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Article

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Leveraging IoT and dedicated social networks to enhance mosque role and activities management in Saudi Arabia[☆]

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ABSTRACT

This paper examines the challenges encountered in mosques activities management and explores the potential use of internet of things. To this end, qualitative methods, surveys and semi-structured interviews, were conducted. The results reveal key challenges, which are related to mosque accessibility, communication, and engagement in decision-making. As a part of the proposed solution, the Mehrab system incorporates a dedicated social networking, smart locks, and smart key delegation. Mehrab was developed using an Agile methodology that involves potential users throughout the development process to ensure the inclusion of essential features aligned with the system's objectives. Mehrab was tested by 400 participants who performed a set of tasks that covered the core functionalities and then answered questionnaires to evaluate application objectives achievement, usability, and technology acceptance. Statistical analysis revealed that participants' evaluations of system objectives differed significantly from a neutral benchmark, indicating a positive perception. A system usability scale survey was used to assess usability, and we achieved an excellent result of 94.23, exceeding the threshold to pass the test. To assess technology acceptance, the technology acceptance model was integrated with institutional theory, offering a robust framework for understanding acceptance factors in religious settings. Regression analysis showed that perceived usefulness, attitude toward using technology, and behavioral intention were the strongest predictors of actual use which commonly interpreted as indicators of technology acceptance, while institutional factors, including normative and coercive pressures, also had significant influence. Moreover, sentiment analysis was employed to measure users' opinion, which indicated that 94.5% of participants had positive opinions.

1. Introduction

In Muslim societies, mosques often serve as religious schools and community centers, beside their primary role as places for the five obligatory prayers. Mosques typically play an active role in the community and have great potential for disaster response and recovery phases through providing shelter, food, and medical supplies (Cheema, Scheyvens, Glavovic, & Imran, 2014; Kotani, Okai, & Tamura, 2023; Mosehi, Dehghani, Masoumi, Sheikhi, & Barghi Shirazi, 2023). They are also expected to provide resolution services in times of dispute between groups, families, couples, or individuals (Al-Krenawi, 2016). Moreover, they play an active role in religious education, which includes conducting Qur'an educational sessions, Qur'an recitation sessions, and preaching lectures. There were differences in how these activities were managed across countries. According to the US mosque survey (Bagby, 2020), almost half (48%) of mosques in the US have

only one governing body that runs the mosque's daily operations; this is usually called a board of directors or executive committee. In Saudi Arabia and other Muslim countries, mosque activities are coordinated by two mosque managers known as the "Imam" and the "Muezzin", who are usually employed by the relevant government authority or non-profit foundations. Regardless of the country, the mosque neighborhood community (the local community) is not involved in the relevant activities or decisions. The US mosque surveys in Bagby (2020) explore who has the final decision-making power in the mosque from 2000 to 2020 over a period of ten years. The results show that in 2000 the board or executive committee was the final decision maker in 59% of mosques, compared to 2% of mosques that involved local community members. Over the following decade, the shift toward centralized control became increasingly evident. In 2020, the proportion of mosques governed by the board or executive committee had increased to 73%,

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with local community involvement declining to zero. This shift has driven the need for more efficient local community involvement that aims to make decisions in the best interests of the intended audience, which may, in turn, enhance the mosques' role in society.

There are many problems associated with the current methods employed for organizing mosque activities and communicating between the Imam, Muezzin, and local community members. Typically, the scheduling of educational sessions and preaching lectures is usually determined by the mosque managers, and there is no way to engage the local community; the target audience. The times are usually announced and disseminated using three main channels: (i) in-person communication within the mosque before or after prayers, (ii) physical posters or digital mosque screens, and (iii) the mosque website. The first two methods predominantly target individuals who physically attend the mosque and, therefore, inadvertently exclude certain demographic groups, particularly female, whose regular attendance is not obligatory and usually pray at home. This communication gap is further exacerbated in newly developed urban areas characterized by the unplanned distribution of mosques without considering the accessibility or proximity to residential zones (Alfawaz, 2018). Such spatial randomness reduces opportunities for social interaction and impedes community members' ability to engage with mosque activities. Moreover, while mosque websites serve as an online communication platform, they are often less effective when compared to mobile-based applications, which have been shown to significantly enhance user experience and accessibility (Ali et al., 2022). Therefore, the current communication mechanisms may be inadequate for fostering inclusive and effective participation in mosque activities.

Mosques usually impose the highest safety and security standards, including the employment of security personnel and the installation of surveillance systems. These measures serve as effective deterrents against unauthorized access and contribute to maintaining a secure environment within mosque premises. Conventional mechanical locks are utilized to secure doors and restricted areas, with mosque managers and designated security staff bearing responsibility for access control. In many Muslim majority countries, regulations prohibit the delegation of physical keys to unauthorized individuals, reflecting concerns over security and accountability. Consequently, in the absence of the mosque manager, the mosque doors will not be opened, and all scheduled mosque social and religious activities will be canceled. This dependency on the physical presence of key holders reveals a critical vulnerability in current mosque access management practices, underscoring the need for more flexible and secure technological alternatives.

Technology can be used to eliminate inefficient processes, improve communication, and optimize the management of resources within worship spaces including mosques. Its integration supports broader initiatives in smart city development and digital transformation, ensuring religious institutions remain functional and relevant in increasingly digitized societies. Although recent research demonstrates the applicability of Internet of Things (IoT) technologies in religious contexts (Ahmad et al., 2019; Al-Ghannam & Al-Dossari, 2016; Alobaid & Rasheed, 2018; Apiza, 2023; Eskaf, Aly, & Aly, 2016; Harsritanto, Dewanta, & Prabowo, 2021; Jahan, Al-Nabhan, Noor, Rahaman, & Al Islam, 2023; Setiawan, Purnamasari, Nuris, Ali, & Narasati, 2021; Yusarelan, Hamid, Rashid, & Ibrahim, 2020), most of these studies adopt a technology-driven approach while failing to investigate the user acceptance factors that underpin successful adoption of IoT technologies in smart worship spaces initiatives. In this paper, we fill the gap by investigating the needs of the Saudi Muslim community, recommending and implementing a potential IoT-based application tailored to mosque affairs management, and evaluating user acceptance of the solution. Unlike previous work, the proposed solution is both need-driven and user-centered, as the requirements were identified through surveys and interviews, and an Agile development methodology was adopted to ensure continuous stakeholder engagement throughout the system lifecycle. Furthermore, this study integrates the Technology Acceptance

Model (TAM) and institutional theory, and validates the extended model through linear regression analysis (Davis et al., 1989; Ritzer, 2004). The results provide insights into the key predictors of technology acceptance in religious settings, contributing to the broader understanding of smart worship environments within smart city frameworks. To complement the extended theoretical model, sentiment analysis and Machine Learning (ML) techniques are applied to short text feedback to detect positive and negative opinions. Saudi Arabia was selected as the study context due to its diverse types of mosques, which offer a wide range of services that can enrich the study findings. Given these considerations, this research seeks to find answers to the following Research Questions (RQ):

- RQ1: What are the challenges encountered in managing mosque activities in Saudi Arabia?
- RQ2: To what extent is there a perceived need for technological support in mosque management?
- RQ3: How willing are users to accept technological solutions for mosque activity management, and what factors influence their acceptance?

In the process of answering the research questions, we envision some research challenges entailing our study. Developing a precise solution necessitates access to an accurate and comprehensive mosque database, containing key attributes such as mosque name, type, and other relevant information such as the names of the Imam and Muezzin. Therefore, the first challenge is to deal with the lack of a mosque database. Testing the proposed solution is the second challenge, as we do not have the authority to deploy and configure the selected IoT devices in actual mosque facilities. Moreover, we need to test the system across different mosque communities and with different mosque managers to ensure the credibility of the research findings. Therefore, it is necessary to design a mosque prototype that simulates the mosque building with IoT sensors installed and configured.

The rest of this manuscript is structured as follows. Section 2 provides a comprehensive review and analysis of the existing literature. The methodology and materials utilized in the study are detailed in Section 3. Section 4 and Section 5 present the results and subsequent discussion, respectively. Finally, the paper concludes in Section 6, with a summary of the key findings, study limitations, and suggestions for future research.

2. Literature analysis

This section reviews and analyzes previous work that utilizes IoT in mosques, along with various applications aimed at enhancing and managing religious activities and resources.

2.1. IoT applications in mosque

A summary of studies utilizing IoT in mosques is outlined in Table 1, highlighting the studies' objectives and the research methodology employed. Among the emerging applications of IoT in religious contexts is the monitoring of worshippers' activities, aiming at recognizing ritual movements such as Takbeer, bowing, sitting, and prostrating (Ahmad et al., 2019; Al-Ghannam & Al-Dossari, 2016; Alobaid & Rasheed, 2018; Eskaf et al., 2016; Jahan et al., 2023). These initiatives are primarily motivated by the desire to enhance Muslim well-being by evaluating the correctness and completeness of prayers, identifying mistakes, and highlighting areas for improvement (Al-Ghannam & Al-Dossari, 2016; Alobaid & Rasheed, 2018; Eskaf et al., 2016; Jahan et al., 2023). In addition, specific applications aim to support individuals with neurodegenerative conditions by tracking worshippers' movements and progress (Ahmad et al., 2019). To achieve these goals, studies commonly rely on wearable technologies such as smartwatches and mobile sensors to collect movement data for analysis using ML algorithms. While this reflects a promising intersection of technology and faith-based practices, a critical observation is that the majority of these

Table 1
Summary of studies on IoT applications to enhance mosque resources and activities management.

Reference	Study objective	Study methodology
Jahan et al. (2023)	Finding mistakes in prayers, pinpointing the areas to focus on, and tracking progress.	A smartwatch was used to collect a dataset from 30 subjects, consisting of samples pertinent to activities in prayers. Multiple ML algorithms were trained to recognize the activities. Before the system was designed and implemented, 124 participants were surveyed to measure willingness to improve prayers with IoTs.
Al-Ghannam and Al-Dossari (2016)	Assessing the correctness and completeness of prayers.	A mobile phone sensor was used to collect data from six worshippers. There were 118 samples representing main worshiper activities. Supervised ML algorithms were used to extract and recognize worshiper activities.
Ahmad et al. (2019)	Observing worshippers and directing those who suffer from chronic neurodegenerative diseases.	A mobile sensor was introduced to recognize specific activities. Datasets from 10 subjects were collected, labeled and used to train ML models.
Alobaid and Rasheed (2018)	Examining the correctness and completeness of prayers.	Data were collected from 20 subjects using mobile phone sensors. Eight supervised ML algorithms were compared with three features selection approaches.
Eskaf et al. (2016)	Activity recognition uses smartphone sensors to recognize simple daily activities and then aggregates these simple activities to recognize a more complex one, such as prayer.	Mobile phone sensors were used to collect data from 10 subjects. The collected data were utilized to train ML to recognize daily activities such as walking, running, and standing. The trained model was used to recognize worshippers' activities.
Yusarelan et al. (2020)	Developing temperature controls to reduce electricity consumption.	Set IoT devices that allow reading the temperature of mosque and then smartly control the fan according to the temperature reading by applying IoT. An evaluation of the system was conducted by comparing electricity consumption before and after the installation of the IoT sensors.
Harsritanto et al. (2021)	Suggest a design strategy for a sustainable mosque using IoT.	A design strategy suggests that IoT could be used to automate the monitoring and control of electricity consumption. No real system was designed.
Apiza (2023)	Control theft and mosque funds using IoT.	Create smart mosque coin boxes that require a password to open and emit an alarm when the password is incorrect. A real-world setting was not used in this study to evaluate IoT functionality.
Setiawan et al. (2021)	Detect and store data on the theft of mosque charity boxes.	The study uses IoT sensors to develop a system that can detect theft, store data on theft, and send short message notifications to smartphones and database servers through a web framework. The study evaluated the IoT functionality without testing the system in a real-world environment.

studies are technically driven, focusing on algorithmic accuracy and sensor performance. As seen in Column 3 of Table 1, none of the reviewed studies address usability concerns, ethical considerations, privacy implications, or incorporate established theoretical models, such as the TAM or diffusion of innovations, to assess user perceptions. The lack of in-depth exploration into factors influencing user acceptance may limit the applicability, scalability, and long-term sustainability of these technologies, particularly within sensitive and context-specific religious environments.

