to the Operational Efficiency/Security dimension. These studies include crowd monitoring, abnormal movement detection, anomaly detection, AI-supported crowd management, and holy-site operational technologies. However, most Hajj/Umrah records in the revised evidence base were available only at abstract level. Their findings are therefore treated as indicative evidence of an emerging research cluster rather than as fully verified full-text evidence.

The energy-related records show a more consistent link between mosque operation and measurable technical outcomes. The full-text confirmed and abstract-level evidence includes studies on smart occupancy sensors, cooling-load prediction, solar lighting, photovoltaic systems, energy-efficient retrofitting, and HVAC control. These studies indicate that mosque energy efficiency is one of the more technically mature areas in the Smart Mosque literature, although full-text confirmation remains necessary for several abstract-only records.

The IoT/automation and digital-management records show that Smart Mosque research continues to emphasize practical systems for mosque operation, including smart switches, smart doors, smart clocks, facility control, congregation services, mosque applications, digital platforms, and mosque-management systems. These studies demonstrate the practical orientation of the field, but the depth of evaluation varies. Some records report prototype or system-development work, while others present conceptual frameworks or abstract-level descriptions that require full-text verification before strong claims can be made.

Overall, the revised results show a broader but more carefully tiered evidence base than the original corpus. The strongest evidence currently comes from the 10 full-text confirmed records, while the 62 limited-access records expand the map of relevant Smart Mosque and Hajj/Umrah technology research but must be interpreted cautiously. The second-reviewer excluded-sample validation particularly strengthened the visibility of AI-enabled Hajj/Umrah crowd-management and operational-security research. The results therefore support a conservative synthesis: Smart Mosque research from 2021 to 2026 is most visibly concentrated in AI-enabled operational security, energy/sustainability, IoT/automation, and digital mosque-management systems, while inclusivity-oriented digital interventions remain comparatively underrepresented.

DISCUSSION

The evidence base indicates that Smart Mosque research from 2021 to 2026 is concentrated in four main directions: AI-enabled operational security, energy and sustainability, IoT/automation, and digital mosque-management systems. This pattern should be interpreted cautiously because only 10 retained records were full-text confirmed, whereas 62 records were available only through abstracts, screenshots, metadata, or other limited-access evidence. The prominence of AI/Machine Learning is partly a consequence of the second-reviewer validation process, which recovered additional Hajj/Umrah crowd-management studies as provisional evidence. Thus, the corpus is useful for mapping the current landscape, but it should not be read as proof that AI systems are more mature than energy or IoT systems in real-world mosque operation.

Compared with the earlier Smart Mosque systematic review by (Sadiq et al., 2024), which emphasized energy-efficient buildings and building automation/smart-building technology, this review shows that the field has broadened toward digital mosque management, AI-supported operation, Hajj/Umrah crowd monitoring, and mosque service applications. The comparison also clarifies why Smart Mosque should not be treated as a simple subset of Smart Building. Smart Building research usually prioritizes building performance, automation, energy optimization, and occupant comfort. Smart Mosque research includes those concerns but adds worship-specific temporal patterns, congregational density during prayer times, mosque finance and donation governance, religious-service delivery, multilingual and disability-inclusive access, and holy-site crowd safety. Thus, the present findings do not contradict the earlier review but suggest that the Smart Mosque concept is expanding from building-level efficiency toward a wider digital-operational and socio-religious ecosystem.

Energy Efficiency/Sustainability remains one of the strongest and most technically measurable impact groupings. Studies in this area address cooling-load prediction, smart occupancy sensors, HVAC control, solar lighting, photovoltaic systems, passive ventilation, and energy-efficient mosque buildings. Mosque energy studies are relatively mature because they often use measurable technical indicators, such as cooling load, occupancy

patterns, electricity use, and system efficiency. For example, (Abdallah et al., 2025) examined smart occupancy sensors for mosque energy efficiency, while (Alaboodi & Alharbi, 2024) assessed the techno-economic feasibility of rooftop solar photovoltaic systems for mosque buildings. These studies show that mosque occupancy patterns, which are intermittent but intense around prayer times, create opportunities for occupancy-aware control and renewable-energy integration.

IoT and automation remain central to Smart Mosque implementation. The retained records include smart switches, IP cameras, smart doors, digital clocks, facility-control systems, congregation-service monitoring, and mosque-management applications. Smart Masjid and Smart Mosque system studies, such as IoT-based facility control and mosque service platforms, show that the field is strongly practice-oriented and often driven by immediate operational needs (Rosad et al., 2025; Thantawi et al., 2023). However, many systems are still reported as prototypes, single-site implementations, or abstract-level descriptions. Future studies should therefore move beyond proof-of-concept development toward multi-site evaluation, long-term reliability testing, usability assessment, and measurable operational impact.

