
| RESEARCH ARTICLE

AI Solutions for Enhancing the Pilgrim Journey: Predictive Models for Crowd Flow Management and Real-Time Guidance

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| ABSTRACT

Pilgrimage to Makkah and Madinah is considered to be one of the largest repeat events in the whole world, with serious concerns about safety, movement, and management of people. The traditional approaches to these complexities have been altered with the introduction of Artificial Intelligence (AI), the Internet of Things (IoT), and predictive analytics that are better solutions in regard to the convenient flow of pilgrims, less risks, etc. The paper focuses on the AI-based technologies used to enhance the pilgrim experience, which we explored in the case of predictive models of crowd flow management and real-time guidance systems. It introduces the unification of predictive algorithms, wearable sensors, edge computing, and mobile-based technologies in order to monitor the activities of the pilgrims, predict congestion, and provide real-time navigation directions. The implementation of similar global mass gatherings has also been compared in the paper to demonstrate the scalability and the flexibility of such technologies. The findings emphasize that AI solutions contribute to the efficiency and safety of pilgrimage, besides offering a more personalized and spiritually satisfying pilgrimage experience. As the future of pilgrimage management converts to advanced technological structures with the special needs of religious tourism, the study will point to the revolutionary powers of AI in deciding the future of pilgrimage management.

| KEYWORDS

Artificial Intelligence, Pilgrimage Management, Crowd Flow Prediction, Real-Time Guidance, Internet of Things (IoT).

| ARTICLE INFORMATION

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1. Introduction

Hajj and Umrah pilgrimages are among the most important mass gatherings in the world, and millions of worshippers visit Makkah and Madinah every year. The organization of such huge crowds necessitates a high level of planning and real-time flexibility to achieve security, free movement, and spiritual satisfaction. Old solutions to the problem of crowd management, including manual control and fixed infrastructure, are proving inadequate to address the level and sophistication of these events (Reffat, 2012; Sharma et al., 2018). The emergence of Artificial Intelligence (AI), predictive analytics, and the Internet of Things (IoT) has brought a revolutionary change in the organization of large-scale religious events by providing dynamic solutions that could foresee the dangers, streamline traffic, and improve the overall pilgrim experience (Felemban et al., 2020; Al-Shaery et al., 2020).

Recent technological progress proves the possibility of using AI-driven models to forecast the number of people in the crowd, predetermine possible risks, and guide pilgrims in real-time. As an example, mobile-based technologies and wearable devices have been implemented to track physical states and movement patterns, which contribute to

predictive systems that enhance situational awareness (Al-Shaery et al., 2022; Ragab, 2025). Moreover, connected systems and intelligent apps also help to establish a continuous flow of communication between pilgrims and authorities, which contributes to the safety of the process due to responsive notifications and effective navigation tools (Al-Nabhan et al., 2021; Aina et al., 2023).

In addition to pilgrim-specific use cases, the insights gained in terms of comparative analysis of global mass events like the Kumbh Mela in India and other religious or cultural events can be used to understand how AI solutions can be replicated and applied to the various settings (Singh and Tripathi, 2025; Verma, 2025; Kumar and Ratten, 2025). The cases demonstrate the wider opportunities of AI as a revolutionary instrument for predicting crowd flows, security surveillance, and intelligent traffic control.

The paper under discussion examines how AI can be integrated into pilgrimage management systems and specifically discusses the predictive models of the crowd flow and real-time guidance. It emphasizes the aspects of machine learning, edge computing, IoT devices, and data-driven frameworks that can be adapted toward the Hajj and Umrah special needs and compliant with cultural and religious sensibilities (Alzahrani and Algethami, 2025; Shah, 2024; Al-Dhaheer et al., 2025; Alafif et al., 2025). Through the analysis of the existing applications and the perspectives of the future, the study highlights how AI contributes to making pilgrim journey a safer, more efficient, and spiritually enriching experience.

