



# رحاب | Rehaab

IT 497: Graduation Project Report

Product Release-2

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# Rehaab| رحاب

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**Abstract (English):** Al-Masjid Al-Haram holds immense significance for the Kingdom of Saudi Arabia and Muslims worldwide serving as the holiest site in Islam and the exclusive venue for Hajj and Umrah pilgrimage. To enhance accessibility for visitors, the government has introduced Al-Haram electric vehicles. However, the current manual reservation process of these vehicles poses challenges, including locating the vehicles, unpredictable waiting times, and lack of real-time vehicle availability information. "Rehaab" system aims to address these challenges by providing an application that serve Al-Haram visitors and vehicle managers, as well as administrators. "Rehaab" has been developed in incremental iterations using an agile software development methodology, specifically the scrum framework. The application website includes a dashboard with real-time information on vehicle information which enhances the functionality and control of the system for administrators. Through real-life evaluation with actual users, "Rehaab" effectively demonstrated its usability and necessity. It is expected to improve the overall experience for Al-Haram visitors. The application will reduce waiting times, provide automatic Tawaf tracking, and enhance accessibility for elderly and disabled individuals. Vehicle managers will gain insights into vehicles usage. Overall, "Rehaab" revolutionizes electric vehicle management in Al-Masjid Al-Haram, ensuring a seamless experience for visitors optimizing their valuable time within the sacred premises.

**للمسجد الحرام أهمية بالغة في المملكة العربية السعودية ول المسلمين في جميع أنحاء العالم، فهو المكان المقدس في الإسلام لأداء فريضة الحج والعمرة وتعزيز إمكانية التنقل للزوار، قدمت الحكومة العربات الكهربائية. ومع ذلك، فإن زوار الحرم يواجهون صعوبة في عملية حجز هذه العربات، بما في ذلك تحديد موقع العربات، وأوقات الانتظار الطويلة غير محددة المدة، وعدم توفر معلومات فورية عن توافر العربات.**  
**يهدف نظام "رحاب" إلى حل هذه التحديات من خلال توفير تطبيق يخدم زوار المسجد الحرام ومدراء العربات، بالإضافة إلى موقع الكتروني يخدم المسؤولين. تم تطوير "رحاب" باستخدام منهجية تطوير برمجيات مرنة، من خلال إدراج التحسينات التدريجية. يتضمن الموقع لوحدة معلومات فورية عن توافر العربات، مما يعزز وظائف النظام والتحكم فيها للمسؤولين. من خلال تقييم تجربة المستخدمين، أظهر "رحاب" قابلية استخدامه بشكل فعال وضروريته. ومن المتوقع أن يحسن "رحاب" تجربة زوار المسجد الحرام بشكل عام. سيقلل التطبيق من أوقات الانتظار، وسيوفر تلقائياً للطوابف، وسيعزز إمكانية الوصول لكبار السن وذوي الإعاقة. سيحصل مدراء العربات على معلومات دقيقة حول استخدام العربات ومعلومات فورية عن توافرها.**  
**بشكل عام، يحدث "رحاب" ثورة في إدارة العربات الكهربائية في المسجد الحرام، مما يضمن تجربة سلسة للزوار وتحسين استغلال وقتهم الثمين داخل الحرم الشريف.**

**Keywords:** Al-Masjid Al-Haram; Al-haram; Hajj; Umrah; Electric vehicle; Islam; Muslim

## 1 Introduction

Al-Masjid Al-Haram, also known as the Grand Mosque, is of utmost importance and value to the Kingdom of Saudi Arabia and Muslims all over the world. Its religious importance emanates as it is the holiest site in Islam, and it is the only place to do Hajj (one of the 5 pillars of Islam) and Umrah. It is also considered a historical and cultural site due to its history, and the Islamic architecture of Al-Masjid Al-Haram. In addition to its religious value, it is also economically important, especially in peak times like Hajj time as announced by the General Authority for Statistics, the total number of Hajj performers was 1,845,045 in 2023 [1]. The total number of Umrah performers varies from year to year, according to 2022, it was around 24 million performers [2].

The government of the Kingdom of Saudi Arabia and the Ministry of Hajj and Umrah have always tried to benefit from modern technology in all areas that serve Hajj and Umrah performers and visitors to Al-Masjid al-Haram. One such example is providing **electric vehicles** (العربات الكهربائية) to help Al-Haram visitors especially the elders and those who find it difficult to walk for long distances to do Hajj and Umrah easily [3].

Electric vehicles are part of the government of the Kingdom of Saudi Arabia's efforts to enhance accessibility and ensure that all individuals can comfortably and conveniently navigate the large mosque. They have witnessed significant development, starting from simple wooden chairs As shown in Figure 1 [4], which are carried by multiple individuals to do Tawaf and Sa'i for Umrah and Hajj performers. Then, manually operated vehicles made of wood and iron, covered with a sponge, were used in Figure 2 [5]. The evolution continued until we reached the electric vehicles As shown in Figure 3 [5], that we witness Today [3]. The electric vehicles themselves have many advantages such as the convenience and support they provide for those in need; however, they have some issues regarding the management and usage of the vehicles.



*Figure 1. wooden chair*

*Figure 2. Vehicles made of wood, iron, and sponge*



*Figure 3. Modern electric vehicles*

One of the issues that Al-Haram visitors often face is that they find it difficult to locate the place where they can obtain a vehicle. Once they find the place, they may be faced with a long queue of people waiting , and they are also unaware of the waiting time till a vehicle is available.

In this project, we propose a solution that will help improve the management of electric vehicles in Al-Masjid al-Haram. We propose to design and implement a system called "Rehaab" to manage the reservation and management of the vehicle. The system will provide an efficient process for vehicle reservation and management using an accessible mobile app, website and will support Al-Haram visitors to make the most of the valuable time they spend in Al-Masjid Al-Haram. vehicle management admin will also find it easy to track and manage the overall process of vehicle reservation in one central dashboard.

## 1.1 The Problem

The Ministry of Hajj and Umrah has developed a mobile app named "Tanaqol" that is concerned with the reservation of vehicles for a specific day [6]. However, even if Al-Haram visitors reserve a vehicle using the app, they must wait in line and then show the vehicles manager at the counter the reservation details to get it. This process takes time for Al-Haram visitors. So, imagine what would happen in the peak times and when Al-Masjid Al-Haram is full of visitors, the vehicle managers do not know when the vehicles will return, or if any vehicle requires maintenance, and how long will it take. In summary, the process of vehicle reservation and management could be improved using a more efficient process with the help of technology.

Al-Haram visitors face several difficulties and hardships in reserving vehicles that help them perform the Tawaf easily, especially the elderly and people with disabilities. One difficulty is that the location of the vehicles might be unknown to visitors, therefore they waste time and effort looking around and asking for the location to get a vehicle. Another difficulty is that the waiting time for an available vehicle is also unknown, this might cause congestion, and long queues, especially at peak times, and make the experience unpleasant for visitors. Vehicle managers also do not know the expected waiting time, as they do not have an immediate exact count of the number of vehicles in-use, the expected time to finish, and the number of available vehicles.

As a concrete example, an elderly visitor in Al-Masjid Al-Haram, who has difficulty walking, had to stand in line and wait for a long time until he could get one of the electric vehicles, which led to hardship and fatigue and hindered him from performing the Tawaf efficiently and at ease.

## 1.2 Objectives

### **Product (customer focus-value)**

The system will provide services for three types of users: (1) Al-Haram visitors, (2) Vehicle managers, (3) Vehicle management admin. Below we provide details for each type of user:

The system has a mobile application that will provide the following features for **Al-Haram visitors**:

- The ability to sign-up, sign-in and sign-out of the app.
- The ability to make a new reservation for a vehicle to do Tawaf.
- The ability to view reservation's details.
- The ability to view my reservation's list.
- The ability to cancel a reservation.
- The ability to reschedule a reservation.
- The ability to find the location of vehicles for pickup and return using a map.
- The ability to call for support while performing Tawaf.
- The ability to track Tawaf status (count round of circumambulations around the Kaaba).