Several studies have highlighted that mosques consume a significant amount of energy, often due to the requirement to maintain comfort in large and open areas (Abdou, Al-Homoud, & Budaiwi, 2005). In response, various IoT-based solutions have been proposed to optimize energy consumption. For instance, researchers in Harsritanto et al. (2021) recommended a design strategy that leverages IoT for sustainable mosque development by automating electricity consumption controls. Similarly, a recent study published in Yusarelan et al. (2020) utilized IoT sensors to reduce energy consumption through intelligent temperature and lighting control. In this approach, environmental sensors monitor indoor temperature and automatically activate or deactivate cooling systems, such as fans and air conditioners, aiming to minimize unnecessary energy usage. While these studies demonstrate the technical feasibility and potential energy savings, their scope remains largely technology-focused, concentrating on system implementation, and operational efficiency. These studies do not address important aspects such as user engagement, maintaining complexity, and implications and cost-benefit of adopting such solutions. Moreover, experiments acknowledge that factors such as mosque design, building materials, spatial composition, and operational support influence energy consumption. These elements are often treated as static rather than dynamic variables that could be integrated into adaptive smart systems. This highlights a gap in current research and points to the need for a more effective energy management approach.

IoT technologies have been employed to enhance the safety and security of worship places, including mosques (Apiza, 2023; Setiawan et al., 2021). In particular, efforts have been made to secure mosque alms, typically collected from local communities, by developing smart charity boxes assembled from IoT components (Apiza, 2023; Setiawan et al., 2021). The system introduced in Apiza (2023) restricted access to the charity box using a password; if the correct password is entered, the lock opens; otherwise, an emergency alarm is triggered. Similarly, the study in Setiawan et al. (2021) proposed a system designed to detect theft attempts and store relevant data, with real-time notifications sent via SMS and web servers to inform responsible parties. While these innovations offer promising solutions to enhance the security of mosque donations, their effectiveness raises several critical considerations. Although the systems function as intended in experimental setups, there is limited evidence of their long-term reliability and resilience under real-world conditions, particularly in communities with limited technical infrastructure. Moreover, the reliance on password-based access and basic alarms may pose security vulnerabilities. The usability and accessibility issues were not discussed, particularly for older or less technologically experienced community members who may struggle with digital interfaces.

Given the foregoing analysis, the methodologies employed in previous studies either failed to effectively evaluate user acceptance of technology or did not test the proposed systems in real-world or simulated environments. Furthermore, all of the studies introduced IoT or ML-based solutions without comprehensively investigating the challenges encountered by Muslim communities or engaging the expected audiences. As a result, while the reviewed literature may address aspects related to RQ2, none adequately address RQ1 or RQ3. The shortcomings identified in the literature prompted the conduction of this research.

Table 2
Key features comparison of applications that offer services comparable to this study.

Features/ Application	Masajid Apps ACE (2024)	Masjidna Live Mansour (2023)	Masjidi UmmahSoft (2023)	Boyout Allah Developers Designers (2023)	MAC MAC (2023)	Prayers connect prayers connect (2023)
	Mobile	Mobile	Mobile	Mobile	Web	Web
System type						
Publish announcements	×	✓	×	×	×	×
IoT utilization	×	×	×	×	×	×
Engage local community in decision-making	×	×	×	✓	×	×
Contact mosque managers	×	×	×	✓	×	×
Mosque details	✓	×	×	✓	✓	✓
Join a mosque	×	✓	×	×	×	×
Target users	Local community	Local community	Local community	Mosque managers & local community	Local community	Local community

2.2. Mosque management applications

Several mobile applications and websites have been developed and used to offer solutions similar to Mehrab (Apps ACE, 2024; Developers Designers, 2023; MAC, 2023; Mansour, 2023; prayers connect, 2023; UmmahSoft, 2023). The key features of these applications are summarized in Table 2. The table indicates that only Masjidna Live stands out with its announcement feature, which allows mosque activity notifications to be sent to users. Boyout Allah is unique in its potential to engage both the local community and mosque managers in decision-making, offering a platform for community members to directly contact mosque managers. The current solutions exhibit critical limitations in several areas. IoT technology is absent from all these applications. Moreover, most applications only present basic mosque information, except for Masjidna Live and Masjidi, which avoid this feature. Masjidna Live functionalities are limited to the option to join a specific mosque and receive notification-based announcements, with no interactive engagement or advanced community management features. Although Boyout Allah aims to serve both mosque managers and local community members, it still lacks integrated tools to effectively manage mosque affairs and foster collaboration between different users. In addition to these shortcomings, the usability of these applications is also a major concern.

It is apparent from the table that no single application is capable of providing all the functionalities required by mosque affairs management. Mehrab addresses these gaps by not only incorporating IoT technology to improve mosque management but also offering a comprehensive set of features that facilitate real-time interaction, community engagement, and efficient mosque administration. These features were derived from user needs collected through surveys, interviews, and feedback across all stages of system development. This potentially helps to empower both local communities and mosque managers with tools that drive collaboration, transparency, and efficiency.

3. Materials and methods

The proposed approach, illustrated in Fig. 1, consists of four main steps, each with distinct outcomes. This section provides a detailed description of these steps, alongside the evaluation criteria and metrics employed in the study. Moreover, the section presents the conceptual model and initial hypotheses for this study, integrating TAM theoretical frameworks and institutional theory to explore the factors influencing the acceptance of IoT technology in mosques.

3.1. Challenges in mosque activity management

In order to identify field challenges, a combination of questionnaires and semi-structured interviews was employed. The questionnaire

was designed to capture the challenges encountered by local community members, Imams, and Muezzins in accessing mosque services or disseminating relevant information to the target audiences. The semi-structured interviews provided deeper insights into these challenges, particularly focusing on the difficulties in managing social and religious activities from mosque managers’ perspectives. The analysis of the survey responses and interview data is presented in the following two subsections; Sections 3.1.1 and 3.1.2.

3.1.1. Survey findings

An online survey was distributed to adult Muslims residing in Saudi Arabia to gather insights on difficulties encountered in managing and attending mosque activities. To enhance the accuracy and comprehensiveness of the findings, the study sought to involve Muslim participants from various national backgrounds living across the thirteen administrative regions of Saudi Arabia. A total of 400 responses were collected, comprising 229 male and 171 female participants. Fig. 2 presents the percentage distribution of responses across the different regions in Saudi Arabia. The survey consisted of twenty questions that covered the following key aspects: (i) the accessibility of mosques, (ii) the effectiveness of current communication channels, and (iii) the availability of information regarding mosque community services, prayer times, and educational sessions. Furthermore, respondents were given the opportunity to provide their views on the challenges they encountered through an open-ended question. The survey also sought participants’ opinions on the potential use of dedicated social network application and IoT technology for mosque activity management. Many of the questions employed a five-point Likert scale to assess the level of agreement or disagreement with various statements.

As a result of the unavailability of mosque managers, 75.6% of respondents reported having visited a mosque at least once and found it closed during times when it was expected to be open, such as ten minutes before or after daily prayers. Interestingly, 82% of male participants, along with a comparable percentage of female participants, indicated that they had visited mosques for Ramadan late-night prayers and found that the prayers had already commenced. This indicates that, regardless of gender, the communication methods used to communicate the flexible prayer times may not be sufficient. This issue was further reinforced by 29% of participants who, through open-ended responses, highlighted the challenge of attending prayers at randomly selected mosques, underscoring a broader communication and coordination gap in mosque operations.

In terms of the means used to contact mosque managers, survey results revealed a notable gender disparity. Among male respondents, 51% reported regularly contacting mosque managers in-person, while 7% indicated having no means of communication. In contrast, 50% of female respondents reported the complete absence of any communication channel with mosque managers, while only 14% had in-person

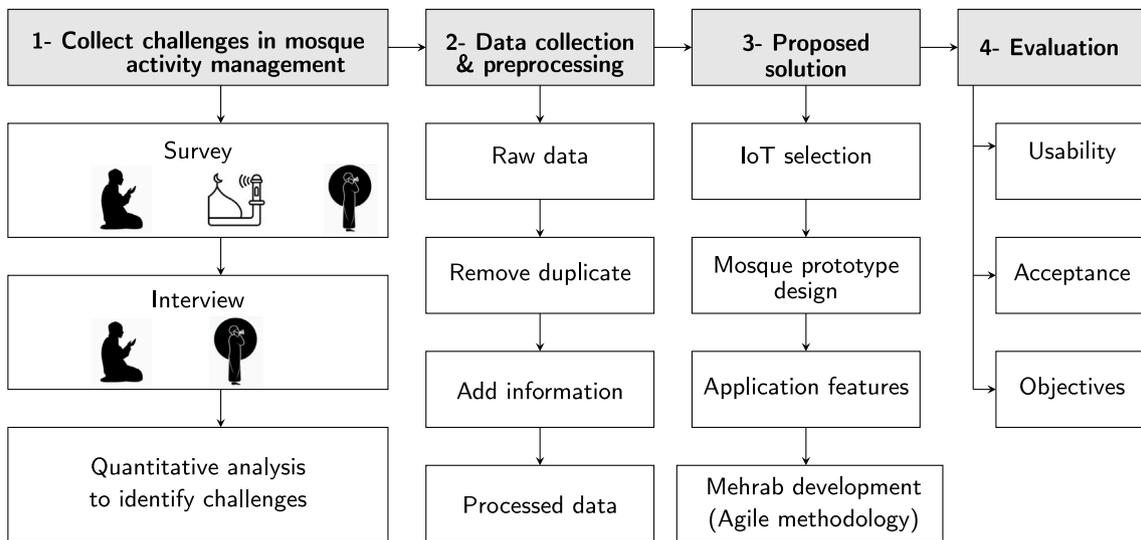


Fig. 1. Overview of the proposed approach.