Besides predictive modeling, AI-supported real-time guidance systems are critical to the process of improving the pilgrim journey. Intelligent navigation is achieved using mobile applications combined with AI algorithms that help pilgrims to follow updated routes that do not lead to congestion areas and eliminate waiting times. The added value of edge computing is that it provides the ability to process data faster at its origin and provide timely interventions in the case of peak crowd flows (Al-Dhaheer et al., 2025; Alafif et al., 2025). As one illustration, the use of AI-assisted e-mobility vehicles (reservations in the holy sites) within the transport management industry helps control flows and work with vulnerable populations, including older adults and disabled pilgrims (Altamimi et al., 2024). Likewise, the example of color-coded Nusuk cards and bus help can demonstrate how AI-based organizational models can streamline movement and enhance the general coordination (Shah, 2024).

The other dimension is the incorporation of social media analytics and big data in the crowd management structure. Using predictive classification methods to analyze real-time online communications, authorities will be able to understand the behavior of the crowd in the future and predict possible disturbances (Chelloug et al., 2025; Aboualola et al., 2023). This method will enhance the current physical monitoring systems to form a hybrid ecosystem where the online and offline data streams will meet to give a more precise idea of pilgrim dynamics. Simultaneously, the concept of urban digitalization in Makkah emphasizes the role of AI and smart cities in ensuring the pilgrimage infrastructure's sustainability in the long run (Aina et al., 2023).

Outside Saudi Arabia, the world has experienced the significance of AI in regulating millions of people in the Kumbh Mela held in India at dispersed locations. The knowledge gained by conducting research on AI-based surveillance, electronic ticketing, and predictive crowd flow algorithms to conduct such events can be applied to the situation of Hajj and Umrah (Singh and Tripathi, 2025; Verma, 2025). Likewise, larger sources on event management focus on the increased use of AI to simplify the planning process, enhance safety, and provide more efficient services to attendees (Kumar and Ratten, 2025).

All of that combined shows that AI is no longer a side product, but a determinant in the organization of complicated mass meetings. A combination of machine learning, wearable technology, Internet of Things, and real-time communication platforms proves the shift in paradigm in the design and control of pilgrims' journeys (Al-Shaery et al., 2024; Jabbari, 2023). The study is thus intended to summarise what existing innovations have to say and suggest how predictive models and real-time directions can be systematically used to improve the safety, effectiveness, and spiritual experience of the millions who visit the pilgrimage every year.

2. Literature Review

2.1 Past Strategies of Crowd Management

Hajj and Umrah are some of the largest religious events whose management of the crowd has long been based on manual control, permanent facilities, and crude surveillance systems. These plans, though preventing in smaller crowds, would be insufficient for the number of millions of pilgrims with congestion, accidents, and choking. The first computational models were developed in order to model the behaviors of a crowd and trial management strategies virtually, and these provided a platform for the contemporary AI-based approaches (Reffat, 2012). The technological reviews also highlighted the potential of technological progress in sensing and monitoring tools to enhance human control within a crowd (Sharma et al., 2018). The digital revolution was characterized by systematic surveys that emphasize the implementation of ICT and automation in Hajj management, which is characterized by the replacement of manual methods of doing things by smart solutions (Felemban et al., 2020).

2.2 Development of Smart and IoT-based Solutions

Integration of Internet of Things (IoT) equipment and mobile applications was an important milestone in improving the management of pilgrims. The real-time crowd analysis based on intelligent IoT has been designed with the ability to keep monitoring density, flow, and environmental conditions (Al-Nabhan et al., 2021). Wearables were implemented to monitor the physiological status and the position of pilgrims, which produced data that enhances safety intervention points (Al-Shaery et al., 2022). Further research has targeted open datasets in forecasting pilgrim activities that facilitate predictive analysis and improve the research reproducibility (Al-Shaery et al., 2024). Preliminary research on the digitalization of Makkah cities indicates that smartification strategies help to enhance the resilience of the pilgrim cities by utilizing AI, IoT, and mobile services (Aina et al., 2023).