And the following features for the **vehicle managers**:

- The ability to sign-in, sign out.
- The ability to make vehicle reservation for *walk-in Al-Haram visitors* (those who did not make reservation through the app)
- The ability to view reservations' list (walk in's reservations).
- The ability to view walk in reservation's details.
- The ability to cancel a reservation for walk-in Al-Haram visitors from waiting list.
- The ability to check-in a vehicle for *Al-Haram visitors* (to ride and start Tawaf).
- The ability to know the estimated time for the next available vehicle in case all vehicles are occupied to inform Al-Haram visitors of the queue waiting time.
- The ability to view vehicles' availability dashboard .

The system has a web-based interface that will provide the following features for the **vehicle management admin**:

- The ability to sign-in and sign-out of the website.
- The ability to configure and update system parameters (ex: total number of vehicles for each type of visitors, number of backup vehicles, etc.).
- The ability to mark vehicles' pick-up and return location on a map (as this can change from season to season).
- The ability to view vehicles' information(Live and historical dashboards).

- The ability to assign vehicle managers.
- The ability to view support notification alerts.
- The ability to detect vehicles' congestion by presenting a vehicle heatmap, which shows areas of congestion.

### **Project (solution focus-plan)**

- Perform domain analysis to understand the process and terminology of electric vehicle usage, management, and handling of reservations.
- Elicit user and system requirements from vehicle management employees and Al-Haram visitors.
- Design the solution, including the system architecture and major components, and identify required tools.
- Detailed design including interface, and sub-components.
- Design and development of algorithms and AI components including data collection, data cleaning, and training the models.
- Design and development of the software including integration and testing.
- Conduct user acceptance testing.

### **Learning (student focus)**

- Use new IDE (Visual Studio).
- Improve coding skills using the Flutter framework for building cross-platform mobile applications using Dart programming language and Django framework for building websites using Python programming language.
- Apply agile software development processes to develop application software.
- Apply Software testing methodologies.
- Learn and understand GPS location algorithms.
- Learn using AI algorithms, such as computer vision and object detection.
- Learn how to create a web-based dashboard.
- Develop and empower presentation skills.
- Enhance important skills such as time management and teamwork skills.

### 1.3 Scope

"Rehaab" includes an android mobile application and a web-based interface that provides many features to enhance the experience of Al-Haram visitors, vehicle managers and admins (see Section 1.2).

The mobile application and web-based interface will support the English language only as it is needed for the users. Moreover, the system in its initial version will focus on vehicle management for Tawaf only, and not include (Sa'i). In addition, it will not cover payment services.

### 1.4 Product Vision

**For** Al-Haram visitors and managers **who like** to use/manage vehicles, "Rehaab" is a software system **that** helps Al-Haram visitors to reserve a vehicle conveniently and easily/ and helps vehicle managers to observe and monitor vehicle status in an easy and efficient way.

**Unlike** other vehicle reservation systems, **our** product can solve the problem of waiting in long queues, help visitors in performing tawaf, and provides alerts to admins when congestions happen.

### 1.5 Approach

The method we employ to develop system is a an agile approach with incremental development in sprints (5 sprints). We studied the competitors and conducted a questionnaire with al-haram visitors and interviews with vehicle managers in order to elicit the system requirements. After collecting users' needs and understanding our system domain, we became able to design Rehaab system and build it by following agile approach which is incrementally implement the product backlog and evaluate it using user acceptance testing at the end of each sprint and it developed using Flutter and Django frameworks. Finally, to ensure that the system functions as intended and complies with user requirements, we conducted user acceptance and NFR testing for the entire system after the last integration of the sprints.

### 1.6 The Solution

To address the aforementioned problems, we present "Rehaab" Al-Haram electric vehicle management system. "Rehaab" offers seamless management, control, and tracking of vehicles. It will enable Al-Haram visitors to conveniently locate vehicles pick-up and return location at Al-Masjid Al-Haram, reserve vehicles, reschedule/cancel reservation, and call for support. Also, it allows vehicle

management admin to view a congestion heatmap and view the vehicles' information. The software will also provide estimated waiting time in case all vehicles are occupied and allows users to plan to wait for the next available vehicle. To improve the system's efficiency and user experience in real life, we will implement two separate counters for Al-Haram visitors and walk-ins (the people who do not have phones or cannot use Rehaab mobile application). This will help reduce long queues and waiting times, making the process more efficient for all users

"Rehaab" will serve pilgrims and visitors of Al-Masjid Al-Haram. It will offer several unique features that assist Muslims in their journey to the House of Allah. "Rehaab" is the perfect companion for visitors of Al-Masjid Al-Haram.

The system will use computer vision for object detection to congestion. Also, it will make use of phone location sensors and location-based services (LBS) and (GPS) to track Tawaf status and count the number of circumambulation rounds around the Kaaba as well as estimate waiting time in case all the vehicles are busy. In addition, reservations are managed through unique barcodes issued, and a barcode scanner is used to verify the reservations of the electric vehicle and to update the availability status of vehicles. We will use YOLO algorithm for detect object and identify congestion by a heatmap.

## 1.7 Report structure

This document starts with an introduction in Chapter -1 which includes a description of the problem, the solution we are presenting, the software product vision, the objectives, the project scope, and the approach we used in Rehaab. Next, in Chapter-2 the background is presented which describes knowledge about the domain including important terminology and the technologies used for the solution such as google maps API, GPS systems, and computer vision. In Chapter-3, we present the literature review which includes an analysis and comparison of similar and related systems and a presentation of some relevant studies that would help in understanding the domain. Then, in Chapter-4 we start with our methodology then we describe the system requirements including system users, requirements elicitation strategies, the development roadmap, user interactions depicted as a use case diagram, and the product backlog showing system features as user stories. Next, we present Rehaab system design including the architecture design, different UML diagrams such as the class diagram, key component level diagrams, data design diagrams and interface design diagrams. Afterwards, we describe and highlight key aspects of Rehaab system implementation. Then, in Chapter-5 we present user acceptance testing methods and results for our system. Finally, in Chapter-6 we present the conclusions of this work and future directions.

## 2 Background

In this chapter, we present important background knowledge on the problem we are addressing, Al-Haram electric vehicle process management and the solution we will provide including the software methods and hardware devices and techniques we are going to use and why we chose them.

### 2.1 Al-Masjid Al-Haram Vehicles

"Rehaab" system is a system that relies on electric vehicles in Al-Masjid Al-Haram and the various procedures required to use these vehicles. The total number of vehicles in the mosque is approximately 8000 (manual and electric), of which 3,000 are electric vehicles [3]. The electric vehicles occupy designated spaces within Al-Masjid Al-Haram, distributed across three locations within Al-Haram. The required procedure to use an electric vehicle involves reserving it through the "Tanaqol" application, one must select the appropriate date and time, choose the type of service (Sa'i - Umrah - Tawaf), and then select the type of vehicle (single-seat or double-seat). The person can choose either self-driving or a driver, and finally make a payment of 100 Saudi riyals for a double-seat vehicle in the case of Tawaf and Sa'i, and 200 Saudi riyals for Umrah, while the single-seat vehicle is priced at half the cost of the double-seat vehicle. Upon completing the reservation and payment, a barcode will be generated, which the vehicle manager must verify before allowing Al-Haram visitors to use the vehicle. The return process of the vehicle is manually handled by the vehicle manager. This manual process results in delays and crowds and makes the situation difficult to manage.

### 2.2 Computer Vision

Computer vision is the field of computer science that focuses on replicating parts of the complexity of the human vision system and enabling computers to identify and process objects in images and videos in the same way that humans do [7].

