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Umroo: A Seamless Digital Smart Umrah Tracker

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ABSTRACT

This study introduces Umroo, a mobile application developed using the Agile development methodology and constructed using the Flutter platform. The Umroo project is designed to address the logistical issues involved in coordinating large groups of Umrah and Hajj pilgrims, including navigation and emergency response services-related issues. Using the Agile Software Development process model, the system incorporates features such as real-time geolocation tracking, emergency notification systems, and health alert systems. A previous survey indicated a high demand for real-time location tracking and emergency response features, which was used to inform the design of the Umroo system to be user-friendly and intuitive. To facilitate digital transformation and enhance the effectiveness of pilgrimage management, the friendly mobile app supported by Google Cloud services and PostgreSQL was conceptualized and developer to supplement existing infrastructure despite limitations brought about by sparseness of networks. The Umroo project achieved 96.8% success rate during user acceptance testing. The Umroo app aims to improve the security and well-being of pilgrims, minimize miscommunication between stakeholders, including mutawwifs and travel firms, and improve general pilgrimage management.

1. Introduction

The Umroo project aims to enhance the spiritual and logistical experience of Umrah and Hajj pilgrims by leveraging modern technology. Utilizing smartphone GPS, the system provides real-time location tracking, emergency notifications, and seamless coordination among stakeholders, including pilgrims, mutawwifs, and travel agencies. Designed with scalability and efficiency, Umroo combines advanced tools with traditional practices to create a secure, organized, and spiritually enriching journey. By addressing critical challenges such as pilgrims getting lost and inadequate communication structures, the project aspires to revolutionize pilgrimage management, making it safer and more convenient for all involved.

According to [1], getting lost or loosing personal belongings in a crowded event is a common problem especially in a high congested crowd. A devastating stampede occurred during the 2015 Hajj

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pilgrimage, resulting in the loss of at least 2,431 lives, with an additional 427 individuals reported missing, representing a profound tragedy in the annals of Hajj history [2].

1.1 Background of the Problem

Umrah and Hajj are among the largest annual religious Muslim congregations, involving millions of pilgrims. Many faced logistical issues, including stampede mainly because of fall down of attendance, temperature and humidity [3], getting lost [4-6], inadequate emergency communication [7], crowd density and mobility restrictions [8], lack of itinerary awareness [9], and even can lead to death cases [4]. Both pilgrims and organizers face additional challenges as a result of these issues, emphasizing the necessity for a comprehensive solution.

1.2 Project Objectives

The project aims to enhance the pilgrimage experience by introducing a GPS-based system for real-time location tracking and emergency communication. It seeks to enable seamless coordination between pilgrims, person-in-charge to handle the pilgrims who are appointed by the respective travel agencies (mutawwifs), and agencies while ensuring safety and convenience. Ultimately, Umroo aspires to create a spiritually enriching, organized journey through adoption of innovative technology.

1.3 Project Scope

The Umroo system focuses on applying digital transformation to enhance and support the Umrah and Hajj experience by integrating advanced technology. The stakeholders for the project are pilgrims, mutawwifs, agency administrators, and system administrators. The project scope includes (1) the design and development of a mobile application; (2) the design and development of a web-based system to address the agency and system administrator's roles to effectively manage pilgrim and mutawwif activities. Nonetheless, the focus of this article is to cover the first scope only, which is specifically for the Umroo mobile app.

1.4 Literature Review

A literature review is essential to understand the current state-of-the-art of the research area, in which it synthesizes prior work, identifying key findings, methodologies, and gaps. A literature study identified and analyzed existing solutions based on crowd management, health support, ethical and social implications, data analytics and pilgrim experience enhancement [7]. Another study in [10] performed a systematic literature review on Hajj and Umrah apps and finally scoped down to ten mobile applications that were selected based on specific criteria. These apps were then evaluated using Mobile App Rating Scale (MARS) method to assess their quality and effectiveness in providing Hajj and Umrah services. In addition, a study [2] defines a taxonomy that classifies the current solution to crowd management (particularly during Hajj) into (1) Wireless Systems, (2) Computer Vision, (3) Spatial Computing, (4) Data Science, (5) Mobile Application, (6) Immersive Technologies, and (6) Crowd and Traffic Modelling and Simulation.

Numerous mobile applications have been developed to address various challenges faced during Hajj and Umrah. As this work falls into the mobile application category, in this literature review, a brief introduction to each of the existing apps are provided. Following that the comparison of these

apps are listed in Table 1 based on some of the provided features, which include real-time tracking, communication, resources, user interface, connectivity.

Nusuk [11] is a digital platform that aims at providing the umrah and Hajj pilgrimage experience in a way that is comprehensive and user-friendly, and supporting the pilgrims on their spiritual trip. The app allows services such as bookings, timetabling Umrah and Hajj rituals as well as travel aids. Through immediate updates and alerts, Nusuk helps pilgrims to remain well-informed about the on-time prayer times, crowd watching, and additional other essential facts. Nusuk includes not only logistical support but educational component as well that guides the users in the details of the ritual. The app provides comprehensive map and guides, thereby making it easier for the newcomers to make the rituals correctly. Nusuk is designed with simple user interface and provide assistance mechanism for millions of pilgrims who wish to follow the Umrah and Hajj rituals.