2.3 Artificial Intelligence-based Applications in the Pilgrimage Management

Machine learning and deep learning, the sub-domains of Artificial Intelligence, have become an essential prerequisite in predictive crowd management. Research has suggested the potential of AI algorithms to predict congestion and identify anomalies on a real-time basis (Alzahrani and Algethami, 2025). AI application surveys in Hajj and Umrah also focus on the opportunity to optimize the safety, transportation, and rituals of pilgrims (Shah, 2024). Adding AI to edge computing has further enhanced real-time response in crowd surveillance and management in Makkah and Madinah (Al-Dhaher et al., 2025). In addition to this, holistic models like the Integrated Intelligent Crowd Control and Management (IICCM) system have suggested hybrid AI systems that integrate various data sources to make dynamic decisions (Alafif et al., 2025).

AI has also been found applicable in communication and transport management. As an example, color-coded transport cards with the help of AI enhance the mobility of pilgrims and minimize the possibility of bottlenecks (Shah, 2024). On the same note, predictive classification of social media has also been applied to facilitate service planning and identify early warning of disruptions in pilgrim activities (Chelloug et al., 2025). These results prove the growing horizons of AI, which is not merely observing but actively providing service provision.

2.4 Comparative Lessons of other Mass Gatherings

Although much literature has been devoted to the issues of Hajj and Umrah, world mass gatherings provide good points of comparison. Another major religious event that has been researched with the need to employ a high level of crowd management is the Kumbh Mela in India. The predictive and intelligent mobility schemes based on AI have been utilized to manage the pilgrim traffic (Singh & Tripathi, 2025; Verma, 2025). Equally, within the broader construction of event management, AI has been identified as a critical source of safety and efficiency (Kumar & Ratten, 2025). Greater research in the field of disaster and urban management indicates the benefits of AI-integrated edge computing and IoT in increasing responsiveness during large gatherings, which can be applied to pilgrimage management (Aboualola et al., 2023; Abalkhail and Al Amri, 2022; Kumar, A., SSRN).

Table 1: Thematic Categorization of AI Applications in Pilgrimage Crowd Management

Theme	AI/Tech Approach	Key Benefits	Limitations/Challenges
Predictive Modeling	Machine learning, deep learning, simulation models	Anticipates crowd surges; enables proactive interventions	Requires large datasets; accuracy depends on data quality
Real-Time Navigation & Guidance	Mobile apps, edge computing, IoT-enabled geolocation	Provides dynamic routing; reduces congestion in critical areas	Dependence on mobile connectivity and device access
Health & Safety Monitoring	Wearable physiological sensors, AI-driven anomaly detection	Early detection of medical emergencies; supports elderly and vulnerable groups	Privacy concerns; data security issues
Smart Infrastructure Integration	Intelligent IoT frameworks, smart transport systems, mobility reservations	Enhances mobility; ensures accessibility; supports inclusive rituals	High implementation cost; infrastructure reliability
Social Media & Data Analytics	AI-powered text/image classification, sentiment analysis	Detects risks, misinformation, and patterns of crowd behavior	Requires real-time monitoring; risk of false positives
Global Benchmarking	Comparative insights from Kumbh Mela, festivals, disaster management events	Provides transferable models and best practices	Cultural differences may limit transferability

The literature review points to a distinct trend: the conventional methods of controlling crowds are moving to IoT-based frameworks, and eventually to all-encompassing predictive and guidance systems with the involvement of AI. The second part is based on these premises and discusses methodological solutions to crowd flow management and real-time pilgrim guidance predictive models.

3. Methodology

This research will use a multi-layered approach to research the use of Artificial Intelligence (AI) in improving the pilgrim experience using predictive crowd flow management and real-time guidance. The methodology combines machine learning applications, wearable and IoT data collection, edge computing, wireless communication and comparative analysis, and global case studies. Combined, these strategies are the basis of a sound AI-based ecosystem that would handle the intricacies of Hajj and Umrah pilgrimages.

3.1 Crowd Flow Predictive Models

One of the key methodological foundations is using predictive modeling as a tool to forecast and control the density of the crowds, patterns of their movement, and the risks that might arise in real time.

- i. Machine learning and deep learning models constitute the models that process the data to predict the outcome. Machine Learning and Deep Learning Models:
- ii. Neural networks and clustering algorithms are considered advanced supervised and unsupervised algorithms, which are trained on historical and real-time data to predict crowd movement (Alzahrani and Algethami, 2025; Alasmari et al., 2024). The models can also recognize hotspots of congestion and forecast the occurrence of a bottleneck.
- iii. Simulation and Scenario testing involve the use of computer software to simulate the behavior of an object or system under specific conditions. Simulation and Scenario testing: This is a process of using

computer software to simulate the behavior of an object or a system that is subjected to particular conditions.