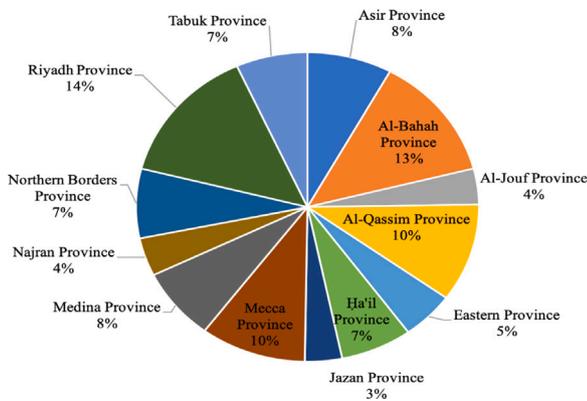


Fig. 2. Percentage distribution of survey responses across the thirteen administrative regions of Saudi Arabia.

contact. Due to these significant gender-based differences, the level of satisfaction with existing communication methods was analyzed based on gender. The results, presented in the first part of Table 3, show that only 39.3% of respondents expressed satisfaction with the current communication channels, predominantly males, while 60.7% were either dissatisfied or held neutral opinions. A total of 19.3% of participants responded to the open question highlighting issues related to communication and inefficient methods of contacting mosque managers. In addition, 63.3% of respondents expressed a preference for using popular social networking platforms, such as WhatsApp or Telegram, to facilitate communication with mosque managers. This finding highlights a clear demand and potential acceptance for a dedicated social networking application tailored to mosque communities, encompassing mosque managers, administrators, and local community members.

The survey findings indicated that mosque community members are primarily informed about social activities, educational sessions, and Qur'an recitation sessions through two main channels: (i) printed advertisements and posters displayed within the mosque and (ii) informal social media groups, such as WhatsApp and Telegram. Over half of the respondents (55%) reported receiving announcements regarding the start times of Ramadan late-night prayers directly from the Imam, typically following obligatory prayers. Despite the use of these communication methods, 22.5% of respondents indicated that obtaining information about mosque activities was extremely difficult. Of these,

66.6% were female. This highlights a gendered disparity in information access, particularly affecting individuals who do not regularly attend mosque prayers or who reside at a distance from the mosque. A majority of female participants commented that they became aware of mosque activities only through male family members, indicating limited direct engagement channels. Moreover, respondents reported that they would only know the start time of prayers after several mosque visits, which was perceived as an inconvenience. Over 84% of individuals who were supposed to attend the lectures and social activities ultimately did not attend due to a lack of timely or detailed information. According to the second part of Table 3, 38.5% of respondents are generally dissatisfied with the current announcement methods, while 30.5% reported neutral opinions. Negative opinions were particularly prominent among female participants, underscoring the need for more inclusive and accessible communication strategies within mosque management systems. Furthermore, 78% of respondents indicated a strong interest in the development of a dedicated mobile application for mosque management. Such an application would serve multiple functions, including keeping community members informed about mosque events and facilitating direct communication with mosque administrators. These findings highlight a clear demand for more participatory and technologically enabled approaches to mosque governance and community engagement.

In light of the foregoing results, three primary categories of challenges were identified that are related to: (i) limited accessibility to mosque facilities, (ii) ineffective communication between mosque managers and community members, and (iii) insufficient mechanisms for community participation in decision-making processes. The results further suggest that the development of a mobile application designed to address these challenges has the potential to improve community satisfaction and strengthen the functional and social role of mosques within the local context.

3.1.2. Interview findings

A total of twenty semi-structured interviews were conducted with mosque managers, comprising ten Imams and ten Muezzins. The primary objective of these interviews was to further explore and clarify the challenges identified in the preceding survey, with a particular focus on operational issues encountered by mosque managers. The interview consisted of nineteen questions regarding current activity management practices, operational challenges, and suggestions for improvement. Several questions explored the extent of community engagement in decision-making processes and the accessibility of mosque services during the absence of the Imam or Muezzin. In the interview, the mosque

Table 3
Responding to questions related to current communication and announcement methods.

1. To what extent you are satisfied with the current communication methods?					
Gender	Strongly satisfied	Satisfied	Neutral	Dissatisfied	Strongly dissatisfied
Male	49 (21.4%)	65 (28.4%)	63 (27.5%)	40 (17.5%)	12 (5.2%)
Female	18 (10.5%)	25 (14.6%)	56 (32.7%)	48 (28.1%)	24 (14.0%)
Total	67(16.8%)	90 (22.5%)	119 (29.7%)	88 (22.0%)	36 (9.0%)

2. To what extent you are satisfied with the current way to announce mosque activities?					
Gender	Strongly satisfied	Satisfied	Neutral	Dissatisfied	Strongly dissatisfied
Male	26 (11.4%)	55 (24.0%)	74 (32.3%)	62 (27.1%)	12 (5.2%)
Female	10 (5.8%)	33 (19.3%)	48 (28.1%)	58 (33.9%)	22 (12.9%)
Total	36 (9.0%)	88 (22.0%)	122 (30.5%)	120 (30.0%)	34 (8.5%)

managers provided details of their responsibilities, which include organizing both religious and social activities within the mosque. Respondents highlighted numerous difficulties in day-to-day operations, with particular emphasis on the need for more efficient management strategies. One of the most frequently cited challenges was effective communication with local community members. They were often contacted directly by the congregation with complaints and questions. When possible, they address these concerns immediately; however, in cases where they are uncertain, responses are often delayed. A general consensus was expressed about the difficulty of following up with individuals who had submitted inquiries or feedback. Therefore, all mosque managers expressed dissatisfaction with the current communication and complaint-handling mechanisms. To communicate mosque activities, various tools such as posters, in-person meetings, social media platforms, and mosque digital screens are currently used. Despite these efforts, interviewees expressed a strong interest in adopting more effective and transparent communication methods. Interestingly, many advocated for the implementation of a smart application to facilitate community participation in decision-making, particularly through features such as voting, which they believe would enhance transparency by allowing all members to view voting results. Despite existing constitutional constraints, several participants acknowledged informally delegating mosque duties, such as unlocking and locking the mosque premises, to trusted community members when they are unavailable. This practice, though unofficial, underscores the need for more structured and formalized support systems. A clear consensus emerged among interviewees regarding the potential value of a dedicated social networking application tailored to mosque operations and community interaction.

3.2. Data collection and preprocessing

There is a lack of mosques dataset. Therefore, the Ministry of Islamic Affairs, Daw'ah and Guidance (MIADG) was contacted and a list of mosques located in nine districts in Riyadh city was obtained. The initial dataset provided by MIADG included basic attributes such as district name, mosque ID, mosque type, mosque name, as well as the names and mobile phone numbers of the designated Imams and Muezzins. To enhance the dataset, data was then prepared by removing duplicate entries and adding additional attributes, such as mosques' geographic coordinates and visual references (mosque images). These supplementary attributes were collected using Google Maps. The final processed dataset comprises information on fifty mosques. A detailed schema of the dataset is presented in [Table 4](#).

3.3. Proposed solution

This section presents the proposed solution, starting with an overview of the IoT devices and sensors that might contribute to addressing the problems identified in the field survey. This is followed by a comprehensive description of the solution, which includes the development methodology and the system features.

3.3.1. Exploring IoT assistance in mosque activity management

To access the mosque premises, mosque managers must either open the door themselves or delegate the process to a trusted individual. In the context of Saudi Arabia, where this study was conducted, key sharing is against the mosque constitution, since the conventional key can be easily duplicated and used at any time without the explicit consent of mosque managers, raising concerns about security and unauthorized access. Smart lock systems present a viable alternative by enabling secure, non-replicable key delegation that complies with constitutional requirements. Unlike conventional keys, digital credentials associated with smart keys can be revoked at any time, thereby enhancing administrative control and oversight over access. Moreover, smart lock systems can strengthen mosque security by notifying mosque managers whenever access occurs and by generating log files that record who opened or closed the door and at what time. Interviews with mosque managers indicated a strong consensus for smart lock adoption, with 64.7% of local community respondents also endorsing the use of smart keys. Furthermore, 62% of community members expressed a willingness to assume responsibility for opening and closing the mosque, contingent upon gaining the trust of mosque managers.

Effective communication between mosque managers and local community members is essential for coordinating religious and social activities. The primary objectives of this communication are to disseminate prayer times, notify the community in cases when prayers are combined due to adverse weather conditions, and share announcements related to social and religious activities. There are a number of ways in which IoT can be utilized to enhance communication within the mosque context. For example, mosque microphones can be integrated with IoT sensors that automatically send notifications to community members when prayers or social activities commence. However, this approach provides minimal advance notice, as notifications are triggered only at the start of the event. An alternative and potentially more effective solution involves the use of a dedicated social networking application, through which mosque managers can share announcements about prayer schedules, educational sessions, and social activities well in advance. This method ensures persistence of information, allowing users to access the history of announcements and providing inclusive access for both male and female members of the community. Given these advantages, this digital solution may be more popular among mosque managers and community members, as indicated in interviews and questionnaires.

Engaging community members in decision-making represents an additional challenge for mosque managers, who are responsible for making choices that align with the interests of the mosque and its local community. Insights gathered from interviews and survey responses suggest that involving community members in the decision-making process can be effectively supported through the implementation of a voting mechanism. Consequently, the same social networking application proposed to address communication challenges can be extended to include a voting feature. This functionality would enable community members to participate in decisions related to religious and social activities. Furthermore, the application may incorporate a private live

Table 4
Data schema for the mosque dataset.

Attribute	Description
District name	The name of the district in which the mosque is located.
Mosque ID	A unique identification number assigned to the mosque.
Mosque type	There are two main types of mosques: small mosques and Jami' mosques. Small mosques host limited religious activities, while Jami' mosques accommodate a wide range of religious and social activities, including Friday prayers and sermons.
Mosque name	The name of the mosque.
Imam	The name of the Imam who leads the worshippers.
Muezzin	The name of the Muezzin responsible for the call to prayer.
Mobile phone numbers	Contact numbers for the Imam and Muezzin.
Location	Geographical coordinates (longitude and latitude) of the mosque based on Google Maps.
Images	Photographs of both the interior and exterior of the mosque.

Table 5
Key features of the Mehrab system categorized by user role.

User role	Feature category	Description & sub-features
Mosque managers	Smart key features	Issue and manage digital keys, delegate and revoke access, view access logs detailing the time and identity of each door interaction, receive real-time notifications of door activity, monitor all active and historical key delegations.
	Communication features	Publish announcements and initiate votes, edit announcements, review voting outcomes, engage with users via private chat.
	Management features	View and search the list of users following a particular mosque, assign trusted status to specific users to enable smart key delegation.
Community members	Smart key features	Control a smart lock using a delegated smart key.
	Communication features	Contact mosque managers, search for a specific mosque, view announcements, participate in voting, view voting results, & filter announcements based on categories.
	Management features	Register an account, join or leave a mosque community, view all followed mosques, browse the complete list of mosques on the system.
Administrator	Management features	Create mosque profiles and mosque manager accounts, view and search all mosques within the system.
All users' categories	Account management features	Login, logout, edit profile information, contact system support, reset or change account passwords.

chat function, allowing individuals to submit complaints or feedback directly to mosque managers. This functionality is intended to promote transparency, improve responsiveness, and strengthen community engagement.