Computer vision technology has undergone significant advancements in recent years and continues to evolve. It has played a key role in various fields and applications, including image and video recognition, image analysis, and image enhancement. It has greatly contributed to the development of systems for recognizing and understanding visual content, such as facial recognition, object detection, and scene understanding. There are different computer vision techniques depending on the specific tasks they are performing and their applications.

The main computer vision techniques are [8] :

- **Image Classification:** Image recognition or classification is the ability of a machine to see an image and classify it or make accurate predictions to which class the image

belongs. Basically, given a set of images within a single category, the algorithm teaches itself to recognize these images the next time it receives them.

- **Object Recognition (object detection):** It uses image classification to detect objects or classes within images. Typically, the algorithm finds a class within an image and localizes the objects using a bounding box. A bounding box is an imaginary rectangle that marks objects in an image, and it is used as a point of reference for object detection.
- **Object Tracking:** As the name suggests, object tracking tracks an object within an image or a video once it is detected. It refers to a computer's ability to predict a target object's position in each consecutive frame of a video once the initial position is determined. A computer can track objects within a video offline or in real-time. Object tracking can be **single object tracking**, tracking one specific object in a video or **multiple object tracking**, detecting, and tracking more than one object in a video while plotting the unique trajectory of each target object.

In "Rehab" system we will use object recognition and object tracking (to help identify and analyze the movement of objects (the electric vehicles) in a given area ,we are using video). So, we can understand the objects' speed, direction, and density which helps us determine congestion levels accurately and represent them as a heatmap. Thus, the live congestion level will be transparent to the administrators in a visual form, and they can make informed decisions.

Heatmaps provide a visual representation of the distribution of values across an image (the electric vehicles for our case, where higher values are typically represented by warmer colors (such as red or yellow) and lower values by cooler colors (such as blue or green)). To represent this heat map, we should choose the input data, it can be an image or set of images along with any relevant annotations or labels. Then we must prepare the appropriate computer vision algorithm to extract relevant features or attributes, this can involve techniques such as object detection. After extracting features, the algorithm assigns a score or confidence value to each feature or region based on its importance or relevance to the task at hand. For example, in object detection, the algorithm may assign higher scores to regions that contain objects of interest. These values are used to create a heat map, each pixel in the heat map corresponds to a pixel in the original image, and its value represents the score, or confidence associated with that pixel. Higher scores are often represented by warmer colors, while lower scores are represented by cooler colors as we mentioned before. Finally, the heat map is visualized by overlaying it on top of the original image or displayed as a separate image. The intensity of the heat

map at each pixel indicates the strength or concentration of the feature or attribute being represented [9] As shown in Figure 4 [10].



*Figure 4. Heat map with the distribution values.*

### 2.2.1 YOLOv8 Model

YOLOv8 is the newest state-of-the-art YOLO model that can be used for object detection, image classification, and instance segmentation tasks. YOLOv8 was developed by Ultralytics, who also created the influential and industry-defining YOLOv5 model. YOLOv8 includes numerous architectural and developer experience changes and improvements over YOLOv5 [11].

We chose to use YOLOv8 over any other versions because it has a high rate of accuracy measured by Microsoft COCO and Roboflow 100 (YOLOv8 has scored better than YOLOv5), it comes with a lot of developer-convenience features, from an easy-to-use CLI to a well-structured Python package and there is a large community around YOLO and a growing community around the YOLOv8 model, meaning there are many people in computer vision circles who may be able to assist us when we need guidance[11].

## 2.3 Location-Based Service (LBS) and GPS

A location-based service (LBS) is a software service for mobile device applications that requires knowledge about where the mobile device is geographically located. The application collects geodata, which is data gathered in real-time using one or more location tracking technologies.

LBS has two types [12]:

- **Pull:** The application user initiates the location-based service processes. One example of a query-based location-based service is a user checking a mobile map application, such as Waze, to find the nearest automated teller machine. Some location-based services also enable users to check in to restaurants, concerts or sporting events using apps such as Foursquare, Yelp or Google Maps.
- **Push:** The application initiates the location process based on a trigger or at regular intervals. The application then presents the user or device with relevant information based on their geographic location. Proximity-based marketing is a push-based location-based service example. Here, a user is sent an advertisement or coupon after the application proactively identifies that person as being near a specific retail outlet.

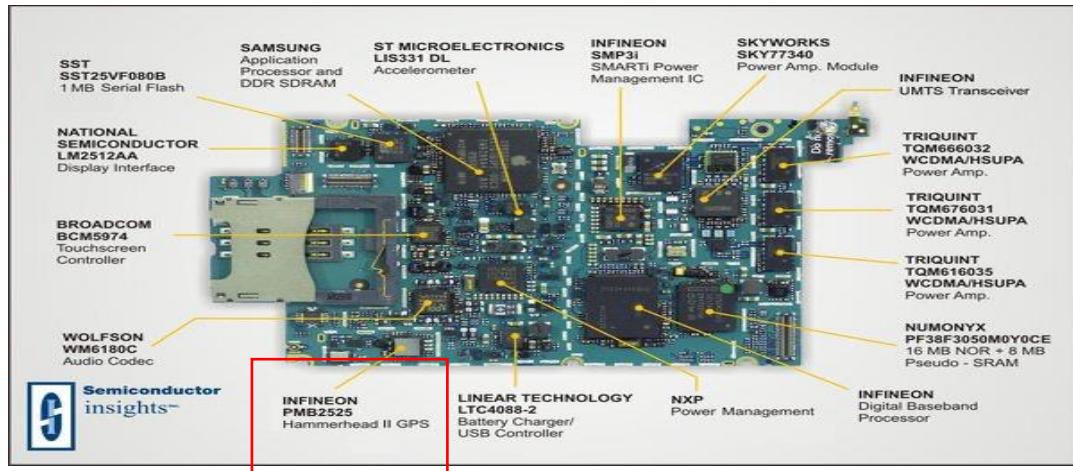
LBS gets and integrates data from various resources and GPS is one of them. GPS is a global positioning system, and it is a network of satellites and receiving devices used to determine the location of something on Earth. Some GPS receivers are so accurate they can establish their location within 1 centimeter (about 0.39 in). A GPS receiver determines its own location by measuring the time it takes for a signal to arrive at its location from at least four satellites [13].

GPS has many types as [14]:

- **A-GPS:** Assisted GPS (A-GPS) is a type of GPS that allows receivers to get information from local network sources, which helps in the location of satellites. Assisted GPS is usually used in areas where satellite signals cannot easily reach.
- **S-GPS:** Simultaneous GPS (S-GPS) is a modification of GPS that allows both voice data and GPS signaling to be transmitted from a phone simultaneously.
- **D-GPS:** Differential GPS (D-GPS) is a correction technique used to increase the accuracy of location data obtained from a traditional GPS receiver. D-GPS is an enhancement to GPS.
- **Non-differential GPS:** Non-differential GPS, as opposed to differential GPS, uses direct satellite signals to deduce positioning. It is less accurate than D-GPS but has a significantly more comprehensive range of use.
- **Mapping and non-mapping GPS:** Mapping GPS is a type of GPS unit that comes with in-built maps. It is also possible to download maps to add to the mapping GPS. This is the type of GPS unit often found in mobile devices and other handheld devices. Non-mapping GPS is a type of GPS unit that comes without maps. It shows you your location and the direction to get to another point without seeing roads or landmarks.