Smart Pilgrim [12] is a mobile application that guides pilgrims through their Hajj and Umrah journeys, offering useful data and services to improve religious experience quality. The app is equipped with options like live tracking of rituals, full maps of sacred places, and timetables to help travelers efficiently organize their time. Furthermore, it includes the emergency contact details and access to the health services guaranteeing that the users can quickly get help if needed.

Nonetheless, Smart Pilgrim is not only providing logistical support, but is also an information provider, guiding users through the journey using detailed explanations and instructions. The app's simple interface and the support of several languages make it possible for a large number of pilgrims with different backgrounds to use it. Through incorporation of the elements mentioned above, Smart Pilgrim tries to design the pilgrimage with safety, order, and spiritual depth. It’s complete approach that made it the best guide for many Pilgrims.

The Pilgrim Companion App [13] is a specialized app that was developed to accommodate both Hajj and Umrah pilgrims while they make their journey. The app features include real time locations tracking, detailed maps, and guide for performing rituals. It further features prayer time reminders, health services, and emergency contacts which allow pilgrims to have all the necessary information and help whenever they need it. The App Pilgrim Companion, through its provision of these resources, aims to improve the pilgrimage by means of an organized and fulfilling spiritual journey for users.

The Mutawef app [14] is a mobile app that supports pilgrims when performing their Hajj and Umrah rites. The app provides a variety of tools such as a guided ritual for each one, current prayer times, and maps of the Holy Sites in Makkah and Madinah. Additionally, it has personalized itineraries that enable users to plan their pilgrimage based on their timetable and tastes. This way they can focus on their spiritual journey without concern about any logistical details. Furthermore, to logistics services, Mutawef app provides the educational materials to assist pilgrims to understand the religious relevance and correct way of performing each ritual. The app features audio and video tutorials together with text explanations in different languages, thus reaching an international audience. It also comes with a community support module that facilitates interaction between other pilgrims, allowing them to exchange their experiences and offer advice.

Another existing work is Mobile Umrah and Hajj application [15]. In this work, the main features of the app are global positioning system (GPS) tracking system and a pedometer that can assist the pilgrims to track the number of completed rounds when the Tawaf is completed. In addition, additional guide for pilgrims are also provided. Table 1 provides comparison of existing similar apps in addressing the challenges.

Table 1
Comparison of existing similar apps

Feature	Nusuk App[11]	Smart Pilgrim App[12]	Pilgrim Companion App[13]	Mutawef App[14]	Mobile Umrah and Hajj application [15]
Real-time Tracking	Yes, ensures pilgrims' safety and location updates	Yes, helps monitor pilgrims' movements and provides immediate assistance	Yes, provides instant location updates to organizers	Yes, uses GPS to help pilgrims find their accommodations	Yes, uses GPS
Communication with Service Providers	Yes, facilitates direct communication	Yes, allows reporting of violations and immediate assistance	No	No	No
Guidance on Rituals	No	No	Yes, offers step by-step training on performing Hajj and Umrah rituals	Yes, provides audio guides in multiple languages	Yes
Internet Connectivity	Yes, requires stable internet connection	Yes, requires internet for real-time tracking and communication	Yes, requires internet for real-time updates	Yes, GPS and guide features depend on internet connection	Yes, GPS and guide features depend on internet connection
Multilingual Support	No	No	Yes, supports multiple languages	Yes, offers guides in multiple languages	Not stated
User Interface	Integrated with Saudi systems for seamless documentation	User-friendly interface for communication and support	Immersive 3D virtual guide	User-friendly GPS navigation and smart guide	Simple
Facility Information	No	No	Yes, detailed information about facilities within the Haram	Yes, provide guide to services within the Haram	No

In brief, the comparative analysis (Table 1) assesses these apps based on features such as real-time tracking, communication with service providers, multilingual support, and user interface. The findings indicate that while existing solutions offer valuable services, gaps remain in areas such as integrated communication, facility information, and accessibility.

2. Methodology

The software development process for this project follows the Agile methodology as shown in Figure 1. Agile software engineering focuses on delivering functionality quickly, responding to changing product specifications, and minimizing development overheads [16]. Agile emphasizes flexibility, continuous feedback, and incremental development to ensure that evolving requirements

are effectively managed [17]. Unlike traditional waterfall models, which follow a linear development cycle, Agile enables teams to deliver functional software in short iterations, known as sprints [18].

This methodology is particularly suitable for this project due to its ability to accommodate changing user needs, promote collaboration among stakeholders, and ensure continuous improvement [17]. Through iterative development, the project team can refine requirements, implement enhancements, and address issues promptly. Additionally, Agile fosters close communication between developers, users, and other stakeholders, ensuring that the final software solution aligns closely with expectations.

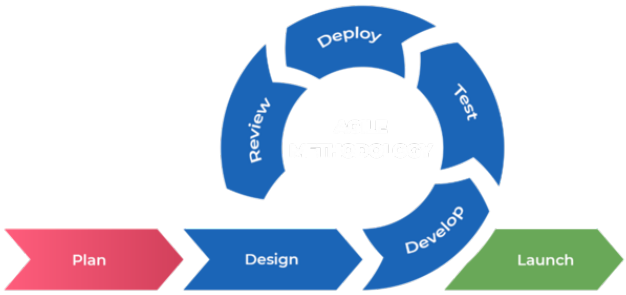

Fig. 1. Agile development process model [19]

The concept phase established a clear vision for the project by addressing challenges faced by Hajj and Umrah pilgrims, such as getting lost and delays in emergency responses. Key objectives, including safety, real-time tracking, and seamless communication, were defined, along with stakeholder identification. This phase resulted in a high-level roadmap and an initial product backlog. During the inception phase, the Agile Scrum methodology [19] was finalized, the development team was assembled, and the technology stack including Flutter, Svelte, PostgreSQL, and Google Cloud. A detailed product backlog was created, featuring core functionalities like GPS tracking, SOS, and itinerary management.