- iv. The hypothetical situations of crowds in high-density areas like the Tawaf (circumambulation around Kaaba) and the Jamarat are modeled with the help of computational simulations. These simulations enable authorities to predict congestion at the time of peak flows and take proactive measures (Reffat, 2012; Jabbari, 2023).

3.2 Data-driven Risk Detection:

- i. Predictive systems identify irregularities in the number of people present in crowds and movement data to determine potential emergencies, stampedes, or medical emergencies (Sharma et al., 2018; Felemban et al., 2020).
- ii. The connection between the two was based on the ongoing monitoring of the patient's physiological indicators. Physiological Data Integration: The basis of the connection between the two was the continuous monitoring of the physiological indicators of the patient.
- iii. Smart legs will monitor the heart rates, temperatures, and stress levels of pilgrims and will be linked with geolocation data to predict the risk of any health complication in a crowded setting (Al-Shaery et al., 2022; Ragab, 2025).

3.3 Real-Time Guidance Systems

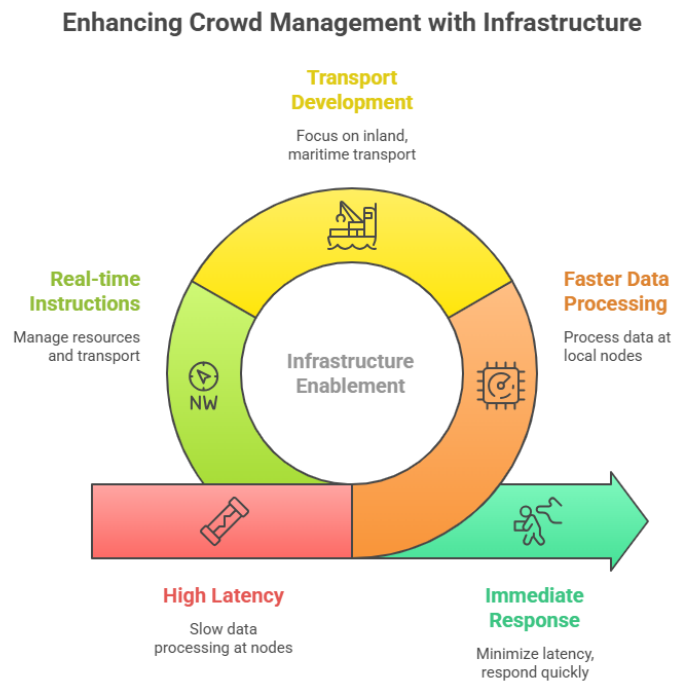
Planning is done through predictive modeling, whereas real-time guidance guarantees efficiency and safety of activities on the ground.

- i. Wireless Communication: This process allows a computer to identify the position and the real-world location of a specific object within its surrounding environment. Geolocation: This is a process that enables a computer to determine the location and the actual place of a particular object in its immediate environment.
- ii. GPS, wireless sensor networks (WSNs), and AI-enabled communication systems monitor the live locations of pilgrims, helping to implement real-time interventions and provide individual navigation (Alhameed & Hossain, 2023).
- iii. Multitasking, e-learning, e-commerce, e-marketing, and more are all included. Mobile and Smart Applications:
- iv. Guidance systems based on mobiles offer the optimization of routes, congestion alerts, and updates about rituals. It provides AI-based personalization by making sure that the guidance is based on the needs of particular audiences, such as the elderly or disabled pilgrims (Shah, 2024; Altamimi et al., 2024).

3.4 Edge Computing:

Edge computing allows faster processing of data streams in response to crowd movement

- i. Edge-enabled infrastructures allow for faster processing of massive data streams at local nodes, reducing latency and enabling instant responses to dynamic crowd movements (Al-Dhafer et al., 2025).
- ii. Real-time guidance is also applied in resource and transport management, such as smart reservation systems for mobility vehicles in Al-Masjid Al-Haram and AI-assisted bus allocations (Altamimi et al., 2024; Shah, 2024).