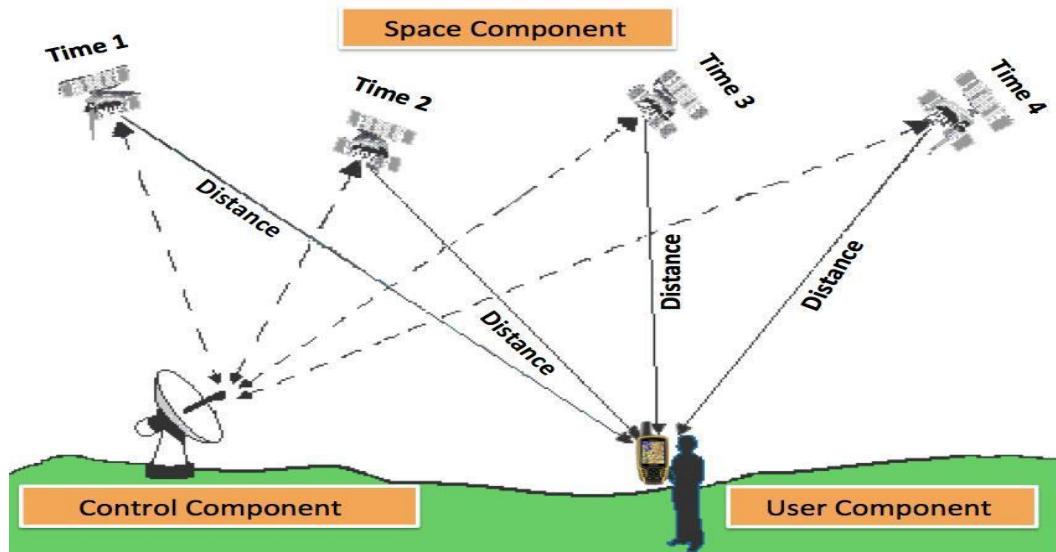
In "Rehab" system we will use the mapping GPS (the mobile phone GPS As shown in Figure 5) [15] to track tawaf status (how many rounds has been completed), know the location of Al-Haram visitors if they call for support and check-out the vehicle automatically if Al-Haram visitor is far enough from Al-Haram.

After extensive and in-depth research, we learned that GPS is considered more accurate than any other sensors. Moreover, the sensors are financially costly.



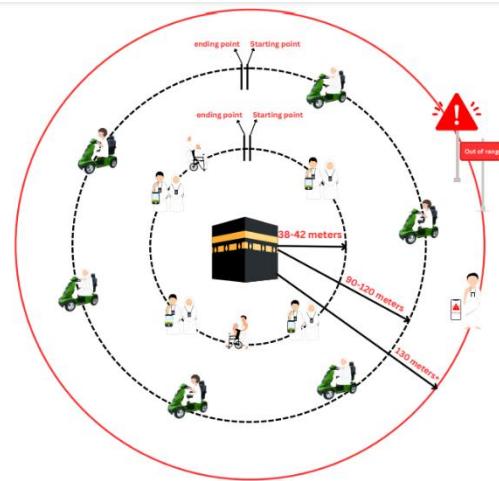
*Figure 5. a detailed image of the motherboard inside an iPhone, illustrating the GPS.*

The GPS in the smart phone consists of three main components GPS receiver, data connection (cellular connection), power source. The receiver listens from GPS satellites, it takes the information from those signals to calculate a position. The cellular connection is used to upload the calculated coordinates to a server or other recipient. The power source provides the necessary power for the other components to work, Figure 6 [16] illustrating the GPS working mechanism [17].



*Figure 6. How GPS components work together.*

If Al-haram visitors *called for support*, their location coordinates (known by their phone's GPS) will be sent to the administrator to offer help. For *tawaf status tracking*, we will define specific coordinates (the center of the Kaaba in our case) with a certain radius range As shown in Figure 7 so when al-haram visitors finish one round, the counter will be incremented automatically till they finish their 7 rounds. For *check-out feature*, it will be done automatically via location GPS, our system will check if the al-haram visitor is far away from the Tawaf area (by getting her/his location from her/his phone's GPS) if so, the system will assume that thy have completed the Tawaf, and therefore the *check-out* will be done automatically as well.



*Figure 7-Radius range for counting Tawaf rounds [18].*

## 2.4 APIs

An API, or application programming interface, is a set of defined rules that enable different applications to communicate with each other. It acts as an intermediary layer that processes data transfers between systems, letting companies open their application data and functionality to external third-party developers, business partners, and internal departments within their companies.

Here are the four main types of web API [19]:

- **Open APIs:** they are open-source application programming interfaces you can access with the HTTP protocol. Also known as public APIs, they have defined API endpoints and request and response formats.

- **Partner APIs:** it connects strategic business partners. Typically, developers access these APIs in self-service mode through a public [API developer portal](#). Still, they need to complete an onboarding process and get login credentials to access partner APIs.
- **Internal APIs:** they remain hidden from external users. These private APIs are not available for users outside of the company and are instead intended to improve productivity and communication across different internal development teams.
- **Composite APIs:** it combines multiple data or service APIs. They allow programmers to access several endpoints in a single call. Composite APIs are useful in microservices architecture where performing a single task may require information from several sources.

## 2.5 Google Maps API

The Google Maps API is a powerful tool that allows developers to integrate various mapping and location-based functionalities into their applications. Here are some key features and capabilities offered by the Google Maps API:

- **Maps Display:** With Google Maps, you can add maps to your application. The plugin automatically handles access to the Google Maps servers, map display, and response to user gestures such as clicks and drags. You can also add markers to your map. These objects provide additional information for map locations and allow the user to interact with the map [20].
- **Geocoding:** The API provides geocoding services, which allow you to convert addresses or place names into geographic coordinates (latitude and longitude) and vice versa. This can be useful for displaying specific locations on the map or performing location-based searches [21].

In Rehab system we will use Google Maps API, which helps us represent map in our application to help Al-Haram visitors find the location of the vehicles easily. We chose Google Maps API to take advantage of Google services as directions, geocoding, and street view.

## 2.6 Queue Analysis

A queueing system is a mathematical model used to analyze and study the behavior of waiting lines. It is a system that manages the arrival and departure of entities, such as customers, tasks, or requests, in a sequential manner. Queuing systems are commonly encountered in various real-world scenarios, including customer service centers, transportation networks, computer networks, and manufacturing processes. In a queueing system, entities arrive at a specific rate, join a waiting line (queue), and are served by one or more service facilities according to certain rules [22]. Our system uses FCFS (first come first served) As shown in Figure 8 [23], we have a specific number of vehicles available per day

so al-haram visitor who makes the first reservation and completes the reservation process will take an available vehicle then the number of available vehicles will be decremented. The system calculates the expected arrival time of the reserved vehicles by calculating the average time people use the vehicles (the time they took from the check-in process till the check-out process), divided by the number of vehicles in use, plus margin of error to avoid any exceptional situations. This way, the reservation opens and closes. Additionally, using this method, we will utilize the expected waiting time to display it to the vehicle managers. In addition, we will use the FCFS algorithm in assigning the available vehicle managers when an Al-Haram visitor calls for support. The system places all available vehicle managers in a list, when a call for support comes from a visitor the system directly assigns the first available manager in the list to assist that visitor, and so on.