The iterations delivered incremental progress over eight sprints. Early sprints focused on backend development, database schemas, and foundational features like GPS tracking and emergency alerts. Subsequent sprints introduced communication tools, refined admin workflows, and enhanced system scalability for high user loads. User Acceptance Testing (UAT) with Umrah operators, including UHB Travel, validated real-world usability, guiding iterative improvements and preparing the application for deployment with optimized workflows and enhanced reliability.

The transition phase marked the deployment of Umroo on Google Cloud, ensuring high availability and scalability during real-world usage. Continuous performance monitoring and user feedback supported enhancements, such as offline itinerary access. In the Maintenance Phase, ongoing support addresses minor bugs, plans additional features, and ensures alignment with user needs. The project employs tools like Flutter, Google Cloud, PostgreSQL, TypeScript, and Hono, ensuring a robust, scalable system that adheres to Agile principles and evolves with user requirements.

2.1 Planning stage

The development of Umroo leverages the Agile methodology, ensuring flexibility, collaboration, and iterative progress. This approach allows for continuous improvement by incorporating regular feedback from stakeholders and end users. Jira [20] was employed as the primary project management tool to streamline planning and tracking, ensuring alignment with Agile principles. In this stage, requirements engineering activities were conducted. For this project, interviews, survey,

prototyping, and observation of similar solutions were among the elicitation techniques adopted to understand the needs of the stakeholders.

2.1.1 Interview

In requirements engineering (RE) phase, a few interview sessions were conducted to understand the needs from mutawwifs, pilgrims, and also administrators' perspectives. These stakeholder interviews serve as a vital tool to ensure that the application addresses the real-world needs of its users effectively. These interviews revealed critical functional and non-functional requirements to be included in the subsequent application's design and development. Each of the stakeholder's views exposed diverse yet interrelated requirements where pilgrims prioritized usability and accessibility, mutawwifs expected efficient communication mechanism, and agencies emphasized operational management. Incorporating these insights ensures that the application enhances the pilgrimage experience through digital innovation while maintaining religious accuracy and logistical efficiency.

2.1.2 Survey

A survey was conducted to gather requirements for the system, which involved 30 respondents. The survey comprises four sections: Section A – Demographics, Section B - Wellbeing and Safety Concerns, and Section C - Privacy and Security. It is worth to note that only simplified information will be extracted from the survey outcome and presented in this paper. Respondents were questioned regarding their primary concerns during Umrah/Hajj as illustrated in Figure 2. "Medical emergencies" are the main concern, followed by "feeling lost or disoriented in crowded areas". Both "dehydration or heatstroke" and "difficulty navigating unfamiliar surroundings" were highly significant. Additionally, the majority of responders cited "getting separated from family or group members" also as among the top concern.

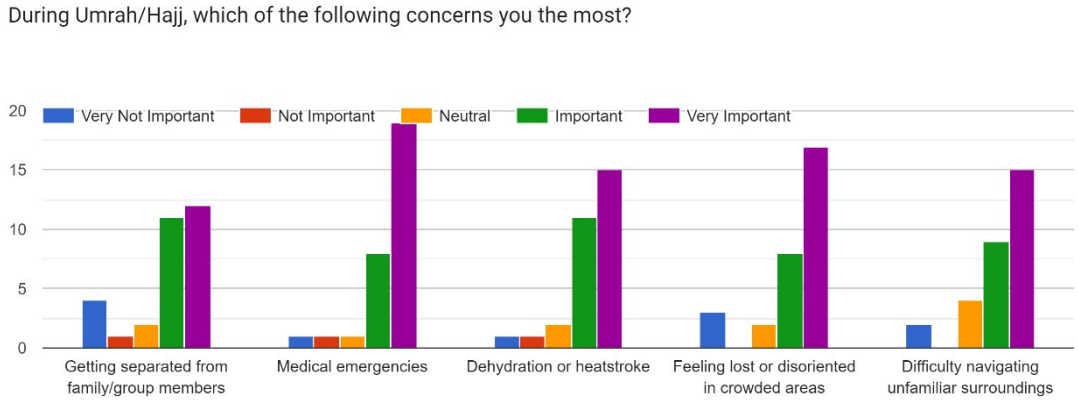

Fig.2. Concerns during Umrah/Hajj

Based on Figure 3, respondents highlighted that the most beneficial features related to wellbeing and safety during Umrah/Hajj would be "real-time location tracking for family/group members". This was followed by "alerts for potential health risks", "an emergency notification system with location tracking for authorities", and both "access to medical resources and nearby medical facilities" and "connection to a helpdesk for assistance with navigation or other needs".