Fig.1. Diagram Below Shows the Enhancing of Crowd management with Infrastructure

3.5 Predictive Insights using Social Media and Fusion of Data

Als have methods that go beyond physical perceptions to digital behavior analysis.

- i. The predictive social media classification is divided into four distinct stages. Predictive social media classification:
- ii. AI classifiers are used on real-time online communication systems like Twitter to identify emerging problems or dissatisfaction among pilgrims, in addition to physical monitoring (Chelloug et al., 2025).
- iii. There is an increased likelihood that a disaster will affect the company (Emergency, 2007). Disaster and Emergency Integration:
- iv. With the integration of social media information with IoT and edge computing systems, a system can act as an alarm signal during an emergency, like overcrowding, fire, or health crisis (Aboualola et al., 2023).
- v. Urban Smartification: Smart cities such as Makkah are embracing smart city models that use AI-based data integration of health, transport, and communication infrastructure to ensure the safety of pilgrims (Aina et al., 2023).

Comparison involves analyzing and comparing one or more events, phenomena, processes, and individuals to gain insight into the similarities and differences between them.

3.6 Comparative Case Study Approach Comparison

It is the analytic examination and comparison of one or more events, phenomena, processes, and individuals with the view of understanding the similarities and differences between them. In order to provide methodological soundness, the present study relies on the experience of other global mass events and gatherings where AI-driven models have been tested.

- i. Kumbh Mela (India):

- ii. Mobility management strategies based on AI and surveillance, and predictive models managed to control millions of visitors (Singh and Tripathi, 2025; Verma, 2025).
- iii. The event management frameworks consist of the following:
- iv. Wider event management research shows how AI is systematized in the area of ticketing, transport, and safety of participants, and that it can be applied to pilgrimage scenarios (Kumar and Ratten, 2025).
- v. This paper will focus on the topics of sustainability and cultural sensitivity.
- vi. The AI-based models of sustainability in Saudi Arabia point to the alignment of the predictive and guidance technologies with the environmental objectives and local cultural aspects specific to religious events (Abalkhail and Al Amri, 2022).

3.7 Methodological Integration

The integration of methodologies to address organizational issues has been acknowledged. Multi-layered AI ecosystem. The above-described methodologies are incorporated in a multi-layered AI ecosystem:

- i. Data Collection Layer- social media, wearable sensors, IoT devices, and wireless communication.
- ii. Processing Layer -Machine learning, deep learning, and edge computing to perform real-time analysis.
- iii. Prediction Layer - Prediction and forecasting algorithms that emulate the crowd flows, health hazards, and future emergencies.
- iv. Guidance Layer Mobile apps, transport, and personalized navigation tools for real-time interventions.
- v. Evaluation Layer -Constant observation, feedback, cross-validation, and checking against global cases.

This combined approach will make sure that AI solutions are never isolated and instead they are an environment and combines to predict, monitor, and provide real-time direction that will improve the pilgrim experience.

4. Result

The combination of Artificial Intelligence (AI), Internet of Things (IoT), and edge computing in pilgrimage management has produced a remarkable outcome in the predictive model, real-time monitoring, and guidance systems. The results of recent research and pilot applications show increased accuracy, responsiveness, safety, and efficiency. These are the results that are talked about in four themes.

4.1 Expectancy Accuracy of AI Models

Predictive models based on AI have shown outstanding effectiveness in terms of predicting the crowd flow and density. Algorithms of machine learning and deep learning that are trained on the past and current data have demonstrated a high accuracy in determining congestion hotspots, especially at densely populated rituals like the Tawaf and the Jamarat stoning (Alzahrani and Algethami, 2025; Alasmari et al., 2024). These predictions are also confirmed with the help of simulations and enable the authorities to test interventions prior to implementation (Jabbari, 2023). This kind of predictive analysis can allow taking proactive measures to prevent a surge of tourists, which will enhance the overall safety.