3.3.2. System design and implementation

This study introduces the Mehrab system, which integrates IoT and social networking features to enhance the user experience and regulate mosque door access via smart lock technology. Table 5 outlines the core functionalities offered by the Mehrab system, categorized according to the three primary user roles: (i) mosque managers, (ii) local community members, and (iii) system administrators, who are responsible for creating mosque profiles and mosque manager accounts. The features available to mosque managers are further organized into three functional domains: (i) smart key management, (ii) communication tools, and (iii) administrative capabilities. Within the smart key management features, mosque managers are empowered to: (i) control the smart lock by means of smart keys that open and close the door, (ii) delegate smart keys to trusted community members, (iii) revoke previously delegated smart keys, (iv) view log files that document door access events, including the identity and timestamp, (v) receive real-time notifications for each smart lock interaction, and (vi) view a comprehensive list of both active and historical key delegations. The communication features enable mosque managers to: (i) publish announcements and initiate community voting processes, (ii) edit or update posted announcements, (iii) review the results of community votes, and (iv) engage in private conversations with community members via an integrated chat interface. Under administrative capabilities, the Mehrab system allows mosque managers to search for and view user accounts of community members who follow the mosque profile. Furthermore, managers may assign elevated privileges to trusted individuals within the community, thereby authorizing them to receive smart keys and participate more actively in mosque operations.

The features available to community members within the Mehrab system are organized according to the same functional categories established for mosque managers. When community members gain the trust of mosque managers, they can be granted a delegated smart key, enabling them to open and close mosque doors. This controlled delegation of access supports operational continuity in the absence of mosque managers and fosters greater community engagement. In terms of communication functionality, community members are provided with tools that facilitate direct interaction with mosque managers via private chat, as well as the ability to search for specific mosques, view announcements in a chronological timeline, participate in voting processes, review voting outcomes, and filter announcements by predefined categories. These categories currently include social activities, religious lectures, Qur'an recitation sessions, and prayer-related updates. In terms of administrative capabilities, community members can register on the Mehrab system, manage their personal accounts, follow or unfollow mosque communities using the mosque name as a reference, access a list of mosques they follow, and browse the complete directory of mosques registered within the system.

The administrators are responsible for creating mosque profiles within the Mehrab system, as well as establishing mosque manager accounts. The credentials for mosque managers accounts will be communicated to the Imam and Muezzin via a short message sent to their mobile phones. For security purposes, mosque managers are required to update their login credentials upon first access, replacing the default credentials generated by the system. The administrator interface provides functionality for viewing a comprehensive list of all registered mosque accounts and supports advanced search capabilities using various identifiers, including mosque ID, district name, mosque name, Imam name, and Muezzin name.

In addition to role-specific functionalities, the system provides a set of core registration and account management features that are accessible to all user categories. These include user authentication (login

and logout), profile editing capabilities, password reset and update functions, and access to system support services.

The Mehrab system was developed using the Scrum framework, a widely adopted Agile software development methodology (Grebic & Stojanović, 2021). The framework involved three key roles: (i) the scrum master, (ii) stakeholders, and (iii) the development team. The scrum master is responsible for facilitating the development process and eliminating any impediments that could hinder progress. Stakeholders, who represent potential end users of the system, included a representative sample of local community members, mosque managers, and system administrators (Admin). These stakeholders were actively engaged throughout the development lifecycle to ensure that user requirements were accurately captured, prioritized, and addressed. The development team was responsible for implementing the system features based on iterative stakeholder feedback. There are three Scrum artifacts, namely the product backlog, the sprint backlog, and the product increment. The product backlog consists of a prioritized list of user stories derived from stakeholder input. For each sprint, a sprint backlog is created, containing selected user stories to be implemented during that iteration. The product increment refers to the functional output delivered at the end of each sprint, representing measurable progress toward the overall system objectives. This iterative and user-centered development process facilitated continuous stakeholder engagement, ensuring that the final application closely aligned with user expectations and practical needs.

Mehrab is an Arabic-language mobile application designed to operate on Android platforms. The application was built using the Flutter framework (Flutter, 2023), which utilizes the Dart programming language. The backend infrastructure is powered by Firebase, which provides real-time data storage, user authentication, and cloud-based user management services (Google developers, 2023). For physical access control, the system integrates the Nuki smart lock (Nuki Home Solutions, 2023), which was selected for its high compatibility with both horizontal and vertical door locks, ease of installation, and robust security features. The security performance of the Nuki smart lock has been evaluated in previous studies, such as Caballero-Gil, Alvarez, Hernández-Goya, and Molina-Gil (2023), which concluded that the device offers a high level of security when the advanced encryption standard is used. In this study, the Nuki APIs were used to control the smart key through the Mehrab application. To enable secure integration, an OAuth2 API token was obtained by registering the smart lock on the official Nuki website (Nuki Home Solutions, 2023). The smart lock ID (printed on the device packaging) and API token were then used in the HTTP POST requests to enable communication between the Mehrab application and the Nuki smart lock. Fig. 3 presents selected screenshots from the English version of the Mehrab application, highlighting key features and user interface elements.

To enable the integration of the Nuki smart lock system, physical installation and configuration on a mosque door is typically required. However, for the purposes of this study, specifically to evaluate the proposed solution and validate system functionality, a prototype simulating a mosque environment was designed and constructed, as illustrated in Fig. 4. This prototype provides a controlled environmental setting in which smart key features of the Mehrab system can be systematically tested across multiple user roles, including mosque managers and local community members. The prototype door locks were constructed with Euro profile cylinder locks (Wels & Gonggrijp, 2005). While one side of the lock was fitted with a blank faceplate (Fig. 4-b), the opposite side was functionally equivalent to a standard keyhole interface (Fig. 4-a). This design ensures compatibility with the Nuki smart lock system while maintaining user familiarity and ease of operation. The use of this setup enabled comprehensive evaluation of the smart access control features under conditions that simulate real-world operation while maintaining experimental control.

3.4. Evaluation criteria

The proposed solution is evaluated across three key criteria: usability, technology acceptance, and achievement of objectives. The measurement instruments used to assess these criteria are presented and discussed in the following subsections; Section 3.4.1 to Section 3.4.3.

3.4.1. Usability

System usability was assessed using the System Usability Scale (SUS), a validated and widely adopted instrument for evaluating system usability (Bangor, Kortum, & Miller, 2008; Kaya, Ozturk, & Altin Gumussoy, 2019). The SUS consists of ten questions rated on a five-point Likert scale, ranging from “strongly disagree” given 1 to “strongly agree” given 5. These questions capture users’ subjective assessments of key usability aspects, including ease of use, learnability, and overall satisfaction. The SUS scores are calculated using a standardized formula. For each participant, the score is derived using the formula $(X + Y) \times 2.5$, where X is the sum of the adjusted scores for all odd-numbered questions minus 5, and Y is 25 minus the sum of the adjusted scores for all even-numbered questions. This yields a total SUS score ranging from 0 to 100, with higher scores indicating better perceived usability (Brooke et al., 1996). The overall usability evaluation is based on the average SUS score across all participants. According to the MeasuringU Research Center (Sauro, 2018), a score of 68 is considered the benchmark for acceptable usability, whereas scores in the 90s are indicative of excellent usability.

3.4.2. Technology acceptance

Hybrid approach is proposed to evaluate technology acceptance, comprising: (i) sentiment analysis of users opinions and (ii) an evaluation grounded in a theoretical framework. This subsection provides a detailed discussion of the theoretical framework-based evaluation component.

Several theoretical frameworks have been developed to assess user acceptance of technology (Davis et al., 1989; Rogers, 2003; Venkatesh, Morris, Davis, & Davis, 2003). Among these, the TAM is one of the most widely applied and validated models. It provides a robust theoretical foundation for understanding the key factors that influence behavioral intentions of individuals and their actual usage of new technologies. The original TAM explains user acceptance based on two core constructs: Perceived Usefulness (PU) and Perceived Ease of Use (PEoU). These constructs influence the user’s Attitude Toward Use (ATU), which subsequently influences their Behavioral Intention (BI) to use the system, ultimately leading to Actual Use (AU). To enhance the explanatory power of TAM, External Variables (EVs) can be incorporated into the model, allowing for the inclusion of contextual, cultural, or institutional factors (Davis et al., 1989; Robles-Gómez, Tobarra, Pastor-Vargas, Hernández, & Haut, 2021). In this study, we extend the TAM framework by integrating constructs from institutional theory, which suggests that individual behaviors are shaped by organizational and cultural environments through mechanisms such as Normative Pressure (NP), Coercive Pressure (CP), and Mimetic Pressure (MP) (Ritzer, 2004). These institutional constructs are modeled as determinants of BI, as they reflect forces that shape technology adoption by reinforcing expectations, obligations, and social conformity within a community. CP refers to formal or informal pressure or demands from religious authorities, such as Imams, Muezzins, and MIADG, that convince individuals to adopt specific technologies or practices. NP captures the social influence exerted when individuals perceive that technology use is expected or encouraged within their community. MP captures the tendency of individuals to emulate the behaviors and attitudes of respected or high-status individuals who have adopted the technology. By integrating these institutional constructs into the TAM framework, this study offers a more comprehensive understanding of how both formal and informal rules within religious and cultural

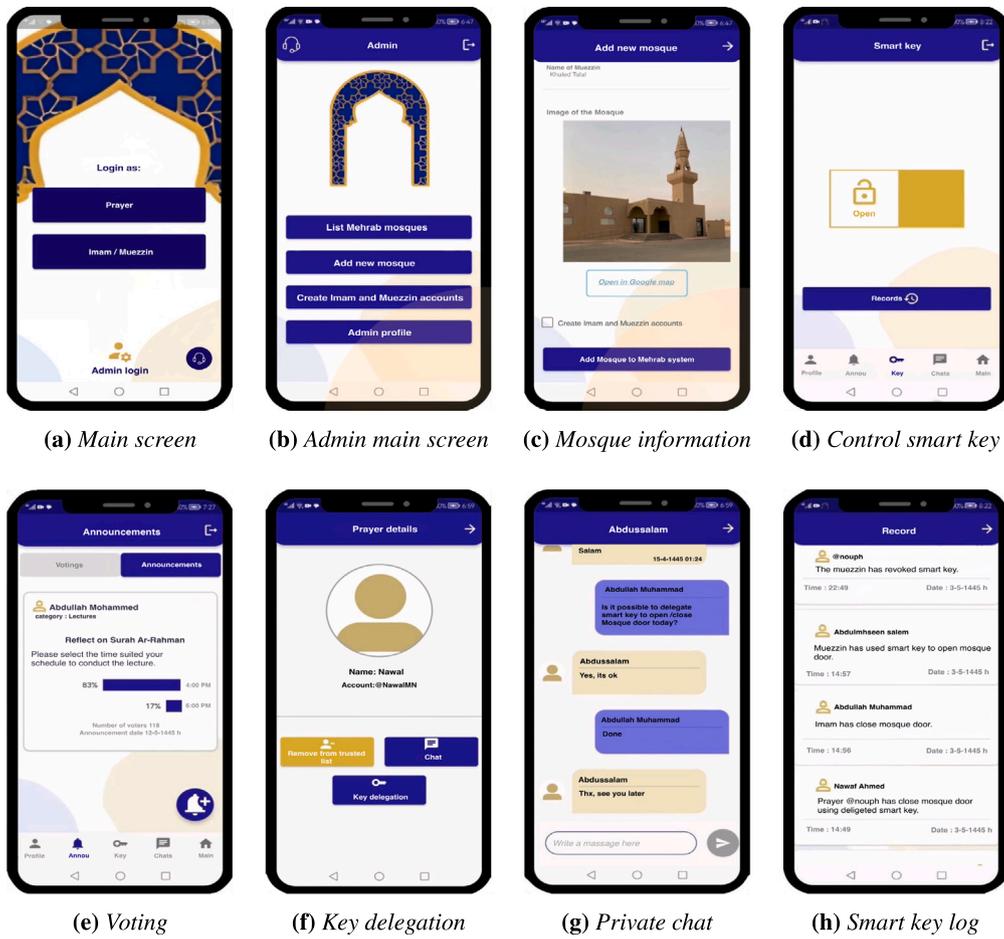


Fig. 3. Screen shots of the Mehrab system interface showing key functionalities.