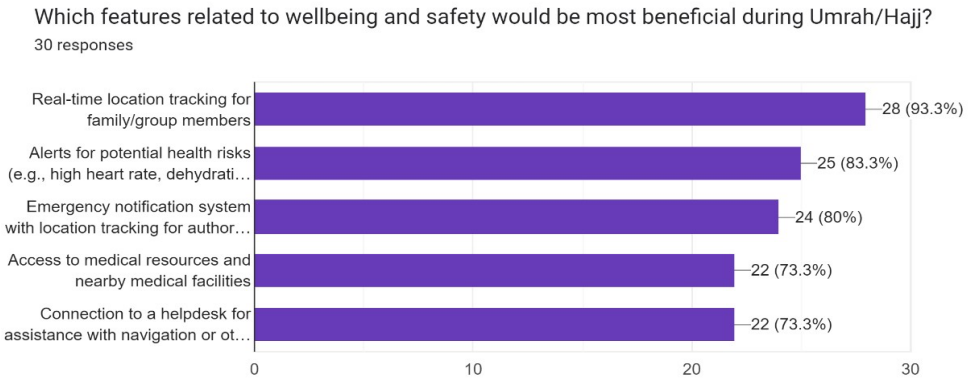

Fig. 3. Wellbeing and safety feature

Based on the Figure 4, when asked if they would be interested in receiving personalized recommendations based on their location and activity levels, majority of the respondents agreed, while only 3.3% disagreed.

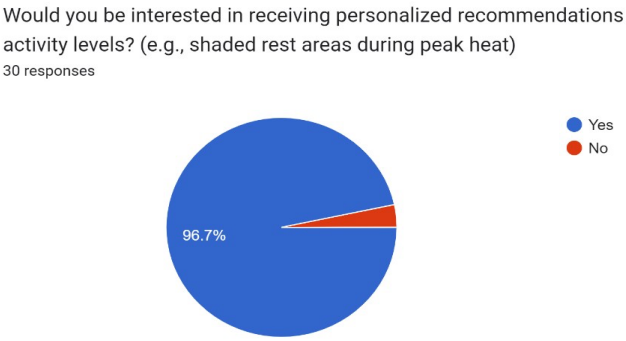

Fig. 4. Personalized recommendations

Respondents were asked what steps would increase their level of confidence with a location tracking device while on pilgrimage (see Figure 5). Among the top three answers for this questions were "A clear and transparent data privacy policy," "the option to opt-out of location tracking at specific times", and "secure data encryption and storage practices", arranged from highest to lowest.

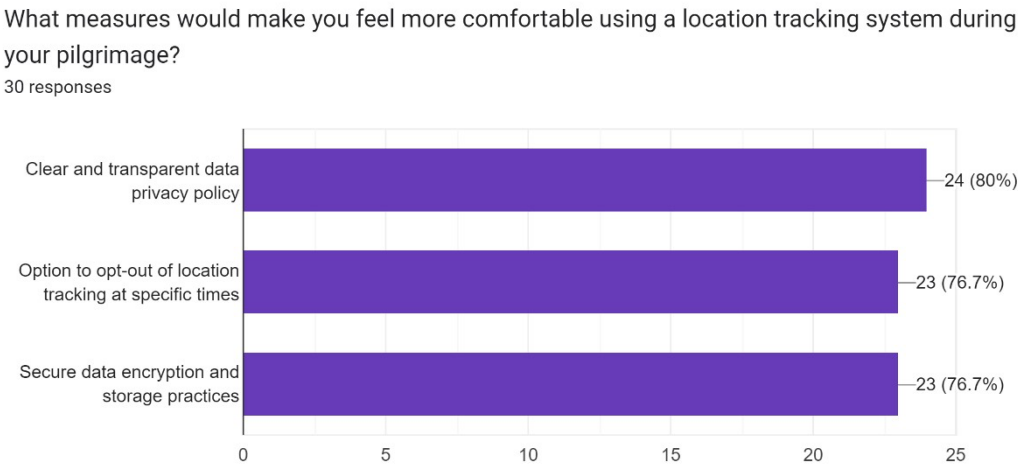

Fig. 5. Security concerns

All the collected feedback from the survey was analyzed and taken into consideration for the subsequent phases.

2.1.3 Prototyping

Prototyping allows stakeholders to execute system operations and validate requirements in a practical context, which helps in identifying errors early in the software development process [21]. Another study highlights that while prototyping is often associated with iterative refinement in back-end design, its role in the early stages is crucial for aligning design outcomes with real stakeholder needs and priorities [22]. By developing interactive prototypes, developers can (1) enhance stakeholder engagement by providing stakeholders with a tangible model that helps clarify expectations and refine feature requirements; (2) identify usability issues by getting feedback from real users before full-scale development; (3) facilitate iterative refinement by having incremental improvements based on stakeholder feedback ensure alignment with user expectations; (4) bridge communication gaps by having visual representation of features makes it easier for non-technical stakeholders to understand and contribute effectively; and (5) validate functional requirements by demonstrating core functionalities through prototypes confirms their relevance and effectiveness. In this project, the prototype was designed and developed using Figma tool.

2.1.4 Observation of similar solutions

Observing existing mobile applications for Umrah and Hajj rituals provides valuable insights for requirements elicitation. The detailed of the outcome will be presented in literature review section. By observing these solutions, (1) feature gaps can be identified; (2) user experience challenges can be analyzed; (3) best practices of the features implemented can be considered; (4) technical limitations could be detected; and (5) security and privacy concerns can be understood. These observations help to refine the application's design by adopting effective elements, mitigating common issues, and introducing innovative solutions to enhance the user experience.