### FCFS (Example)

Process	Duration	Oder	Arrival Time
P1	24	1	0
P2	3	2	0
P3	4	3	0

### Gantt Chart :



P1 waiting time : 0

P2 waiting time : 24

P3 waiting time : 27

The Average waiting time :

$$(0+24+27)/3 = 17$$

Figure 8. An example of FCFS

## 2.7 Terminology

**Al-Masjid Al-Haram:** “Also called **Holy Mosque** or **Haram Mosque**, mosque in Mecca, Saudi Arabia, built to enclose the Kaaba, the holiest shrine in Islam. As one of the destinations of the Hajj and Umrah pilgrimages, it receives millions of worshippers each year. The oldest parts of the modern structure date to the 16th century.” [24]

**Kaaba:** “**The cube**, shrine located near the center of the Great Mosque in Mecca, Saudi Arabia, and considered by Muslims everywhere to be the most sacred spot-on Earth.” [24]

**Tawaf:** “‘To encircle something’ or ‘to walk around something’. In the Islamic context, Tawaf refers to taking rounds or encircling the Holy Kaaba seven times in an anti-clockwise direction as part of Umrah or Hajj.” [25]

**Hajj:** “The pilgrimage to the holy city of Mecca in Saudi Arabia, which every adult Muslim must make at least once in his or her lifetime. The hajj is the fifth of the fundamental Muslim practices and institutions known as the Five Pillars of Islam. The pilgrimage rite begins on the 7th day of Dhū al-Hijjah (the last month of the Islamic year) and ends on the 12th day.” [26]

**Umrah:** “The ‘minor pilgrimage’ undertaken by Muslims whenever they enter Mecca. It is also meritorious, though optional, for Muslims residing in Mecca. Its similarity to the major and obligatory Islamic pilgrimage (Hajj) made some fusion of the two natural, though pilgrims have the choice of performing the *Umrah* separately or in combination with the Hajj.” [27]

**Sa’i:** “Originally the word Sa’i comes from the Arabic word Sa’a which linguistically means to pursue or to walk or to strive. However, according to Islamic terminology, the meaning of Sa’i is to run or walk between Safa and Marwa while performing Hajj or Umrah. Performing Sa’i is the fourth compulsory rite of Hajj or Umrah. Muslims are obligated to perform Sa’i after the completion of Tawaf and its prayers.” [28]

**Al-Hajar Al-Aswad:** “It is a sacred stone situated in the eastern corner of the Holy Kaabah in the city of Makkah, Saudi Arabia. The holy stone is placed in a silver encasement. However, today, the sacred stone’s physical appearance comprises eight small rocks mounded together using Arabic frankincense. Moreover, while performing Tawaf during Hajj and Umrah, Muslims face the sacred stone.” [29]

### 3 Literature Review

This chapter describes the literature review, which includes review work on sensing the crowds and a study of competitive applications which are like the proposed application. This will help us identify the gap and what is needed in the market for our specific application.

#### 3.1 Related Research in Crowd Detection

In this section, we will briefly review work on sensing the crowds for Hajj and Umrah. Current techniques for sensing crowds evolved around computer vision, participatory sensing, and sensor networks. One notable study uses Bluetooth low energy (BLE) tagging as an alternative method. When low-cost BLE tags are set in advertisement mode, they can be detected by smartphones. In this paper [30], the design for sensing the crowds is by requiring a large population carrying cheap off-the-shelf BLE proximity tags, and fewer participants to run scanning application on their smartphones to collect data. The proposed BLE tagging approach offers a cost-effective and scalable solution for crowd sensing by leveraging the existing capabilities of smartphones. While it may not provide the same level of detailed information as computer vision, it presents advantages in terms of privacy since The BLE tags do not collect or store personal data or transmit any sensitive information. But privacy is not considered negative for us in using computer vision because we will place them in a public place, and as we have learned in Cyber security governance (IT471) that placing cameras in a public place does not violate privacy. Additionally, it is important to note that there is a possibility of individuals forgetting to carry the BLE tags, which can result in decreased accuracy. Furthermore, it cannot be guaranteed that every visitor to Al-Haram will have the BLE tag with them, further affecting the overall accuracy of the crowd-sensing system. Other similar systems [31] propose a framework to count the moving people in the video automatically in a very dense crowd situation. Median filter is used to segment the foreground from the background and blob analysis is done to count the people in the current frame. Optimization of different parameters is done by using a genetic algorithm. This framework is used to count the people in the video recorded in the Mataf area where different crowd densities can be observed. An overall people counting accuracy of more than 96% is obtained. The work presented in [32] proposed a computer vision-based analytical framework to compute crowd density estimation, congestion detection, and dominant pattern identification using videos from IP cameras installed in Masjid al-Haram. Dominant flows and scene summaries were calculated initially. Summaries of all the short views were calculated next. Based on the above, crowd density and congested areas were calculated and detected, and security management was informed. Rehaab system will detect the congestion of electric vehicles instead of people. The work in [33] proposed an IoT-

based technology that manages and controls the pilgrim's movement in Mina area based on the possible hazards, pilgrim behavior, and environmental conditions and identifies evacuation paths for pilgrims to guide them to avoid congestion, to evaluate this technology, AnyLogic -a multi-method simulation modeling tool- is used to perform simulations based on real data sets and scenarios. But not every scenario involving a crowd will be considered, which means the crowd problem will not always be solved.

### 3.2 Competitive Product Analysis

By conducting market research, the strengths, and weaknesses of applications like "Rehaab" were identified. This information can be valuable for understanding market trends, identifying opportunities for improvement, and developing a competitive edge in the religious services app industry.

These applications vary in terms of their internal services and the range of services they offer. Some applications primarily specialize in providing reservation services for electric vehicles, while others incorporate electric vehicle reservations as part of their broader service offerings. Additionally, there are applications that provide a variety of services related to the Al-Masjid Al-Haram.

In this section, we will describe applications that are like our work. Each of the competitive applications will be described with the features which differentiate them.

- **Tanaqol Mobile Application**

"Tanaqol" is an online mobile application that provides services for reserving electric vehicles. The reservations serve different purposes one for performing the Tawaf, another for the Sa'i, and a third option is for Umrah. Users can also choose the type of vehicle they prefer, whether it is a single or double vehicle, with or without a driver, As shown in Figure 10. Once the booking is complete, users are required to keep the QR code, As shown in Figure 11, which will be shown to receive their electric vehicle.



Figure 9. Tanaqol logo

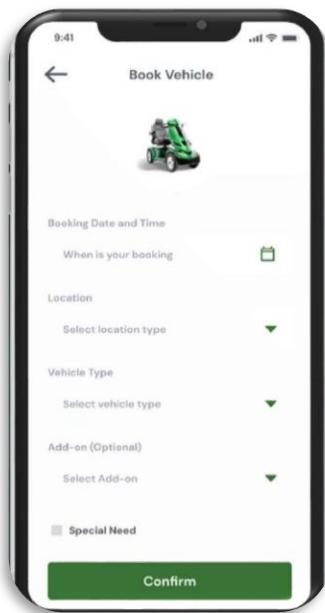


Figure 10. Tanaqol app

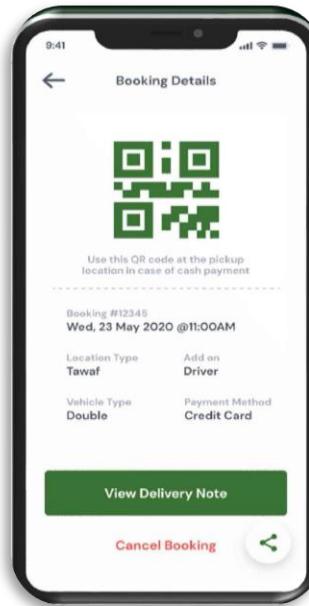


Figure 11. Tanaqol app

#### • Umrah + Mobile Application

"Umrah +" is an online mobile application that enables the user to count the number of times of circumambulation and sa'i through a manual counter (by the user) that is pressed to count each round. It also provides users with an easy interface to read the prayers, As shown in Figure 13.



Figure 13. Umrah+ app



Figure 12 .Umrah+ logo

### • Al-Haramain Mobile Application

"Al-Haramain " is an online mobile application that uses modern technology to serve visitors, and mo'tamren (those who perform Umrah). The application contains Information about the Al-Masjid Al-Haram and the Prophet's Mosque, Prayers time live broadcast from the Al-Masjid Al-Haram and the Prophet's Mosque, GPS service to guide you to the point that you wish to go inside the Two Holy Mosques , As shown in Figure 16, and E-services , As shown in Figure 15, it's provides for the visitors vehicle reservation (not electric vehicles) so when the user wants to reserve, he/she will be directed to "Nafath" app. Also, it allows the user to report problem and communicate with the General president by entering the user information, message title, and message content. The applications also allow users to request for Itikaf (staying in the Holy Mosque in the last ten days of the holy month of Ramadhan), wheelchair, visiting permission to Kiswa (the cover for the Kaaba made from cloth) factory.