(a) Mosque building prototype



(b) Nuki smart lock installed on the interior side

Fig. 4. Mosque prototype with installed Nuki smart lock.

institutions shape user acceptance. The proposed conceptual model, given in Fig. 5, illustrates theoretical integrations and aligns with similar extensions of TAM presented in various contexts, such as a cloud acceptance study conducted by Robles-Gómez et al. (2021).

The following hypotheses were derived from the variables and their interconnections shown in Fig. 5:

H1: The PEoU variable has a positive and significant effect on the PU variable.

H2: The PEoU variable has a positive and significant effect on the ATU variable.

H3: The PU variable has a positive and significant effect on the ATU variable.

H4: The ATU variable has a positive and significant effect on the BI variable.

H5: The PU variable has a positive and significant effect on the BI variable.

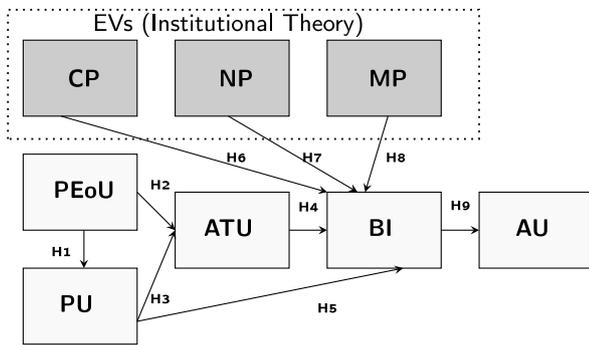


Fig. 5. Conceptual framework based on TAM and institutional theory constructs.

- H6: The CP variable has a positive and significant effect on the BI variable.
- H7: The NP variable has a positive and significant effect on the BI variable.
- H8: The MP variable has a positive and significant effect on the BI variable.
- H9: The BI variable has a positive and significant effect on the AU variable.

These hypotheses were tested using linear regression analysis, with each independent variable examined for its direct effect on the corresponding dependent variable. Demographic characteristics such as gender, age, and level of technical experience may influence technology acceptance, particularly when social and contextual factors are considered (Dabaj, 2009). Therefore, to enhance the analysis, these demographic characteristics were included as control variables. Furthermore, a one-way Analysis of Variance (ANOVA) and post hoc tests were conducted to determine whether statistically significant differences existed in the mean scores of TAM constructs across subgroups defined by the control variables.

3.4.3. Objectives achievement

To evaluate the extent to which the system fulfills its intended objectives, three questionnaires were developed, each designed for a specific user category. These instruments served as objective achievement measures, with questionnaire items aligned with the system's core goals, namely improving mosque activity management, enhancing communication, increasing mosque accessibility, and facilitating community engagement in decision-making processes. Respondents were asked to indicate their level of agreement with each statement using a five-point Likert scale, thereby enabling a quantifiable assessment of the system's perceived effectiveness using a one-sample t-test.

4. Experimental setup and results

This section details the experimental setup and presents the evaluation results of the Mehrab system.

4.1. Experimental setup

The experiment began by selecting participants from the three primary user categories of the Mehrab system. Each participant was granted access to the Mehrab mobile application, and where necessary, the mosque prototype was used to simulate real-world interaction with the smart lock functionality. Participants were instructed to perform a series of tasks that reflected the system features listed in Table 5. Prior to commencing the tasks, informed consent was obtained from all participants, followed by a fifteen minutes familiarization period during which they explored the application independently. After this orientation phase, participants completed a set of predefined tasks designed

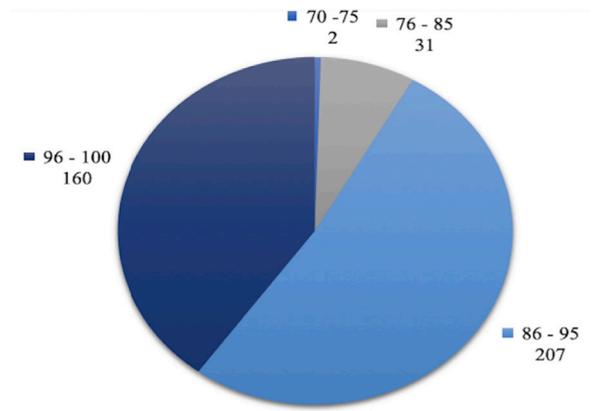


Fig. 6. Percentages distribution of participants across different SUS score ranges.

to assess their ability to navigate the system, execute key functions, and achieve specific user objectives. Upon task completion, participants provided evaluative feedback through both structured questionnaires, based on a five-point Likert scale, and open-ended responses. The evaluation focused on three main dimensions: system usability, user acceptance, and the extent to which the application achieved its intended objectives. These aspects were assessed using the instruments described in Section 3.4. Table 6 presents the demographic characteristics and technical background of the participants. A total of 400 responses were collected. The sample comprised 200 community members, 110 mosque managers, and 90 administrators. The gender distribution was relatively balanced, with 52.5% male and 47.5% female participants. Regarding age, 60 participants were between 18–20 years, 100 were aged 21–26, another 100 were between 27–35, and 140 were aged 36 and above. In terms of technical expertise, 70% of respondents identified as having a moderate level of proficiency, while 20% reported a high level, and 10% a low level of technical competence.

4.2. Evaluate system usability

To evaluate the usability of the Mehrab system, all 400 participants who interacted with the Mehrab application completed the SUS questionnaire (Brooke et al., 1996). Table 7 presents the SUS items, along with the frequency and percentage distribution of participant responses. The SUS consists of ten items designed to measure perceived usability, with alternating positive and negative statements. The odd-numbered items are positively worded, reflecting favorable aspects of the system, whereas the even-numbered items are negatively worded, capturing potential usability issues or dissatisfaction. Fig. 6 shows the percentage distribution of participants based on their overall SUS scores across defined intervals. As illustrated in the figure, the majority of participants (207) reported scores within the range of 86–95, followed by 160 participants scoring between 96–100, 31 within the 76–85 range, and only 2 participants scoring between 70–75. The average SUS score across all respondents was 94.23, significantly exceeding the widely accepted benchmark of 68 for acceptable usability (Bangor et al., 2008). These findings indicate that the Mehrab application demonstrates excellent usability, reflecting high levels of user satisfaction, learnability, and ease of use.

4.3. Evaluate system technology acceptance

This section presents the results of the technology acceptance evaluation, which employed a hybrid methodology comprising: (i) sentiment analysis and (ii) a theoretical framework grounded in the TAM and institutional theory.

Table 6
Demographic and technical background of study participants.

Variable	Category	Number of participants (%)
User Role	Community members	200 (50.00%)
	Mosque managers	110 (27.50%)
	Administrators	90 (22.50%)
Gender	Male	210 (52.50%)
	Female	190 (47.50%)
Age group (years)	18–20	60 (15.00%)
	21–26	100 (25.00%)
	27–35	100 (25.00%)
	36 and above	140 (35.00%)
Technical background	High	80 (20.00%)
	Medium	280 (70.00%)
	Low	40 (10.00%)

Table 7
SUS items and distribution of participant responses.

SUS item	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. I think that I would like to use this system frequently	0 0.00%	5 1.25%	9 2.25%	50 12.50%	336 84.00%
2. I found the system unnecessarily complex	302 75.50%	97 24.25%	1 0.25%	0 0.00%	0 0.00%
3. I thought the system was easy to use	0 0.00%	1 0.25%	10 2.50%	60 15.00%	329 82.25%
4. I think that I would need the support of a technical person to be able to use this system	260 65.00%	130 32.50%	9 2.25%	1 0.25%	0 0.00%
5. I found the various functions in this system were well integrated	0 0.00%	1 0.25%	5 1.25%	34 8.50%	360 90.00%
6. I thought there was too much inconsistency in this system	320 80.00%	67 16.75%	11 2.75%	2 0.50%	0 0.00%
7. I would imagine that most people would learn to use this system very quickly	0 0.00%	3 0.75%	11 2.75%	76 19.00%	310 77.50%
8. I found the system very awkward to use	354 88.50%	45 11.25%	1 0.25%	0 0.00%	0 0.00%
9. I felt very confident using this system	0 0.00%	0 0.00%	11 2.75%	49 12.25%	340 85.00%
10. I needed to learn a lot of things before I could get going with this system	260 65.00%	120 30.00%	10 2.50%	0 0.00%	10 2.50%

4.3.1. Sentiment analysis approach

To assess user acceptance of the technology, sentiment analysis was performed on Arabic textual feedback provided by all 400 participants. Each participant submitted a brief written opinion regarding their experience with the Mehrab system and its smart locks feature. These responses were analyzed to classify sentiments into three categories: positive, negative, and neutral. The preprocessing of the Arabic text involved several steps to address the unique characteristics of the Arabic language. The first step was to clean the text by removing stop-words using the default stop-word list in the Natural Language Toolkit (NLTK) package.¹ Given the rich morphology of Arabic, where words may have multiple meanings differentiated by diacritics or variations of the same letter, such as Alif and Hamza, additional cleaning steps were performed. This included the removal of diacritics, punctuation, and numbers. Next, the text was normalized by unifying letters such as Alif, Yaa, Haa, Taa Marbuta, and Waw to their general forms. Tokenization was then carried out using the SentencePiece tokenizer, which employs a Unigram subword model (Kudo & Richardson, 2018). This approach has been shown to outperform some tokenization methods, primarily due to its strong capability to capture and represent complex linguistic structures (Qarah & Alsanoosy, 2024). The resulting tokens were used as input to a pre-trained sentiment analysis model, as described in Khooli (2024).

The sentiment analysis component of this study employed a fine-tuned version of the XLM-RoBERTa-Large model, a state-of-the-art multilingual transformer architecture that has been extensively pre-trained on text from 100 different languages, including Arabic. Unlike

lexicon-based approaches, which often struggle with the morphological richness and dialectal variation of Arabic, XLM-RoBERTa relies on deep neural network representations learned from large-scale sentiment-labeled datasets. This enables the model to effectively capture contextual and semantic nuances, and handle variations in dialects, morphology, and word usage that are often challenging for lexicon-based approaches. Empirical evidence from recent experiments (Dadure, Dixit, Tewatia, Paliwal, & Malla, 2025) demonstrates that the XLM-RoBERTa model outperforms several other pre-trained models in Arabic sentiment analysis tasks, particularly for texts devoid of emoji, making it a suitable and robust choice for this research. The model's integration into the analysis pipeline enabled the extraction of sentiment labels with a high degree of accuracy, contributing to a nuanced understanding of user attitudes toward the Mehrab system. The analysis of participant feedback indicated that 378 responses (94.5%) expressed a positive sentiment, 10 responses (2.5%) were negative, and 12 responses (3%) were neutral. Notably, the majority of positive sentiments were submitted by female participants. The ten most frequently occurring words in the feedback were: "comprehensive", "beautiful", "Imam", "application", "usage", "easy", "smart", "lock", "amazing", and "mosque". These findings suggest a high level of user acceptance and satisfaction with the system and smart lock features in religious settings. However, the application of advanced sentiment analysis techniques alone does not reveal the underlying factors driving these sentiments or the long-term user engagement with the system.