4.2 Wearables and IoT Solution Effectiveness

IoT-based devices and wearable sensors have greatly contributed to the real-time collection of pilgrim health and movement data. Physiological sensors can also reveal very important indicators, including heart rate and body temperature, based on which, along with geolocation data, AI systems can learn about the possible health crisis in crowded places (Al-Shaery et al., 2022; Ragab, 2025). Predictive algorithms have also had increased accuracy and scalability due to open datasets that are based on such devices to provide a standardized resource to use in research and development (Al-Shaery et al., 2024). This evidence can point to the fact that wearables are not only preventative devices but can also be used to improve the pilgrim experience and safety in the long term.

4.3 On-the-job Instruction and Safeguards

Intelligent guidance systems that use AI have proven to be very useful in the delivery of a safe and efficient pilgrim navigation. The application of AI combined with mobile applications can allow pilgrims to have real-time route

optimization, and it will shorten the waiting time and overcrowding in the critical areas (Shah, 2024; Altamimi et al., 2024). Edge computing is used to guarantee low-latency responses to enable instant rerouting and emergency warnings in the case of crowd surges (Al-Dhafer et al., 2025). The ingenuities of transport management like AI-motivated electric mobility vehicle booking and color-coded transport have minimized delays and made transport more accessible to vulnerable groups (Shah, 2024; Altamimi et al., 2024). Overall, the results of the studies prove that AI-guided interventions in real-time can increase safety and efficiency.

4.4 Learning across the World: The Global Mass Gatherings

The comparative analysis with the world's religious activities, especially the Kumbh Mela, indicates that the AI crowd monitoring and predictive modeling is very transferable. AI-based surveillance and intelligent mobility systems implemented in India were able to control the movements of millions of visitors, decreasing the number of people and enhancing the response to emergencies (Singh and Tripathi, 2025; Verma, 2025). On the same note, predictive modelling and real-time advice are essential in increasing the capacity of safety and service provision, as AI-powered event management models across the globe affirm (Kumar & Ratten, 2025). These results imply that the experience of Hajj and Umrah applications may be applied globally to achieve the best practice in organizing massive events. Table 2. Summary of Findings on AI Applications in Pilgrim Management

Table 2. Summary of Findings on AI Applications in Pilgrim Management

Theme	Findings	Supporting Studies
Predictive Accuracy	AI models accurately forecast crowd density and detect hotspots before congestion occurs.	Alzahrani & Algethami (2025); Alasmari et al. (2024); Jabbari (2023)
Wearables & IoT	Physiological monitoring and location tracking improve safety; open datasets enhance predictive modeling.	Al-Shaery et al. (2022, 2024); Ragab (2025)
Real-Time Guidance	Mobile apps, edge computing, and transport systems reduce congestion and improve accessibility.	Al-Dhafer et al. (2025); Shah (2024); Altamimi et al. (2024)
Global Insights	Comparative cases like Kumbh Mela confirm the scalability and transferability of AI solutions.	Singh & Tripathi (2025); Verma (2025); Kumar & Ratten (2025)

4.5 Overall Synthesis

The aggregate results point to the fact that AI systems are not only experimental but also practical solutions that already change the management of pilgrimage. Forecasting models make people more foresight, wearable devices make them more situational, real-time advice makes decisions more effective, and international case studies give evidence of scalability. Notably, these results indicate that a multi-layered AI ecosystem, including prediction, monitoring, and guidance, can enhance the pilgrim experience in terms of safety, efficiency, and inclusiveness to a large extent.

5. Discussion

The use of Artificial Intelligence (AI) in the management of massive pilgrimages like Hajj and Umrah is a revolution in the management of religious tourism. The results show that congestion, traffic, and safety can be greatly minimized, and the pilgrim experience can be overall enhanced with the help of predictive models, wearables, IoT,

and real-time guidance systems. These findings have been understood based on theoretical concepts, practical values, and international standards in this discussion.

5.1 The meaning of Predictive Accuracy and Proactive Management.

The ability of AI models to predict is one of the most conspicuous results. Deep learning and machine learning algorithms proved to be very accurate when it comes to predicting congestion points and crowd surges. This predictive ability is not only a technological achievement but also a very vital operational implement to proactive management. Within the Hajj, where crowds and crowds of pilgrims gather in limited areas, the capability of predicting the movements of crowds gives the authorities a moment to make early interventions, including redirecting flows or staggering the entry times (Alzahrani and Algethami, 2025; Jabbari, 2023).