AI and machine-learning studies are most visible in mosque or holy-site operation and Hajj/Umrah crowd management. Their dominance in the updated corpus is understandable for three reasons. First, Hajj and Umrah create safety-critical crowd conditions that naturally attract research on anomaly detection, prediction, video analytics, RFID, and decision support. Second, several AI/ML studies can be evaluated using video, sensor, or simulation data without requiring direct intervention in worship spaces. Third, the post-2023 growth of applied AI research has made crowd-monitoring and operational-security topics more visible in indexed publication channels. Studies on intelligent crowd analysis and Hajj/Umrah crowd-management technologies illustrate this direction (Al-Nabhan et al., 2021; Almutairi et al., 2024; Shah, 2024). However, most Hajj/Umrah records in this review were limited-access or abstract-only. This cluster should therefore be read as an emerging operational-security research direction rather than as a fully verified body of deployed Smart Mosque evidence. Stronger conclusions require full-text access, dataset descriptions, model-validation details, performance metrics, and evidence of operational adoption.

Digital management and mosque service platforms form another important cluster. These studies include Smart Mosque applications, digital mosque information systems, digital da'wah services, mosque-management platforms, and social-network-supported mosque activity management. The development of Smart Mosque applications (Thantawi et al., 2023), IoT-based mosque role and activity (Almutairi et al., 2024), and digital da'wah or chatbot-oriented systems (Fathoni et al., 2025) indicates that Smart Mosque development is not limited to physical infrastructure but also includes administrative, informational, and congregational-service functions. The methodological depth of this cluster varies: some studies report system development and evaluation, whereas others remain conceptual. Future work should report clearer user requirements, system architecture, data governance, privacy considerations, user testing, and adoption outcomes; these requirements are especially important as Smart Mosque platforms increasingly combine physical infrastructure, information services, and congregational data (Abdallah et al., 2025; Thantawi et al., 2023).

Economic transparency and mosque-related digital finance remain visible but less developed than energy and IoT/automation. Studies on zakat, waqf, blockchain, and financial information systems suggest that digital governance may improve transparency and accountability in mosque-related fund management (Makarim & Hamzah, 2024; Mokodenseho et al., 2023). However, evidence on real-world adoption, user trust, and measurable improvement in zakat or waqf realization remains limited. This indicates that the technology is conceptually promising, but stronger empirical evaluation is needed before firm conclusions can be made.

Congregational Inclusivity appeared less frequently than the other dimensions. This underrepresentation may reflect several structural factors: accessibility interventions often require user-centered fieldwork with persons with disabilities or elderly worshippers; outcomes such as dignity, wayfinding confidence, comprehension, and service experience are harder to measure than energy use or detection accuracy; and mosque technology funding may still prioritize infrastructure, security, or energy savings over inclusive digital services. This does not reduce the importance of inclusivity; rather, it indicates that accessibility-oriented digital interventions remain underdeveloped in the peer-reviewed Smart Mosque literature. Studies on AI-enhanced mosque accessibility for persons with disabilities point to the importance of this direction (Ibrahim et al., 2025), while real-world developments such as sign-language services and multilingual smart screens at major holy sites suggest that practice may be moving faster than academic evaluation (Arab News, 2022; Gulf News, 2026). Accessibility for persons with disabilities, multilingual assistance, elderly worshipper support, sign-language services, wayfinding, and inclusive digital interfaces remain important future directions.

The field remains fragmented across engineering prototypes, energy studies, information-system papers, Hajj/Umrah crowd-technology studies, and conceptual frameworks. The full-text confirmed records provide better methodological detail, but even this subset is still weighted toward prototypes, modelling, single-site implementations, and system-specific evaluations rather than long-term multi-site deployment studies. This matters because Smart Mosque systems are operational technologies: reliability, maintainability, user acceptance,

privacy, and governance determine whether a prototype becomes useful infrastructure. Evidence from mosque energy modelling, occupancy sensing, photovoltaic feasibility, and Hajj/Umrah crowd-intelligence studies shows that technical performance must be interpreted together with operational setting and deployment readiness (Abdallah et al., 2025; Alaboodi & Alharbi, 2024; Alrashidi, 2023; Halboob et al., 2024; Shah, 2024). The five-dimension impact framework used in this review helps separate energy, sustainability, economic/data management, inclusivity, and operational/security outcomes. Nevertheless, future reviews should ideally use full database exports from multiple indexed sources, full-text screening for all retained studies, and two independent reviewers for screening and quality appraisal, consistent with systematic-review reporting expectations (Page et al., 2021).