4.3.2. Theoretical approach

To identify the key factors influencing user acceptance, the theoretical framework detailed in Section 3.4.2 was applied. Data were collected through a structured questionnaire administered to participants

¹ <https://www.nltk.org>

Table 8
Cronbach's alpha, Skewness, and Kurtosis values for model constructs.

Test/variable	PEoU	PU	ATU	BI	CP	NP	MP	AU
Cronbach's Alpha	0.833	0.803	0.804	0.806	0.818	0.860	0.823	0.819
Skewness	-0.654	0.292	-0.115	-0.312	-0.405	-0.730	0.093	-0.087
Kurtosis	1.846	-0.278	0.302	-0.283	0.158	0.354	0.195	0.104

following their interaction with the Mehrab system and the proposed IoT solution. The questionnaire comprised 41 items distributed across eight constructs: PEoU (seven items), PU (six items), ATU (six items), BI (five items), CP (six items), NP (four items), MP (four items), and AU (three items). Each item was rated on a five-point Likert scale, ranging from 1 ("very low") to 5 ("very high"), enabling the quantification of participants' perceptions across the model constructs. In total, responses were obtained from 400 participants.

IBM SPSS statistics software was employed to analyze respondent characteristics and summarize key study variables. The validity and reliability of the questionnaire instruments were assessed through internal consistency measures using Cronbach's alpha. As presented in Table 8, the reliability coefficients for each construct ranged from 0.803 to 0.860, all of which exceed the commonly accepted threshold of 0.70, thereby indicating strong internal consistency and reliability of the measurement scales (Kılıç, 2016). The overall Cronbach's alpha for all instruments was 0.840. Furthermore, Skewness and Kurtosis values were calculated for each construct to examine the normality of the data distribution. As shown in Table 8, the Skewness values ranged from -0.730 to 0.292, and Kurtosis values ranged from -0.283 to 1.846. None of the values indicated extreme deviation from normality, with all falling within the commonly accepted ± 2 threshold (Field, 2024; Gravetter & Wallnau, 2011). These results confirm that the data distributions are approximately normal and valid to proceed with parametric statistical analysis such as regression.

The nine hypotheses outlined in Section 3.4.2 were evaluated using linear regression analysis. Each independent variable was examined for its direct effect on the corresponding dependent variable. The assessment of these hypotheses was based on three key statistical indicators: the coefficient of determination (R^2), standardized regression coefficients (β), and significance levels (p), which collectively assessed the strength, direction, and statistical significance of the relationships. The significance threshold was set at 0.05, in accordance with established research conventions in the technology acceptance literature (Jan, Lu, & Chou, 2012; Kang & Hwang, 2022). The detailed regression analysis outcomes are summarized in Table 9. The findings offer robust empirical support for the proposed theoretical model, with all proposed hypotheses confirmed. Each relationship was found to be statistically significant and positively correlated, with p values well below the conventional threshold 0.05. However, the strength and explanatory power of these relationships varied across constructs, as reflected in the diversity of β and R^2 values. In particular, PEoU had a positive effect on PU, supporting a core assumption of the TAM framework. This moderate effect implies that users who find the system easy to use are more likely to perceive it as useful, although ease of use explains only 17.5% of the variance in PU. This relationship underscores the importance of system design simplicity, user interface intuitiveness, and reduced cognitive effort as key determinants influencing users' perception of value and functional utility of the system. A statistically significant but weaker relationship was observed between PEoU and ATU ($\beta=0.315$, $R^2=0.099$), suggesting that while ease of use contributes to a positive attitude, its influence is limited in comparison to other factors. In contrast, PU emerged as a dominant predictor of ATU, explaining 83.5% of its variance, thereby reinforcing its central role in shaping positive user perceptions. Furthermore, ATU significantly predicted BI, explaining about 26.2% of its variance. This result aligns with model predictions, confirming that positive user attitudes lead to stronger intentions to adopt and continue using the system.

The institutional theory constructs demonstrated statistically significant and positive effects on BI, confirming their theoretical relevance within the context of technology acceptance in religious institutional settings such as mosques. CP exerted the strongest influence on BI ($\beta=0.623$, $R^2=0.389$), indicating that formal expectations, directives, or implicit mandates from religious authorities, such as Imams, Muezzins, and MIADG, play a critical role in shaping individual adoption behaviors. This suggests that religious authority can serve as a powerful enabler of digital transformation in religious institutions. NP also had a notable and statistically significant effect, indicating that social norms and the desire to align with community expectations encourage users to engage with the Mehrab system. In contrast, MP had the weakest effect among the institutional constructs ($\beta=0.313$, $R^2=0.098$), suggesting that while the emulation of respected or high-status individuals contributes to BI, its influence is relatively limited. This finding implies that although users may be somewhat motivated to adopt the system based on the behaviors of influential peers or organizations, such imitation is less influential than other institutional or attitudinal factors. Furthermore, BI demonstrated a strong and statistically significant predictive effect on AU, accounting for approximately 46% of the variance. This finding aligns with the foundational assumptions of the TAM and is consistent with prior empirical research, reinforcing the critical role of intention as a proximal determinant of actual system usage.

Control variables were examined to evaluate their potential influence on the constructs of the proposed model. Accordingly, ANOVA tests were conducted to determine whether statistically significant differences existed in the mean scores of model constructs across categories defined by the control variables. The results, presented in Table 10, indicate that both age and gender significantly influenced several core constructs in the model. These findings are consistent with prior studies emphasizing the role of demographic factors in shaping technology acceptance (Dabaj, 2009; Jan et al., 2012; Mazman & Usluel, 2011). Technical experience demonstrated a moderate influence on three key constructs (PEoU, ATU, and MP). Interestingly, despite its impact on these intermediary constructs, technical experience did not exhibit a direct significant effect on BI or AU in this study. This finding contrasts with some previous studies which have reported a more direct relationship between technical proficiency and intention to use (Ezeudoka & Fan, 2024). The absence of a direct influence on BI in this context may suggest that while technical experience shapes underlying perceptions such as PEoU, ATU and MP, these do not always translate directly into BI or AU. In worship-based environments, generational or gendered norms regarding technology use may shape BI more strongly than individual experience or technical competence.

The descriptive statistics derived from the ANOVA analysis examining model constructs across gender groups revealed notable findings. Regarding PU, female participants rated the system as more useful than male participants. The Mean (M) and Standard Deviation (SD) for females were $M = 4.26$, $SD = 0.35$, compared to $M = 3.97$, $SD = 0.30$ for males, indicating a stronger perceived utility of the system among female users. Similarly, in terms of ATU, female participants had a more positive attitude toward using the technology in mosques than male participants. This difference was supported by the ANOVA results, $F(1, 398) = 86.345$ and $p < 0.05$, indicating that gender significantly influences user attitudes toward technology adoption in religious settings. A comparable pattern was observed for BI, where female participants reported a higher intention to use the system than males, reinforcing the trends noted in PU and ATU. In addition, female

Table 9
Summary of hypothesis testing results using linear regression analysis.

Metric	H1 PEoU→PU	H2 PEoU→ATU	H3 PU→ATU	H4 ATU→BI	H5 PU→BI	H6 CP→BI	H7 NP→BI	H8 MP→BI	H9 BI→AU
R^2	0.175	0.099	0.835	0.262	0.248	0.389	0.183	0.098	0.459
β	0.418	0.315	0.914	0.512	0.498	0.623	0.428	0.313	0.677
P	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Table 10
ANOVA results indicating the statistical significance of demographic control variables on the proposed model constructs. A check mark (✓) indicates a statistically significant effect ($p < 0.05$); a cross (×) indicates no statistically significant effect.

Demographic variable	PEoU	PU	ATU	BI	CP	NP	MP	AU
Age	×	✓	✓	✓	✓	✓	✓	✓
Gender	×	✓	✓	✓	✓	✓	✓	✓
Technical experience	✓	×	✓	×	×	×	✓	×

participants reported higher CP scores ($M = 4.17, SD = 0.28$) compared to male participants ($M = 3.92, SD = 0.37$), suggesting that female perceived stronger formal or institutional expectations to adopt and align with the use of the technology. The analysis also indicated a significant gender effect on NP, with the ANOVA result ($F(1, 398) = 18.34$ and $p < 0.05$) showing that gender differences explained a notable proportion of the variance in NP scores. Female participants perceived greater social pressure to adopt the technology in the context of worship. Likewise, MP showed a statistically significant difference between genders, $F(1, 398) = 36.501$ and $p < 0.05$, with female participants again reporting higher levels than males. These findings suggest that gender plays a substantial role in shaping susceptibility to mimetic influences, whereby female may be more inclined to adopt new technologies by observing and emulating respected or influential individuals within their community. Furthermore, gender had a significant effect on AU, with the ANOVA yielding $F(1, 398) = 306.132$ and $p < 0.05$. Female participants reported significantly higher levels of actual system usage compared to males. This result highlights that gender not only influences perceptions and intentions but also translates into tangible differences in behavioral engagement with the system, further underscoring the critical role of gender in technology acceptance within religious contexts.

If a significant difference was identified in the ANOVA tests for age or level of technical experience, post hoc analyses using Tukey’s Honestly Significant Difference (HSD) test were conducted to identify specific group differences. The findings from these analyses are summarized below:

PEoU: Post hoc comparisons revealed a statistically significant effect of technical experience on PEoU. Participants with low technical experience ($M = 3.93$) reported significantly lower PEoU compared to those with moderate ($M = 4.17$) and high technical experience ($M = 4.22$). However, no significant difference was observed between the moderate and high experience groups ($p = 0.652$), suggesting a threshold effect in which moderate experience may be sufficient to perceive the system as easy to use.

PU: Tukey’s HSD test revealed a significant difference in PU based on age. The younger participants (aged 18–20) reported the highest PU scores, forming a distinct homogeneous subset, while older participants (ages 27–35 and 36+) clustered into lower-scoring subsets. These findings indicate that age significantly influences PU, with younger users generally viewing the system as more beneficial. This aligns with prior research indicating that older individuals often approach new technologies with greater caution, potentially reducing their PU (Morris & Venkatesh, 2000).

ATU: Significant differences in ATU were observed across age groups. The oldest participants (ages 27–35 and 36+) reported the lowest ATU scores and formed a single homogeneous group. Participants aged 21–26 reported significantly higher ATU, while those

aged 18–20 had the highest scores, significantly differing from all other age groups ($p < 0.05$). Although the ANOVA test showed a slight increase in ATU across levels of technical experience, the differences were not statistically significant ($p > 0.05$). This finding suggests that ATU system were relatively consistent regardless of prior technical experience.

BI: Tukey’s HSD results analysis of BI demonstrated a clear age-related trend: participants aged 18–20 reported the highest BI scores, with a progressive decline observed among older age groups. This pattern reinforces the role of age in shaping users’ behavioral intentions to adopt the system.