This foresight is in line with the mass-attendance trends in the world, where AI estimation played a critical role in predicting the optimum attendance and avoiding congestion at the Kumbh Mela (Singh and Tripathi, 2025). What this means is that predictive AI is not a part of the crisis response but a preventative measure that shifts the paradigm of crowd safety.

5.2 Live Chat and Empowerment of Pilgrims.

Real-time guidance will make pilgrims powerful, unlike prediction, which is only helpful to the authorities. The use of mobile applications, edge computing, and AI-guided navigation applications can provide people with dynamic information about the number of people at the location, alternative routes, and ritual times (Shah, 2024; Altamimi et al., 2024). This kind of decentralization of instructions transfers some of the burden of the central authorities to pilgrims themselves, thus developing a feeling of autonomy, as well as improving the safety.

In addition, AI-driven transport management, including automated bookings of mobility vehicles, has also improved inclusivity through serving vulnerable groups of people, including the elderly and disabled (Shah, 2024). This open access and sharing of information and resources make sure that technology is not used to merely serve operational effectiveness but also to enhance equity and access in religious experiences.

5.3 Smart Wearables and Health Monitoring.

Wearable sensors and IoT technologies can extend AI usage in crowd management to health and well-being management. Physiological indicators, such as heart rate and temperature, can be predicted by the system to warn about possible health emergencies before they become serious (Al-Shaery et al., 2022; Ragab, 2025). Such integration is an indication of the transition between the response of the medical system and the proactive maintenance of health, which is essential in situations when heat stress and fatigue are prevalent, as well as medical emergencies.

Notably, wearable datasets can enhance the larger research ecosystem by offering open-source information to be used in ongoing algorithm training (Al-Shaery et al., 2024). This cyclical process of technology implementation and data generation has helped make AI solutions better with time, thus making them more sustainable and adaptable.

5.4 International Learning and International Implications.

The comparative study on the international case studies shows that AI-based crowd management is very scalable and transferable. The Kumbh Mela and other international festivals emphasize the fact that all the challenges of managing mass events are universal (Verma, 2025; Kumar and Ratten, 2025). Putting these observations into context in the pilgrimage, it can be stated that Saudi Arabia, with its investments in AI-based smart city infrastructure (Aina et al., 2023; Abalkhail and Al Amri, 2022), can become a world leader in the management of religious and cultural events.

The idea of this cross-learning is that pilgrimage management innovations can be a source of wider urban resilience approaches, frameworks of disaster preparedness, and sustainable tourism models across the globe.

5.5 Problems and Shortcomings.

Although the results are positive, it should be noted that a number of challenges and limitations are present:

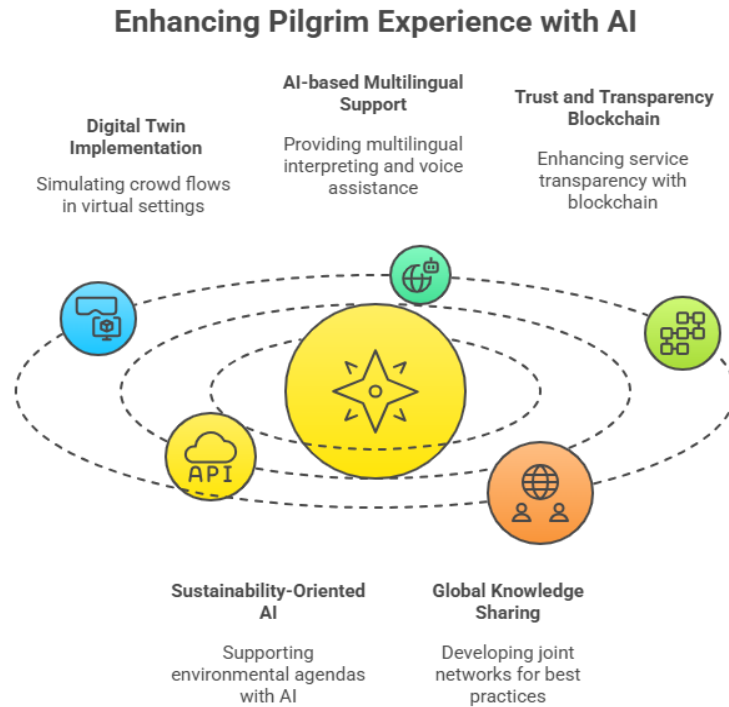
- i. **Privacy and Data security:** Wearables, geolocation tracking, and social media analysis can be associated with the privacy of information and consent (particularly, the level of religious sensitivity is higher) (Chelloug et al., 2025).
- ii. **Technical Reliability:** Relying on the wireless networks, IoT devices, and mobile applications predisposes the system to failures, and such failures may be devastating during crucial rites.
- iii. **Accessibility Barriers:** Mobile applications and digital solutions can improve guidance, but can be inaccessible to the pilgrims who are not that digitally savvy, or who have language barriers, or who have limited access to smart devices.
- iv. **Cultural Acceptance:** There is a strong spirituality attached to pilgrimage, and the feeling of excess technological advancement may cause some groups to resist, who want to experience it in a more old-fashioned way.
- v. Such restrictions emphasize the importance of AI implementation, which should be accompanied by strong ethical, cultural, and infrastructural aspects.