2.2 System Design

Use case diagrams facilitate in gathering and clarifying requirements by visually representing user interactions with the system and also serve as a communication tool among stakeholders [23]. The Umroo use case diagram includes primary actors that are pilgrims, mutawwifs, agency administrators, and system administrators. The Umroo use case diagram as shown in Figure 6 illustrates main scenarios such as the pilgrims can easily locate their mutawwifs if they are apart and can even communicate directly with the mutawwifs if needed. The mutawwifs are able to track everyone's location in real-time, get emergency contact information, and even monitor if pilgrims' devices are working properly to avoid further issues. Agency admins monitor and manages the centralized operations. They are also able to post feeds about any announcement that can be seen like social media. Mutawwifas can get an insight into all aspects of their operations and track pilgrims in real time. System admins can easily scale the platform by adding more users and devices as needed. They can easily monitor all connected devices and users for centralized control and overall system maintenance.

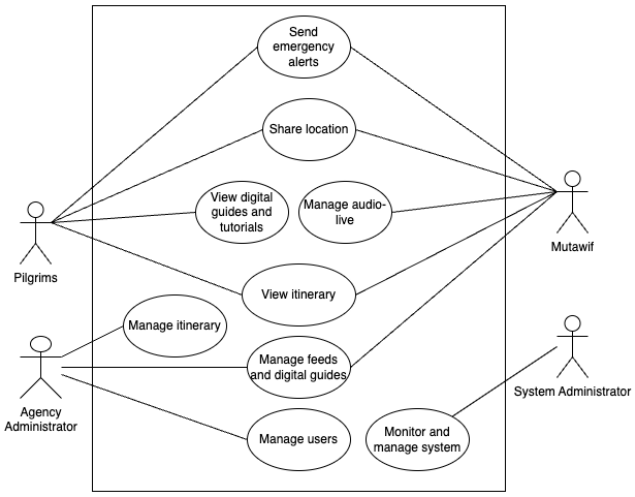

Fig. 6. Use case diagram for Umroo

2.2.1 Architecture Diagram

The architecture diagram for the Umroo project (see Figure 7) illustrates a comprehensive system integrating backend, frontend, third party services, and deployment components. The backend utilizes PostgreSQL (with and without Supabase) for database management, alongside Hono.js with TypeScript for handling the server-side logic. The backend supports real-time functionalities through services like Agora for communication, Firebase for notifications and messaging, and Cloudflare R2 for cloud storage.

Frontend technologies include Wordpress, SvelteKit, and Flutter, ensuring a seamless user interface across devices. The system integrates third-party services such as sms360 for communication, weather API for environmental updates, Google Maps for navigation, and JAKIM for Islamic calendar features.

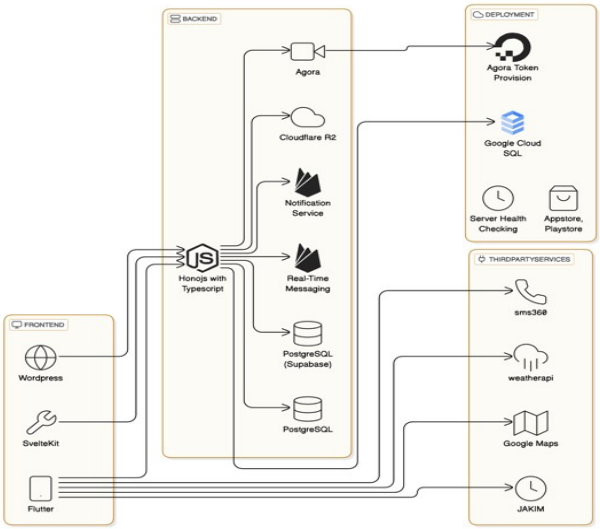

Fig. 7. Umroo Architectural Diagram

Deployment includes tools like Google Cloud SQL and Agora token provisioning, with health checks for maintaining uptime. This architecture emphasizes real-time tracking, scalability, and cross-platform compatibility, tailored to the needs of Hajj and Umrah pilgrims.

2.2.2 Database Design

The Entity Relationship Diagram (ERD) of the Umroo system outlined the database structure, showcasing the entities and their relationships to support system functionalities. Key entities include User, which represents pilgrims, mutawwifs, and administrators with attributes such as user roles, contact details, and credentials. The Location entity stores real-time GPS data, linking to users for precise tracking. Emergency Alerts capture notifications sent during critical situations, connecting to user and location data for efficient response. The Accommodation entity manages lodging details, while the Itinerary entity organizes schedules for individual pilgrims. Additionally, the Audio Room entity supports communication between mutawwif and pilgrims through in-app sessions. The ERD ensures data consistency and efficient integration of features like tracking, communication, and itinerary management, forming a robust foundation for the Umroo system.

2.2.3 User interface design

The user interface design exercise is explained in more detail in this section. Figma was utilized to execute this task. The user interface for the Umroo mobile app was created first, in accordance with the specifications, and then the web-based app's administrator role user interface was created. Only selected interfaces will be provided due to space constraints.

The remaining processes will be elaborated in the subsequent result section as they are the outcomes of the project based on the requirements, and the design of the expected features.

3. Result

This section provides the detailed elaboration of the Umroo development, deployment, and testing activities.

3.1 Development

The Umroo app achieves seamless by integrating multiple components, ensuring functionality, scalability, and reliability for end-users, including pilgrims, mutawwifs, and administrators. Built on a modular architecture, the system integrates a mobile application, an admin panel, and a backend database, each designed to complement and enhance the overall performance of the platform.