Figure 14. AlHaramain logo



Figure 15. AlHaramain app

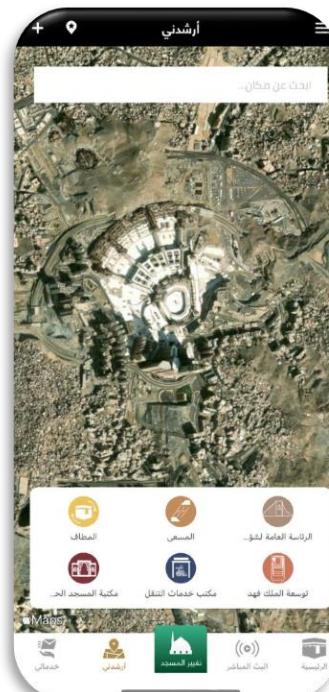


Figure 16. AlHaramain app

#### • Gazal Mobile Application

"Gazal" is an online mobile application that is a micro-mobility solution for contributing to the transportation industry. It displays a map to the user with the scooter's locations, and then the user makes a scan on his/her phone to book for the period he/she needs and requires payment to start the ride, As shown in Figure 18.

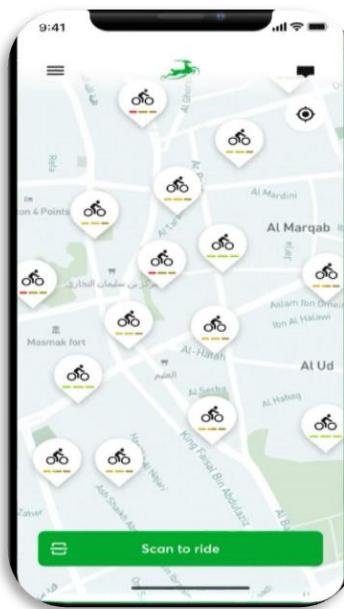


Figure 18. Gazal app



Figure 17. Gazal logo

#### • Almutawaf Mobile Application

"Almutawaf" is an online mobile application that displays the crowd status and density of pilgrims during the three Hajj rituals (Tawaf, Sa'i, Jamarat). This app assists pilgrims in performing the rituals with ease. "Guide Me" services aims to aid pilgrims by providing maps to their places of residence and hotels within Al-Haram, regardless of their location. "My Journey" is an interactive forum for pilgrims and Umrah pilgrims to share their spiritual experiences of Hajj and Umrah journeys. It allows for the exchange of comments and discussions.



Figure 19. Almutawaf logo

#### •Nusuk Mobile Application

"Nusuk" is a mobile app that helps people during their Hajj and Umrah journeys. It serves as a helpful guide, providing information and assistance from the beginning of the rituals until the end. The app offers a digital experience, allowing travelers to plan their trip, manage their arrivals and departures, find transportation options, and stay updated with live prayer times. Users can also reserve vehicles and make online payments through the app, also includes a feature that displays the schedule of imams and facilitates the issuance of permits for Hajj. This feature helps users access information about the imams leading the prayers and enables them to obtain the necessary permits for their Hajj journey.



Figure 20. Nusuk logo

[Table 1 . Competitive applications comparison]

Feature/application	Tanaqol	Umrah+	Alharamain	Gazal	Nusuk	Almutawaf	Rehab
<b>Find the location of vehicles.</b>	✓		✓	✓	✓	✓	✓
<b>Reserve vehicle.</b>	✓		✓	✓	✓		✓
<b>Call for support</b>							✓
<b>Track Tawaf status.</b>		✓					✓
<b>View Prayers time Live broadcast.</b>			✓		✓	✓	
<b>Know the estimated waiting time in the queue.</b>							✓
<b>Online payment.</b>	✓			✓	✓		
<b>Reschedule</b>							✓
<b>Track crowd status</b>			✓		✓	✓	✓
<b>Supported Languages</b>	English, Arabic, Urdu	Arabic	English, Arabic, Urdu	English, Arabic	English, Arabic, Urdu ,French, Turkish	English, Arabic	English

As shown in Table 1, we identified the key features that distinguish each competitor.

Despite the existence of several competitors with similar systems to ours, we believe that each may have a crucial missing feature that could discourage users from adopting them. Therefore, before implementing our software, we conducted a thorough market analysis and compared our product to other locally used software in Saudi Arabia, such as Tanaqol, Umrah+, Alharamain, Almutawaf

,Nusuk and Gazal by doing so, we aimed to identify similarities and differences between our software and the competitors.

We can notice that only one of the competitors' applications has a feature that tracks part of Tawaf status which is counting rounds of circumambulation around the Kaaba manually. Unfortunately, it is not done automatically and does not provide the expected time for the completion of the circumambulation as "Rehaab" app does. Furthermore, competitors that offer reservations are reservation-based applications usually, current reservation systems, such as the Tanaqol, Alharamain, Nusuk, and Gazal do not provide significant benefits for Al-Haram visitors, as both those who make reservations in advance and those who reserve upon arrival experience lengthy wait times, these applications usually lack the option for users to reschedule their reservations.

On the other hand, the "Rehaab" system distinguishes itself by providing flexibility in rescheduling to accommodate the needs of our customers. This feature allows users to adjust their reservations according to their preferences and requirements. The "Rehaab" app aims to introduce a unique feature providing estimated waiting times in the queue. This feature is expected to enhance the user experience by offering transparency and allowing visitors to plan their visit more effectively.

The point that distinguishes "Rehaab" and will entice users to use it include several features. These features include call for support (user can easily request assistance or support through the app) – know the estimated waiting time in the queue, track Tawaf status (automatically)- reschedule reservation-congestion management. "Rehaab" system includes a heatmap on a map that helps the admin visualize and manage congestion within the area. This capability allows for proactive measures to be taken to optimize the flow of visitors and enhance their experience. Almutawaf ,Nusuk and Alharamain app display the crowd status and density of pilgrims to Al-haram visitors. On the other hand, Rehaab system will display this information to the admin, enabling them to provide effective management and implement necessary reforms. These features collectively enhance the user experience, provide convenience, and improve efficiency.

## 4 System Design and Development

### 4.1 Methodology

The Rehaab system was developed using the agile approach, which involved breaking down the project into smaller units. This allowed for focused design, implementation, and testing of each unit before integration into a complete system. The iterative and collaborative nature of agile development ensured a high-quality functioning product for our system. We implemented the scrum framework, an agile practice, to guide the development of the Rehaab system. The framework consisted of specific roles, events, and artifacts that facilitated our agile approach.

In terms of roles, our scrum team comprised three key positions. The product owner took charge of overseeing the system's comprehensive implementation, evaluating user stories, and defining acceptance criteria. The scrum master ensured adherence to the scrum framework, resolved obstacles faced by the team, and maintained the correct implementation of scrum practices. Lastly, the developers were responsible for executing the work, adjusting as necessary, creating and breaking down user stories, and delivering the final product.

The project was divided into sprints, each consisting of five events. The planning event initiated each sprint, during which we determined the work to be undertaken and the deliverables for that sprint. Daily scrum meetings allowed us to review our progress and address any workflow issues. The sprint review event involved evaluating the project's advancement, while the retrospective event focused on self-assessment of our performance and identifying areas for improvement.