CP: The Tukey’s HSD results analysis for CP revealed statistically significant differences across age groups. Each group formed a distinct homogeneous subset, with CP scores increasing as age decreased. The youngest group (18–20) reported the highest mean score ($M = 4.28$), while the oldest group (36+) reported the lowest ($M = 3.87$), with all between-group differences reaching statistical significance ($p < 0.05$). These findings suggest that younger participants were more responsive to institutional expectations. This may be due to greater sensitivity to religious authority or higher receptiveness to digital initiatives. In contrast, older individuals may rely more on traditional practices or exhibit resistance to institutional influence, possibly due to established routines or lower levels of digital fluency.

NP: In terms of NP, the oldest age group (36+) reported the lowest mean score ($M = 3.79$), forming a distinct group compared to younger participants. In contrast, participants aged 18–20 and 21–26 reported higher NP scores ($M = 3.99$ and $M = 4.08$, respectively), forming a separate homogeneous subset. However, the associated p values between these groups ($p = 0.057$ and $p = 0.584$) suggest that these differences were not statistically significant. Despite this, the trend implies that younger individuals may experience greater social expectations or peer influence to adopt the technology, a pattern consistent with literature linking youth to greater susceptibility to social influence in technology adoption contexts (Morris & Venkatesh, 2000).

MP: Although mean MP scores were slightly higher among younger participants (ages 18–20) compared to other age groups, the differences were not large enough to reach statistical significance. Similarly, Tukey’s HSD test showed no significant differences across levels of technical experience, as all p values exceeded conventional significance threshold. Nevertheless, the pattern of means suggests a potential trend, with participants possessing low technical experience reporting the lowest MP scores ($M = 3.73$), and those with moderate and high experience reporting higher MP scores ($M = 3.99$ and $M = 3.86$, respectively).

AU: The analysis of AU across age groups revealed a clear trend; younger participants consistently reported higher level of actual system usage than the older participants. This finding suggests that age may influence not only users' perceptions but also their actual behavioral engagement with the technology.

4.4. Evaluate system objective achievement

There are three questionnaires that aim to measure Mehrab objectives achievements each targets specific category of user each of which will be discussed in the following subsections; Section 4.4.1 to Section 4.4.3.

4.4.1. Mosque managers related objectives

We received responses from 110 mosque managers who participated in the survey, providing data on four key evaluation objectives related to the Mehrab system: (i) management-related functionality, (ii) communication with community members, (iii) support for decision-making within mosque administration, and (iv) overall system effectiveness and efficiency. To determine whether participants' evaluations significantly differed from a neutral benchmark value of 3 (representing neutrality on a five-point Likert scale), a series of one-sample t-tests were conducted. For the first objective, results revealed a statistically significant positive deviation from the neutral benchmark, $t(109) = 14.597$, $p < 0.05$, with a mean difference of 1.30. This indicates that respondents rated Mehrab management-related functionalities significantly above neutral, suggesting strong agreement that the system effectively supports mosque administration tasks such as task delegation, monitoring, and traceability. Moreover, respondents agreed that the system offers practical solution to challenges such as monitoring complaints, managing suggestions, and controlling mosque door operations. Regarding communication, all mosque managers participants strongly agreed that the announcement feature is an effective tool for disseminating mosque-related news and activities. This reflects a high level of satisfaction with Mehrab's role in facilitating communication between mosque managers and the broader community. To evaluate perceptions of the system's support for decision-making, a one-sample t-test yielded a statistically significant result, $t(109) = 20.45$, $p < 0.05$, with a mean difference of 1.57. This indicates strong consensus among mosque managers that Mehrab enhances decision-making processes within mosque administration. Finally, overall perceptions of system effectiveness and efficiency were assessed through an additional t-test, which also revealed a highly significant positive evaluation, $t(109) = 26.02$, $p < 0.05$, with a mean difference of 1.72. These results reinforce the system's perceived value and relevance in supporting real-world mosque operations.

Given the foregoing, these findings affirm that the system effectively achieves its intended objectives and provides substantial practical value in supporting mosque management, communication, and decision-making processes.

4.4.2. Local community members related objectives

Responses were obtained from 200 participants who identified as local community members. These individuals evaluated the Mehrab system across four key dimensions: (i) accessibility of mosque activities, (ii) communication with mosque manager, (iii) management-related functionality, and (iv) involvement in decision-making. All participants reported that Mehrab facilitated access to mosque activities through features such as announcements and smart key delegation. Regarding communication, a substantial majority ($n = 179$) strongly agreed that the system enhanced interaction with the Imam and Muezzin. This perception was statistically confirmed by a one-sample t-test, which indicated a significant deviation from the neutral point, $t(199) = 45.56$, $p < 0.05$, with a mean difference of 1.83. These findings demonstrate a high level of consensus that Mehrab effectively supports communication between mosque administrations and the broader community, an

essential objective of the system. Similarly, participants evaluations of the system's management-related functionality revealed a statistically significant positive deviation from neutrality, $t(199) = 38.67$, $p < 0.05$, indicating that the community perceives Mehrab as substantially enhancing the organization and coordination of mosque operations. The evaluation of the decision-making dimension also yielded a highly significant result ($p < 0.05$), suggesting that users believe Mehrab contributes meaningfully to inclusive and participatory governance decision-making practices within the mosque context. Furthermore, participants evaluated Mehrab's role in fostering a sense of belonging and encouraging community engagement. A one-sample t-test revealed a statistically significant positive deviation from the neutral benchmark, with the majority expressing strong agreement that the system strengthens their connection to the mosque community.

Collectively, these findings suggest that Mehrab not only improves communication, administrative functionality, and participatory decision-making, but also plays a critical role in strengthening community engagement and identity.

4.4.3. Administrator related objectives

An empirical evaluation was conducted with 90 participants serving as mosque administrators to assess key system objectives related to administrative functionality. All participants agreed that the Mehrab system effectively ensures the credibility of user, mosque, and mosque manager accounts. This credibility is attributed to the system's automated account generation process for Imams and Muezzins, which is based on verified assignments recorded in the administrative dataset (see Table 4). Consequently, the system restricts the creation of Imam and Muezzin accounts to officially authorized individuals, thereby safeguarding authenticity and minimizing the risk of impersonation. Furthermore, 82 administrators strongly agreed that Mehrab provides a practical and efficient platform for managing mosque related affairs. Participants emphasized that the system supports real-time monitoring and activity tracking, thereby enhancing administrative oversight and operational transparency. To statistically examine these perceptions, a one-sample t-test was conducted to determine whether the administrators' evaluations significantly deviated from a neutral benchmark value of 3. The results revealed a statistically significant difference ($p < 0.05$), confirming a strong level of agreement regarding the system's effectiveness. These findings provide robust empirical support for the conclusion that Mehrab significantly contributes to the efficient and secure administration of mosque operations, while also reinforcing the capacity of authorized personnel to manage and monitor organizational tasks effectively.

5. Discussion

This section interprets the findings in relation to the broader literature on digital transformation, smart communities, and technology adoption within religious and community-based institutions. It synthesizes the empirical results with theoretical insights and addresses the practical, policy, and economic implications of implementing IoT technologies in mosque management. The discussion is organized into several thematic areas: a summary of contributions and findings, theoretical contributions, cost-benefit analysis and business model, comparative evaluation with existing applications, as well as a dedicated sections on the practical and policy implications of deploying IoT solutions in mosque settings.

5.1. Summary of contributions and findings

This study provides a novel contribution to the under-explored domain of IoT integration within religious institutional contexts, particularly focusing on their acceptance in mosque management and implications for broader community engagement. The study investigated

the integration of smart devices designed to overcome challenges identified using qualitative methods. Analysis of the participants' responses reveals that more than half (60%) experienced the same challenges, which primarily related to mosque accessibility, communication, and involvement in decision-making. The proposed solution addresses these challenges and fills a significant gap in the existing literature, which has largely overlooked religious institutions in discussions of digital transformation and smart community development. This contribution is especially pertinent given the increasing role of religious institutions in shaping social cohesion, providing a model for future smart community initiatives in similar contexts, and contributing to the ongoing evolution of how technology can shape community-based organizations. This development aligns closely with the objectives of Saudi Vision 2030, which emphasizes digital transformation, innovation, and the modernization of public services across all sectors, including religious and community-based institutions.

The findings revealed that mosque community members, managers, and administrators view IoT systems as beneficial for managing daily operations, improving transparency, and fostering a more connected and responsive environment. This result reflects a growing recognition within religious institutions, in Saudi Arabia, of the value that digital technologies can offer in enhancing organizational efficiency. It also indicates a shift in mindset, where faith-based communities are increasingly open to integrating modern technological tools particularly to support administrative functions. This underscores the potential for religious institutions to play an active role in the broader digital transformation of society, particularly in the development of smart, inclusive, and culturally grounded communities, thereby contributing meaningfully to the broader national transformation agenda.

5.2. Theoretical contributions

From a theoretical standpoint, the study expands the scope of digital transformation literature by incorporating religious and cultural institutions into the discourse. It also offers a novel theoretical contribution by integrating the TAM with institutional theory to assess IoT acceptance in a mosque context, a setting that has received limited attention in technology acceptance research. This integrated framework allows for a more comprehensive understanding of technology adoption that reflects both the rational decision-making of individuals and the embedded institutional dynamics within faith-based organizations.

The findings suggest that, beyond considerations of efficiency and usability, the adoption of smart technologies in religious settings is significantly shaped by perceived institutional and authoritative expectations, such as coercive pressure from religious leadership or mosque managers, alongside prevailing social norms within the worship community, and the role of religious leadership in legitimizing technology use. The findings also reveal distinct patterns in how age and gender influence the acceptance of IoT technologies within mosque settings, offering critical insights into user segmentation in culturally sensitive environments. Age emerged as a more consistent and robust predictor of technology acceptance across multiple constructs, including PU, ATU, BI, CP, NP, MP, and AU. Younger participants, particularly those aged 18–20, consistently reported higher acceptance levels, suggesting that digital nativity and greater exposure to smart technologies may facilitate more positive perceptions and engagement. This aligns with prior research indicating that younger individuals are typically more open to technological innovation, perceive greater benefits, and exhibit higher behavioral intent to use digital systems (Morris & Venkatesh, 2000).

The analysis showed that technical experience had limited to no significant effect on most core model constructs. Although participants with higher technical proficiency demonstrated slightly elevated scores in constructs like PEOU, these differences did not consistently translate into stronger intentions to adopt or use the system. This suggests that technical competence is not a prerequisite for acceptance in this

context, possibly due to the intuitive design of the system or the influential role of social and institutional factors that outweigh individual technical skill.

In contrast, gender was statistically significant in several constructs. Female participants demonstrated higher scores in PU, ATU, BI, and AU. Notably, females also reported higher levels of CP, indicating a stronger perception of external demands or obligations, such as expectations from religious authorities or community norms, encouraging their adoption of the system. Additionally, higher MP scores among female participants suggest a more pronounced internal drive or sense of personal responsibility to comply with these expectations. Together, these results imply that females' acceptance of IoT technologies in mosque settings may be shaped by a combination of external institutional pressures and internalized social roles. These dynamics highlight the importance of considering gender-specific pathways in technology adoption, particularly in socio-religious contexts where authority structures and communal expectations significantly influence behavior. These findings highlight the importance of designing differentiated engagement strategies that account for generational and gender-specific drivers of technology acceptance, particularly in conservative or faith-based environments.