The distinction between full-text confirmed and limited-access provisional records is an important interpretive safeguard. The 10 full-text confirmed records provide the strongest evidence for synthesis, while the 62 limited-access records help map the breadth of the field but remain provisional. Quality appraisal for provisional records was deliberately conservative: items related to method description, data or evaluation, result support, and limitations were scored as weak or unverifiable when the abstract or metadata did not provide enough detail. This means that provisional records can support landscape mapping, topic discovery, and identification of emerging clusters, but they cannot support strong claims about effectiveness, methodological rigor, deployment maturity, or causal impact. This tiered interpretation prevents overstatement where methods, data, limitations, or evaluation procedures could not be fully verified.

Several limitations should be considered. Scopus could not be searched because institutional access was unavailable. Google Scholar retrieval through Publish or Perish was restricted by automated unusual-traffic protection, limiting reproducible Google Scholar export. Crossref title-based searching is broad and may include records that require careful screening. Although second-reviewer validation strengthened the reliability of screening and helped identify 13 additional provisional records from the excluded-sample check, many retained records were still available only at abstract, screenshot, metadata, or other limited-access level. This limits the depth of quality appraisal and prevents strong conclusions about methods, datasets, implementation quality, and long-term effectiveness.

The updated 72-record corpus also did not yet contain consistently verified country, study-setting, and primary-methodology fields for all records. Therefore, this review did not present a formal geographic distribution map, a technology-by-impact cross-tabulation, or a detailed primary-methodology distribution. Future reviews should extract country, study setting, research design, evaluation type, and system-architecture variables systematically to support geographic mapping and richer cross-dimensional analysis.

In addition, the review retained 2026 records because they captured emerging Smart Mosque and Hajj/Umrah technology studies available at the time of searching. However, the 2026 evidence should be interpreted cautiously because it covered only publications available up to August 2026 and was not projected to a full-year trend. A future update may restrict analysis to complete publication years, such as 2021-2025, or treat 2026 as a separate update period. Arabic-language and other non-English/non-Indonesian sources may also be underrepresented, which is important given the relevance of Middle Eastern contexts to mosque and Hajj/Umrah technologies.

Despite these limitations, this review provides a transparent map of the Smart Mosque research landscape. Its main contribution is the explicit separation of confirmed and provisional evidence, the consistent use of a quality threshold, and a framework that captures both physical infrastructure and digital-operational dimensions. The policy implications are also important. Mosque digitalization increasingly involves personal, behavioral, financial, accessibility, and crowd-safety data; therefore, future Smart Mosque initiatives should include clear data-governance rules, privacy safeguards for worshippers, transparent management of zakat/infaq/waqf information, cybersecurity requirements for connected devices, and accountability mechanisms for AI-supported services. Recent Hajj/Umrah AI and wearable-sensor studies reinforce this need because crowd-management systems increasingly depend on personal, behavioral, location, and physiological data (Al-Shaery et al., 2024; Derhab et al., 2024; Halboob et al., 2024). The evidence suggests that future Smart Mosque research should prioritize full-text-verifiable empirical studies, multi-site system evaluation, AI and IoT reliability testing, disability-inclusive digital services, and governance models that protect both operational effectiveness and congregational trust.

CONCLUSION

This systematic literature review mapped Smart Mosque research published between 2021 and 2026 using a Context-Technology-Impact framework and retained 72 records from reproducible PubMed and Crossref searches plus second-reviewer validation, consisting of 10 full-text confirmed records and 62 limited-access provisional records. The evidence indicates that Smart Mosque research is expanding from energy-efficient buildings and smart-building automation, as emphasized in earlier work by (Sadiq et al., 2024), toward a broader digital-operational ecosystem involving AI-enabled operational security, IoT and automation, mosque-management platforms, Hajj/Umrah crowd technologies, digital governance, and congregational inclusivity. However, because many retained records were available only at abstract or limited-access level and 2026 data only cover publications

available up to August 2026, these developments should be interpreted as emerging directions rather than definitive trends. This review contributes by separating confirmed and provisional evidence, applying second-reviewer validation, defining five impact dimensions from the start of the synthesis, and clarifying the difference between Smart Mosque and general Smart Building research. Future Smart Mosque studies should prioritize full-text-verifiable empirical research, multi-site evaluation, long-term system reliability, user-centered assessment, privacy and data-governance analysis, and inclusive digital services for diverse worshipper needs.

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DATA AVAILABILITY STATEMENT

The search logs, exported bibliographic records, screening decisions, quality-appraisal forms, PRISMA selection-flow table, and evidence-status classifications supporting this study are available in the supplementary files accompanying the manuscript, including the raw-data spreadsheet and evidence document prepared for this review. Additional supporting files are available from the corresponding author upon reasonable request. No personal, confidential, or participant-level data were generated or analyzed in this study.

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