The Flutter-based mobile app provides real-time GPS tracking, emergency alerts, and audio guidance for pilgrims. The app seamlessly interacts with backend services through RESTful APIs, enabling real-time data synchronization for tracking, notifications, and user interactions. The admin panel, which was developed with Svelte, allows agency administrators to monitor and manage pilgrim activities. It integrates directly with the backend database via TypeScript and Hono, ensuring secure and efficient data handling. The PostgreSQL database underpins the system, providing structured and relational storage for user data, location details, and emergency alerts. Google Cloud ensures high availability and scalability, particularly during peak pilgrimage seasons.

The following sub sections elaborate the selected Umroo features. The implementation of Umroo followed a structured approach, which is divided into three main components: front-end development, back-end implementation, and system integration. Each component was developed with specific consideration to scalability, performance, and user experience, ensuring that the final system would meet all specified requirements while maintaining reliability and efficiency.

3.1.1 Front-end development

The front-end development of Umroo focused on creating an intuitive and responsive user interface that could effectively serve both pilgrims and mutawwifs. The implementation utilized Flutter's powerful framework capabilities to ensure cross platform compatibility and optimal performance. The location tracking interface was developed with particular attention to user experience and battery efficiency. The system implements real-time GPS tracking visualization through Flutter Maps, with custom markers distinguishing between different user types. The implementation includes sophisticated geofencing capabilities that trigger boundary alerts when pilgrims move beyond designated areas. To optimize battery consumption, the location update frequency was carefully balanced against accuracy requirements.

The audio room feature represents a significant technical achievement in the frontend implementation. The system successfully implements voice streaming capabilities with minimal latency, allowing mutawwifs to guide pilgrims effectively through various rituals. The push-to-talk functionality was designed with careful consideration of network conditions, implementing automatic quality adjustment to maintain communication clarity even in challenging network environments.

Figure 8 indicates that authentication module for the Umroo users to log into the system. The flow starts with the role selecting and continues with mobile number. The system then checks the existing of the number first before requesting the pin. OTP number will then be sent to the registered account allowing the user to sign in to the application. Meanwhile, Figure 9 shows the profile screen based on user's role. In this screen, a user can easily manage their own personal information such as emergency contact, picture profile, and device information. From here, users can also view the feeds stories, which are maintained by the agency administrator as shown in Figure 10.

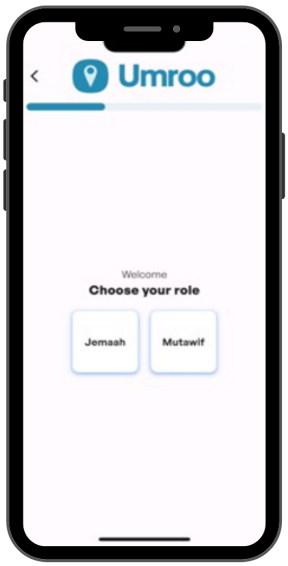

Fig. 8. Selecting role screen

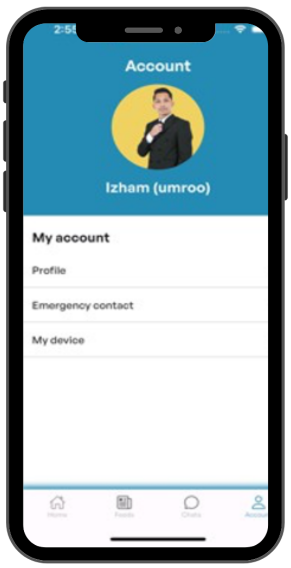

Fig. 9. Profile screen

Fig. 10. Feeds screen

Figure 11 denotes that mutawwif views where all the mutawwif contact details will be displayed. Figure 12 and 13 show the chat feature where mutawwif and pilgrims can directly communicate, and residence information, which can be updated by the agency administrator.

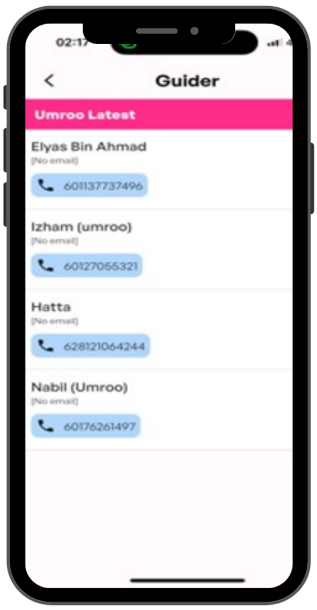

Fig. 11. Mutawwif view

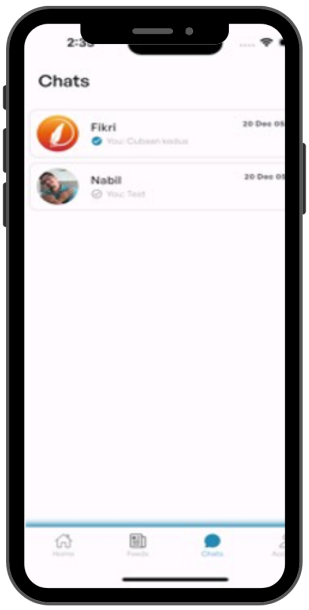

Fig. 12. Chat feature

Fig. 13. Residence info

Figure 14 shows the itinerary feature where all the pilgrims and mutawwif can view the itinerary details. Figure 15 allows the live audio screen where mutawwifs are able to monitor pilgrims when performing the tawaf ritual. In addition, the mutawwif can directly broadcast to the pilgrims to make any announcement. Tawaf, or the act of circumambulating the Kaaba seven times, is performed by pilgrims in the Mataf, the open space encircling the Kaaba inside Masjid al-Haram in Mecca. According to [24], Mataf can accommodate about 107,000 pilgrims every hour. Hence, this feature is crucial when making the tawaf ritual, mutawwifs and travel agencies need an efficient mechanism to monitor, control and communicate with pilgrims particularly when the Mataf area is overcrowded.. See Figure 16.