5.3. Cost-benefit analysis and business model implications

Implementing IoT in mosques presents a compelling cost-benefit opportunity, particularly in terms of energy efficiency and operational savings. Research indicates that smart mosque solutions can reduce energy consumption by 40% and water wastage by 25%, resulting in substantial long-term financial savings. For instance, transforming 6,600 medium-to-large mosques in Saudi Arabia into smart buildings could yield savings of approximately 2.9 billion SAR over ten years (AEC, 2025). These cost reductions are primarily attributed to IoT-enabled automation systems for lighting, heating, ventilation, air conditioning, and water usage, combined with occupancy and environmental sensors that enhance resource optimization (AEC, 2025).

Although initial investments in IoT infrastructure, such as sensors, centralized control platforms, and network integrations, can be significant, they are typically offset by decreased utility bills and lower maintenance expenses. Among these components are smart locks and smart keys. On average, the installation of a smart lock system ranges from 400 to 700 SAR per unit, depending on the features and level of integration such as remote access and biometric control. Smart locks include a limited number of keys, which can provide credentials to a restricted number of authorized users, with replacement and management introducing additional operational costs. However, these systems can substantially reduce the need for manual supervision, lower the risk of unauthorized access, and streamline mosque entry control, particularly beneficial for larger mosques with multiple prayer areas or entrances. Over time, reduced administrative burden and improved security can contribute to indirect cost savings, such as fewer personnel required for access management or incident response.

The payback period for such investments is expected to shorten as IoT technologies become more widely adopted and scalable (AEC, 2025). To support such transformation, a sustainable business model might integrate public-private partnerships with community-led initiatives. Government funding would align with national sustainability goals, such as those outlined in Saudi Arabia's Vision 2030, which emphasizes energy efficiency and digital transformation (AEC, 2025). Corporate sponsorships could offer another avenue, wherein technology companies subsidize IoT deployments in exchange for branding opportunities or data-sharing agreements. In addition, mosques with existing charitable endowments could allocate a portion of their funds toward IoT upgrades, using savings to replenish the endowments over time (AEC, 2025). Platforms like Ehsan, which facilitate charitable giving and are endorsed by the Saudi government, could serve as critical

enablers in mobilizing microdonations for IoT-related mosque infrastructure (Ehsan Platform, 2025). Microdonor campaigns, supported by transparent IoT systems, such as smart charity boxes that offer real-time donation tracking, may also appeal to high level of technological proficiency donors by enhancing trust and accountability (AEC, 2025). Beyond cost efficiency, IoT adoption in mosques could also positively impact local economies. It can create employment opportunities in areas such as IoT installation, system maintenance, and data analytics (AEC, 2025). Furthermore, by decreasing energy and water demand, IoT integration could help alleviate the financial strain on municipal utility services.

5.4. Comparative analysis with existing applications

The prior work in Harsritanto et al. (2021), Setiawan et al. (2021), Yusarelan et al. (2020) established the potential of IoT in optimizing mosque energy efficiency and security. However, they neglected critical aspects such as community involvement, decision-making, and ease of use, limiting the impact of these solutions on broader mosque management. The study presented in this paper introduces a significant advancement through the Mehrab system, a novel integration of IoT (smart locks) and a dedicated social network platform tailored for mosques. This system not only automates access control securely, but also empowers community members through features like voting, announcements, real-time chat, and activity tracking. The system's significance lies in its inclusive design: it incorporates perspectives from Imams, Muezzins, and local communities using Agile development and mosque prototypes. With a SUS of 94.23 and 94.5% positive sentiment from users, Mehrab effectively addresses usability, engagement, and security concerns. It exemplifies the user-centered IoT approach advocated by Jahan et al. (2023), highlighting its relevance not only within religious contexts but also as a model for inclusive smart community applications. Therefore, Mehrab significantly expands the scope and societal role of mosques by fostering transparency, accessibility, and communal participation.

5.5. Practical implications

The Mehrab system has demonstrated potential impacts on activity management and religious education. To evaluate these effects, the system's social networking features were piloted in ten mosques. Participated community members and mosque managers were asked to communicate exclusively through the system, avoiding alternative channels, and subsequently provided feedback via a semi-structured questionnaire. We received two hundred and fifteen responses, comprising 126 male and 89 female participants. The findings revealed a slight increase in attendance at preaching lectures, Qur'an education sessions, and Qur'an recitation sessions. In addition, a majority of mosque managers (89%) recognized the utility of the system voting feature, originally designed to promote community participation in decision-making, as a valuable tool for evaluating mosque services. The system was adopted for the purpose of providing volunteer in managing, recommending, and organizing social events and educational services. Local community members have used Mehrab system to connect with various volunteer opportunities that match their skills and interests in such a way that increase transparency in mosque operations. This streamlined approach encouraged broader participation and fostered a stronger sense of communal engagement. Although Mehrab offers comparable features to other social applications, participants emphasized its distinct advantages: (i) no limit on the number of participants, (ii) protection of user privacy by eliminating the need to share phone numbers, and (iii) verified authenticity of mosque manager accounts. In total 93% of respondents agreed that Mehrab enhanced community morale and a sense of belonging, primarily through increased involvement in mosque activities and decision-making. Qualitative feedback from the questionnaire highlighted several key themes.

Participants noted that Mehrab enabled more inclusive and transparent dialogue and improvement opportunities within the mosque community. Notably, many female respondents reported improved access to mosque-related information, which in turn led to higher levels of engagement and satisfaction.

Based on the results of the regression analysis, several practical and theoretical implications can be drawn for the development of digital mosque systems. First, the findings underscore the critical role of institutional forces, particularly coercive and normative pressures, on BI to use such systems. This suggests that digitization efforts are more likely to succeed when backed by top-down endorsements from religious authorities such as Imams, Muezzin, and government religious bodies. For system designers and policy makers, this highlights the importance of formal support mechanisms, including policies, guidelines, or mandates, as effective drivers of adoption. Second, mimetic pressure, or the tendency to imitate high-status users, was statistically significant but relatively weaker. This suggests that while observing technology use in prominent mosques may encourage adoption, it is not a decisive factor. Still, highlighting success stories from leading mosques can serve as a motivational tool, especially for communities hesitant to adopt digital solutions. Third, the analysis confirms that PU strongly influences ATU, affirming a foundational tenet of the TAM. This underscores the need to design technologies that clearly deliver functional benefits, such as enhanced access control, communication, and event management. PEoU while also significant, had a more limited impact, indicating that usability should support, but not replace, clear functional benefits in the design strategy. Fourth, the strong predictive relationship between BI and AU reinforces the importance of fostering positive user attitudes and intentions early in deployment. Strategies such as user training, clear demonstrations of value, and iterative feedback loops can help build and sustain engagement over time.

Importantly, demographic variables such as age and gender showed statistically significant effects on technology acceptance. Younger users (particularly those aged 18–20) and female participants were more receptive to the system, suggesting that tailored outreach and support strategies should be designed with these demographics in mind. In contrast, technical background did not significantly influence adoption, indicating that the system's intuitive design can effectively bridge gaps in digital literacy and make the system accessible to users regardless of technical proficiency.

5.6. Policy implications

The effective implementation of the Mehrab system within religious settings necessitates strategic policy development to address the legal, ethical, and social challenges associated with digital transformation.

The deployment of smart locks and social networking features in religious context, as enabled by the Mehrab system, raises critical concerns regarding user privacy, data protection, and surveillance. Given the inherently sensitive nature of religious environments, the collection of access data, communication logs, or usage analytics must be subject to strict governance. The MIADG or non-profit organizations must ensure that any implementation of such technologies complies fully with Saudi Arabia's Personal Data Protection Law (PDPL) (Nusairat, 2024), which mandates explicit user consent, data minimization, purpose limitation, and secure data handling practices. Religious institutions, in this case MIADG, may require additional oversight or guidance to ensure alignment with these legal standards, particularly in cases when data is processed by third-party vendors or stored in cloud-based infrastructures.

Beyond privacy considerations, ensuring digital inclusion and accessibility is critical for delivering equitable benefits through smart mosque technologies. While younger, high level of technological proficiency individuals may readily adapt to platforms such as Mehrab, older congregants, low-income users, and those with limited digital literacy may face significant barriers. To address this, religious institutions and

mosque administrations should consider investing in digital literacy initiatives and providing multilingual support. Ensuring the platform adheres to universal design principles will help promote its use across a diverse user base.

Another policy consideration involves the need for technical standardization and interoperability. As multiple mosques adopt digital infrastructure, the absence of unified standards could lead to fragmented systems that are inefficient, insecure, or difficult to scale. The MIADG, as the representative of national religious authorities, should consider issuing technical guidelines and interoperability protocols to support consistent integration with broader smart city initiatives or government digital platforms. This approach would also facilitate centralized compliance monitoring and coordinated system updates.

6. Conclusion, limitations, and future work

This study explored the design, implementation, and evaluation of the Mehrab system, a smart mosque management platform integrating social networking features, smart locks, and delegated access control. The system was developed in response to the growing need for digitally enabled religious spaces that support operational efficiency, community engagement, and inclusive participation. In addition to empirical evaluation, this study theoretically examined technology acceptance by integrating the TAM with institutional theory, providing a more comprehensive understanding of user adoption within socially and religiously embedded contexts. While TAM offered insights into perceived usefulness and ease of use, institutional theory helped explain how organizational norms, cultural expectations, and regulatory pressures shape technology acceptance in religious settings. The application was evaluated using data collected from 400 users across three main user categories; mosque managers, local community members and administrators. We found that the system achieved promising results in terms of usability and objectives achievement. Moreover, the results show that Muslim community has a high acceptance rate to use IoT technology. Female participants were more likely to accept technology compared to male participants. Comparable results were obtained by analyzing short texts provided by participants using sentiment analysis. Therefore, the findings of this study may provide valuable insight into how Muslims engage with technology in their worship spaces.

While this study presents valuable insights into the feasibility and social impact of the Mehrab system, several limitations must be acknowledged. First, the research was conducted within a specific socio-religious context, mosques in Saudi Arabia, where the alignment between religious governance and national digital transformation policies is relatively strong. As such, the system's applicability and acceptance may differ in other cultural or institutional settings, particularly where religious institutions are decentralized or where public trust in digital governance is weaker. Second, the pilot study was limited in duration and scale, involving only ten mosques and a limited user base, which restricts the generalizability of the results and precludes the observation of long-term behavioral patterns. From a theoretical standpoint, although the study integrated the TAM with institutional theory, this dual lens approach may not fully capture the complex socio-technical dynamics of religious environments. Other frameworks could offer broader analytical depth, particularly in exploring cultural norms, power relations, and infrastructural constraints.

Future research and development could extend the Mehrab system to accommodate the needs of diverse religious communities, thereby fostering opportunities for interfaith dialogue and collaboration. The platform could be adapted for the management of multi-faith prayer spaces, promoting inclusivity and helping to bridge social and cultural gaps between communities. Enhancements to the Mehrab application may include the integration of multilingual support, additional functionalities, and expanded use of IoT sensors to improve user experience and operational efficiency. Furthermore, incorporating advanced technologies such as virtual reality and live-streaming capabilities could enable remote participation in lectures and mosque activities, thereby increasing accessibility for community members who are unable to attend in-person.

CRedit authorship contribution statement

Nawal Almutairi: Project administration, Formal analysis, Supervision, Investigation, Conceptualization, Writing – original draft, Methodology, Data curation. **Abdussalam Elhanashi:** Writing – review & editing.

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Data availability

The data that has been used is confidential.

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