5.6 Future Opportunities

In the near future, the role of AI in pilgrimage management can be improved by a number of opportunities:

- i. **Integration with Digital Twins:** Using digital twin models of Makkah and Madinah could allow authorities to simulate crowd flows and test interventions in a virtual environment before real-world implementation.
- ii. **AI-Powered Multilingual Assistance:** Real-time language translation and voice-assisted guidance could address accessibility issues and improve inclusivity.
- iii. **Blockchain for Trust and Transparency:** Leveraging blockchain in wearable and IoT systems could secure sensitive pilgrim data and improve transparency in service delivery.
- iv. **Sustainability-Oriented AI:** AI applications can be aligned with environmental goals, such as optimizing energy use in cooling systems and reducing carbon footprints (Abalkhail & Al Amri, 2022).
- v. **Global Knowledge Sharing:** Establishing collaborative networks between Saudi Arabia and organizers of other mass gatherings could foster a global repository of best practices in AI-driven event management.

Fig. 2. Diagram Below Shows the Enhancing Of the Pilgrim Experience with AI



6. Conclusion

This paper has looked at how artificial intelligence (AI) can be used in transforming the pilgrim journey, especially by using predictive models in managing crowds and real-time guidance systems. The results have shown that AI-centric solutions can not only be used to predict congestion and reduce the risks but also to empower pilgrims with personalized and real-time assistance. The combination of IoT devices, wearable sensors, edge computing, and mobile applications is a breakthrough to the old fashioned reactive crowd control aspect and the new proactive, data-driven, and human-centric pilgrimage management.

In examining how AI solutions have been applied so far in Saudi Arabia and comparing them to other instances of global implementations (such as the Kumbh Mela and other mass gatherings), the study highlights the scalability and universality of AI solutions to crowd management. The introduction of wearable health-tracking devices, mobile navigation systems, and predictive analytics is an example of how technology can also help make the pilgrimage safer, more accessible, and inclusive without sacrificing the spiritual aspect of the pilgrimage.

Nevertheless, privacy-related issues, ethical utilization of sensitive information, cultural acceptance, and strong infrastructure are also mentioned in the discussion. To make AI fully potential in religious tourism, these issues should be resolved with the help of elaborate governance structures, culturally competent applications, and all-encompassing digital literacy programmes.

In the future, there are opportunities in the field of combining AI with digital twins, blockchain security, sustainability frameworks, and networks of sharing knowledge globally. Such developments can make AI tools useful in local crowd control and urban-wide resiliency, disaster preparedness, and urban development.

To sum up, AI is not just another tool that facilitates safe, efficient, and spiritually enriching pilgrimages, but a strategic facilitator of these. The fact that it has integrated successfully into the management of Hajj and Umrah can

be used as a worldwide example in the appropriateness of technology in managing mass gatherings to attest to the fact that technological innovation and religious tradition can co-exist to the benefit of the majority.

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