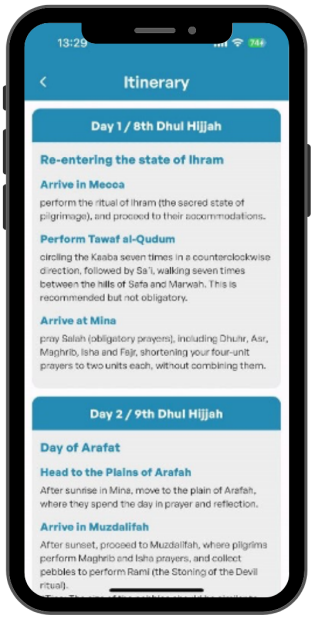

Fig. 14. Itinerary view

Fig. 15. Live audio screen

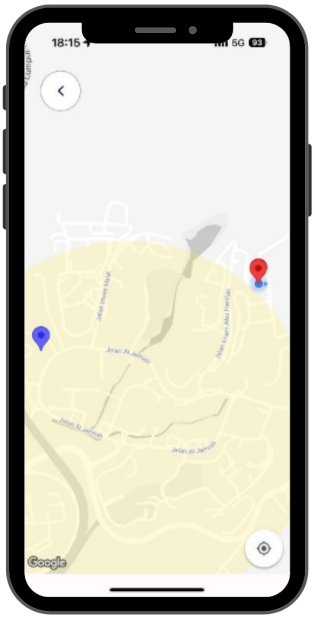

Fig. 16. Real-time tracking location

3.1.2 Back-end development

The backend system, developed using TypeScript with Hono, forms the core of Umroo's data processing and business logic implementation. The API architecture follows RESTful principles, with carefully designed endpoints that handle data management efficiently. The implementation includes comprehensive request validation and rate limiting to ensure system stability under heavy load.

Data processing capabilities were implemented with careful consideration of real-time requirements. The system processes location data continuously, performing complex geospatial calculations to support features such as proximity alerts and location-based services. The implementation includes sophisticated caching mechanisms that optimize performance while maintaining data accuracy. Security implementation received particular attention during backend development. The system employs JWT-based authentication, with all data encrypted both at rest and in transit. Comprehensive input validation and sanitization protect against common attack vectors, while role-based authorization ensures proper access control throughout the system.

3.1.3 Integration development

The integration phase brought together frontend and backend components into a cohesive system. Service integration was implemented through carefully designed APIs, with particular attention paid to error handling and recovery mechanisms. The implementation includes sophisticated data synchronization protocols that ensure consistency across all system components. Data flow management was implemented with scalability in mind. The system employs efficient cache invalidation strategies and load balancing mechanisms to maintain performance under varying load conditions. Real-time data synchronization ensures that all users receive timely updates while minimizing system resource usage.

3.2 Testing

The test plan for the Umroo application outlines a structured approach to evaluate the system's usability, functionality, and reliability. The plan aims to ensure that the application provides a seamless and user-friendly experience for pilgrims, mutawwifs, and administrators while meeting its intended objectives. This includes enhancing real-time tracking, emergency response features, and communication tools for better itinerary management.

3.2.1 Testing plan

The testing plan is organized into key components including testing objectives, tasks, participants, equipment, and responsibilities. The testing phase of Umroo employed a comprehensive, multi-layered approach to ensure system reliability, security, and performance. Through systematic testing at unit, integration, system, and user acceptance levels, the system's functionalities were validated while identifying and addressing potential issues. The testing process utilized automated testing frameworks alongside manual testing procedures, providing thorough coverage of all system components and their interactions. For this article, only User Acceptance Testing (UAT) will be included.

3.2.2 Testing procedure

The testing procedure as depicted in Figure 17 focuses on testing navigation ease, feature intuitiveness, and the system's performance under varying conditions. Participants with diverse profiles, including language preferences and varying familiarity with Umrah and Hajj rituals were briefed about the testing procedure. Initially, all testing materials and pre-installed Umroo apps were prepared. Then, the participants were briefed, provided with the Umroo app, and were asked to perform the testing steps. While performing the steps, their logs were recorded, and the responses were collected in real time. After that, they were given post-survey to get additional in-depth feedback. By leveraging controlled and simulated environments, the plan ensures accurate and actionable insights to address usability issues before deployment, ultimately enhancing user satisfaction, reducing technical queries, and building brand trust.