Scrum artifacts played a crucial role in our development process. We established the product backlog, which contained all the features as user stories, prioritized based on importance. For each sprint, we selected a set of features to work on, considering their type and dependencies. At the end of each sprint, we integrated these features with one another and with previously completed user stories, resulting in a Product Increment.

The adoption of the agile approach was a significant step in our project's success. By involving users in the development process, we were able to gather valuable feedback and make adjustments accordingly. The agile principles we practiced, such as prioritizing important functions, committing to regular meetings, and focusing on delivering a functioning system quickly, enabled us to meet our objectives within a short timeframe.

Within the scrum framework, our team had the autonomy to determine how the work was divided based on individual capabilities and skills, supported by the trust of the product owner. This

empowered us to complete tasks efficiently. Additionally, we fostered continuous improvement by engaging in self-assessment and work reviews, striving to enhance our talents and productivity. During the development of Rehaab, we relied on two significant tools: GitHub and Jira. These tools played a vital role in supporting our project and making the system management and development processes more efficient.

Jira<sup>1</sup> proved to be invaluable as it provided a platform for creating user stories and organizing them into sprints. We utilized Jira to define and prioritize the features of Rehaab, ensuring a structured approach to development. Additionally, Jira enabled us to generate reports documenting our weekly meetings with the product owner, allowing for effective communication and progress tracking. This helped us stay aligned with project goals and requirements.

GitHub<sup>2</sup>, on the other hand, facilitated seamless collaboration and version control. Each team member was assigned a separate branch on GitHub to upload their work. This allowed us to work independently, prevent code overlap, and maintain orderliness. The use of GitHub as a code repository ensured the safety of our work and provided a reliable system for version control. It allowed us to track changes, collaborate efficiently, and easily manage the project's codebase.

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<sup>1</sup> <https://jira.external-share.com/issue/f877c3b9-a037-4d86-994d-ead777afaf2b>

<sup>2</sup> <https://github.com/latifa22altamimi/2023-GP1-2.git>

#### 4.1.1 System Users

The "Rehaab" system serves three key user categories: Al-Haram visitors, vehicle managers, and administrators. Al-Haram visitors, the primary users, reserve vehicles tailored to their needs, with varying ages and educational backgrounds. They possess basic technical skills, and some may have prior experience with similar systems. Vehicle managers oversee vehicle operations, drawing from experience in related fields and familiarity with reservation systems. Administrators manage system operations, requiring advanced technical proficiency and overseeing tasks such as vehicle management and user supervision. Effective communication is essential across all user categories for seamless system interaction and efficiency.

#### 4.1.2 Requirements Elicitation and Analysis

To elicit the requirements, we used several methods such as interviews with vehicle managers and publishing a survey to the public who are considered visitors to Al-Haram.

### Survey analysis

To develop solutions that meet the needs of the users, an online survey was done with a focus on Al-haram visitors who speak Arabic or English to learn about their needs and preferences and to identify the biggest issues they face. The survey was created using a Google form and shared on social media to reach as many members of the target audience as possible. It has 16 questions, and 99 people responded to the survey.

Following the responses, 68.7% of participants were females, 39.4% were between the ages of 30 and 50, 32.3% were under the age of 30, and 28 (28.3%) were above the age of 50. From this, we can allocate a portion of the vehicles to the elderly because there are many of them who require electric vehicles for tawaf. A significant percentage (74.7%) 74 of the participants have experience using electric vehicles, 63 (85.1%) of them usually reserve the vehicle at Al-haram instead of using a mobile application.

To suit the preferences of the users, we asked them how long they would be willing to wait to receive the vehicle they had reserved. The vast majority (86.9%) said they would wait no more than 10 to 15 minutes. As a result, we should devise a strategy to cut waiting time to the greatest extent possible.

We discovered that most of the participants (81.8%) carry their phones when doing tawaf, In addition, It turns out that 86.5% of vehicles users did not encounter trouble while using the vehicles, still 13.5% of them encountered problems such as sudden stops, battery exhaustion, and vehicle slowness, and they typically call the customer support line or approach one of the vehicles manager personnel to seek for help, And we could offer an easier approach to report any problems that may arise when using vehicles.

When asked about the frequency of encountering congestion while using a vehicle for Tawaf at Al-Haram, 44.6% of respondents reported experiencing it sometimes. Additionally, they expressed that congestion has a detrimental effect on their worship performance. For instance, it leads to dispersal among worshippers and hinders their ability to focus on worship. Due to this, we must address the crowding problem to prevent these problems. We found that more than half of them (58.6%) use their minds to keep track of their tawaf rounds.

When asked how important it is to be aware of their tawaf completion time, the results were as follows: 54.5% said it is not important, 30.3% said it is important, and the remaining 15.2% said they think it is an especially important thing to be aware of.

Moreover, to find the difficulties the visitors are facing, we asked them how easy for them to locate the pickup/return places for electric vehicles as new guests, and many of them (46.5%) found it easy, however, 34.3% of them which is 34 participants found it difficult to find. This gave us the idea of providing these locations in our system as a feature that would make it simple for all visitors to reach them.

To elicit additional information, we asked them a couple more questions. The first was about the difficulties they encountered when attempting to reserve a vehicle for Tawaf. We received a variety of responses, the most common of which were the crowd on the reservation line and the long distance to reach the pickup/return vehicle locations. The second was about whether they had any suggestions to improve reservation management, they suggested developing a vehicle reservation app and increasing the number of pickup/return locations at Al-haram. In summary, Al-haram visitors face several obstacles when riding electric vehicles. As a result, we must supply a solution to assist in dealing with these issues. The full questions and responses can be found in Appendix A.

## Interview analysis

Interview is one of the methods we used to collect information and knowledge about al-masjid al-haram field, how they deal with the electric vehicles and how they manage any problem they face. We

interviewed 1 adman and 2 vehicle managers who have tried working inside the field. We asked them 5 questions about the challenges they usually face when managing the vehicles' reservation, also what techniques, and mechanisms they use to figure out any congestion. We asked about the approximate number of daily breakdowns that the vehicles experience and if they have any alternative vehicles. Of course, we had to ask them about some abnormal scenarios that may happen, like leaving the vehicle in a random place rather than return it to its designated spot, or a haram visitor tried to use the vehicle twice in row without paying and how they deal with these kinds of scenarios. We must not forget to ask if they have any recommendations that can improve our system's features and expand our knowledge.

First, we interviewed the vehicle manager Khalid Al-harbi via phone call on 16<sup>th</sup> of September 2023. He started to talk about the challenges they face in reservation management, he mentioned that in peak times like Ramadan (especially in the last 10 days and between 6:00 pm to 2:00 am) and Hajj time (especially from 10<sup>th</sup> of Dhu al-Hijjah to 15<sup>th</sup> of Dhu al-Hijjah) managing getting harder for them because of the congestions in the tawaf area and in vehicle reservation queues also because of the increasing demand of vehicles. With regards to how they detect congestion, he said they usually notice it when the tawaf area is full or the vehicle reservation queue is too long. He said that the vehicles rarely experience a breakdown due to the vehicles workshop in Al-haram and there are 2 warehouses full of alternative vehicles and these vehicles are always ready to use. When we mentioned the abnormal scenarios (as mentioned before) he said that usually the vehicle cannot be left inside the tawaf area without using it, due to the presence of vehicle managers everywhere. If this happens, the vehicle manager quickly takes it to a special warehouse for vehicles, so that it can be ready for another user. Finally, he recommended having larger vehicles that can accommodate 4 or 5 seats, allowing for more passengers in a single vehicle, which is beneficial in reducing congestion.