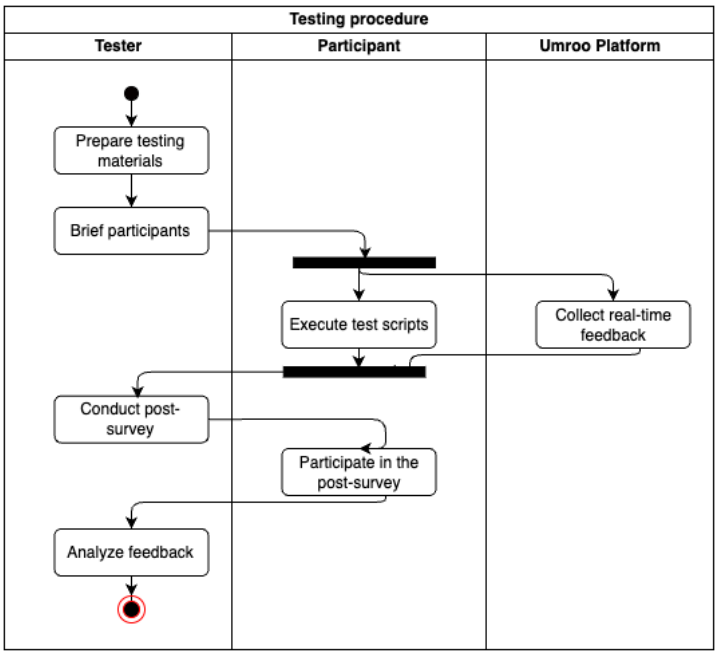

Fig. 17. Testing Procedure

3.2.3 User Acceptance Testing (UAT)

User Acceptance Testing (UAT) involved real-world users testing the system in actual usage scenarios. The testing group included a total of 45 participants across different user categories i.e. pilgrim, mutawwif, and administrator, providing valuable insights into system usability and functionality as summarized in Table 2. In average, the UAT result is 96.8%, which can be considered high.

Table 2
UAT participant demographics and results

User Category	Participants	Tasks Completed	Success Rate	Issues Reported
Pilgrim	25	125	96.8%	2
Mutawwif	10	80	97.5%	1
Administrator	10	60	96.2%	1
Total	45	265	96.8%	4

3.3 Deployment

The deployment of Umroo has been guided by extensive iterations of feedback and testing. Over three phases, the app has been deployed and used in six Umrah trips and trialed internationally, highlighting its commitment to continuous improvement through iterative enhancements. Each phase addressed critical user feedback, ensuring better functionality and user satisfaction. In Phase 1, Umroo was first deployed by UHB Travel Agency in July 2024. While largely functional, issues with the Live Call feature were reported, with some users were unable to hear the speaker. These issues, flagged as critical during discussions with the trip coordinator, were addressed and fixed. Eight major tasks were completed, improving audio functionality for subsequent trips. Phase 2 evidenced the adoption by Qasswa Umrah and Pewira Umrah Agencies in September 2024, where feedback revealed inefficiencies in the Admin Panel's Create and Update User functions. These redundancies were resolved in later sprints, streamlining administrative processes. Finally, phase 3 focused on Amani Travel and Tours Agency trip, where a duplicated room creation issue in the Live Call feature was promptly identified and resolved. This ensured seamless operations for the rest of the trip. Umroo's phased development highlights its dedication to operational efficiency and user satisfaction, integrating real-world feedback to refine its features and functionality. Figure 18 and Figure 19 illustrate the availability of the Umroo app in the Google Play Store and the Apple App Store, respectively.

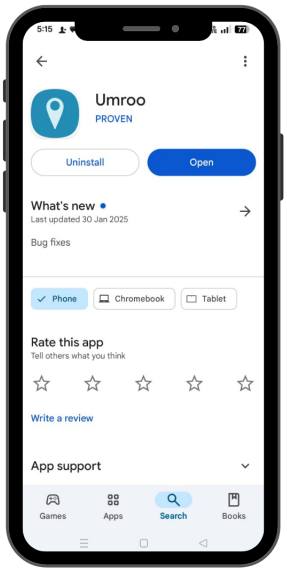

Fig. 18. Umroo in Google Play Store [25]

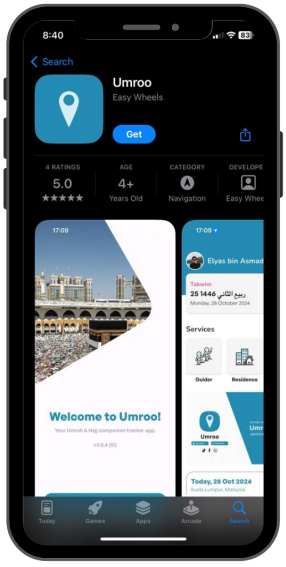

Fig. 19. Apple App Store [26]

4. Conclusions

In terms of future development, a number of important areas have been acknowledged. Adding offline capabilities would greatly increase the system's dependability in places with inadequate connectivity. In addition, technical advancements can include automating data parsing procedures and increasing compatibility with IoT devices. Strengthening the platform's value proposition would require additional feature improvements such connectivity with current pilgrimage systems, improved privacy restrictions, and integration with health monitoring.

As a conclusion, the Umroo app has successfully addressed the critical challenges in Umrah and Hajj management through innovative digital transformation. The high user acceptance rate

demonstrates the system's effectiveness in meeting pilgrim, mutawwif, and agency administrator needs during the pilgrimage duration. Despite technical challenges, the implementation of real-time tracking, emergency communications, and digital guides provides a solid foundation for enhanced pilgrimage management. While certain limitations exist, particularly regarding connectivity and hardware compatibility, the project has established a promising framework for future developments that will further enhance the pilgrimage experiences.

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