The second interview was with Fahad Al-Ahmari via phone call on 20<sup>th</sup> of September 2023. When we asked him about the challenges, he said it is hard for them to manage during the peak times and sometimes it is hard to accommodate all reservations and needs. About how they detect congestion, he agreed with Khalid that they notice the congestion when the tawaf area is full or the vehicle reservation queue is too long. We asked him if he know the approximated number of broken-down vehicles and he said that he does not know the exact number, but there are regular maintenance procedures carried out on the vehicles. About the abnormal scenarios he mentioned that this could happen in peak times, but it is rare and if it happened, the individuals responsible for such actions will be punished. He recommended providing a comprehensive system for both manual and electric vehicles.

The last interview was with Ahmad Al-mukhati (admin) via phone call on 20<sup>th</sup> of September 2023. We asked Ahmad the same questions and he agreed with Khalid and Fahad in all the answers, but he recommended delivering the vehicle to the user's location.

In conclusion, during peak times such as Ramadan and Hajj, managing vehicle reservations becomes challenging due to congestion in the tawaf area and increased demand for vehicles, congestion is typically identified by observing the tawaf area or long queues in the vehicle reservation system, vehicle breakdowns are rare due to regular maintenance procedures. In the event of a breakdown, there are alternative vehicles available in two warehouses, ensuring uninterrupted service, leaving vehicles unused inside the tawaf area is not permitted, and vehicle managers ensure compliance. If such a scenario occurs, the vehicle is quickly relocated to a special warehouse. Any abnormal behavior, such as unauthorized use, is subject to punishment. The full questions can be found in Appendix B.

## Findings

Based on the survey findings and interviews, we have gathered the following insights from the point of view of Al-Haram visitors. Many visitors use their mobile phones during Tawaf, but most of them make vehicle reservations in person at Al-Haram. This practice results in visitors arriving without prior knowledge of reservation availability. Most visitors find a waiting time of 10-15 minutes in the vehicle queue acceptable. Additionally, some visitors encounter challenges in locating specific areas for picking up and returning electric vehicles. They often need to ask multiple questions to get directions, causing confusion and inconvenience. Another issue is the delay in responding to maintenance requests. Some vehicles experience sudden stops or empty batteries, requiring assistance from maintenance or security personnel. This problem becomes more critical during peak periods when visitors are engrossed in their worship, increasing the risk of accidents or collisions. Furthermore, many visitors mentally keep track of the number of circumambulations they have performed by minds, which can lead to forgetfulness and confusion. From the viewpoint of vehicle managers, they recognize the importance of organizing and managing reservations effectively to meet users' needs and streamline operations.

After defining our goals and vision for the project, ensuring its feasibility, and analyzing the interviews with vehicle managers, admin and the survey with Al-Haram visitors distributed through social media channels, we propose Rehaab system, the application will enable Al-Haram visitors to find the location of vehicles for pickup and return using a map, call for support while performing Tawaf, track Tawaf

status automatically (the count of rounds of circumambulation around the Kaaba), make a new reservation for a vehicle. In addition, the vehicle manager will complete vehicle reservation for walk-in Al-Haram visitors (those who did not make reservation through the app), know the estimated time for the next available vehicle in case all vehicles are occupied to inform Al-Haram visitors of the queue waiting time. The system also needs an admin who can configure and update system parameters, mark vehicles' pick-up and return location on a map (as this can change from season to season), view vehicles' information, assign vehicle managers, view support notification alerts, track vehicles by presenting a heatmap on a map, which shows areas of congestion through a dashboard.

#### 4.1.3 User Interactions

A Use Case diagram illustrates a set of use cases for the "Rehaab" system, showcasing the primary actors who initiate interactions with it. These primary actors include Al-Haram visitors, vehicle managers, and administrators. The diagram also includes a secondary actor, Google API. The relationships between these actors and the respective use cases are depicted in Figure 21.

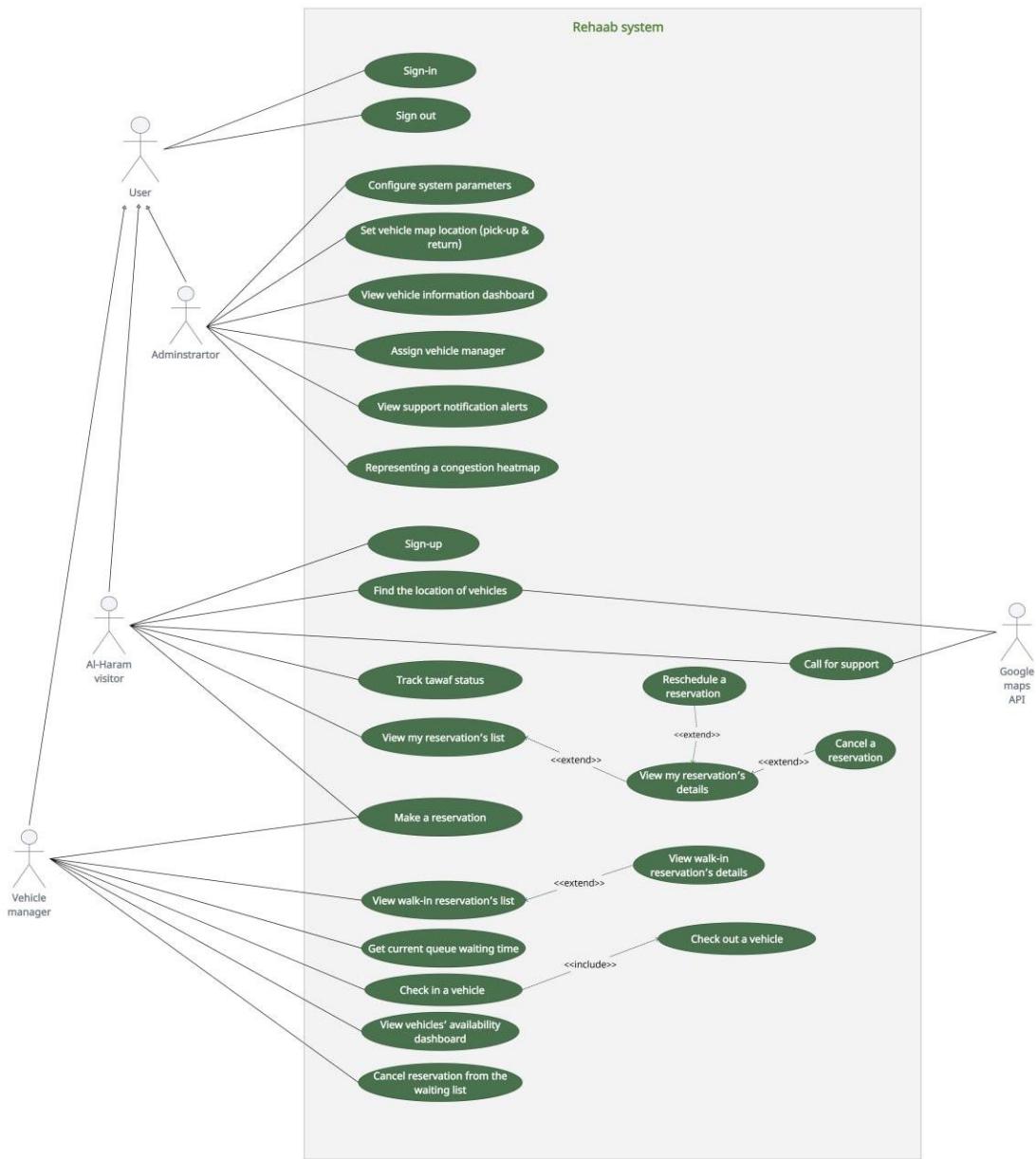


Figure 21. use case diagram

#### 4.1.4 Roadmap and Product Backlog

This section presents the product backlog and roadmap of Rehaab system.

The product backlog is presented below, regarding story points we have approximated the size using the following guide [34].

### Roadmap

This section outlines our Rehaab system's roadmap As shown in Figure 22 and Table 2, which include sprints and task distribution during the sprints.

2023/2024

## Rehaab roadmap

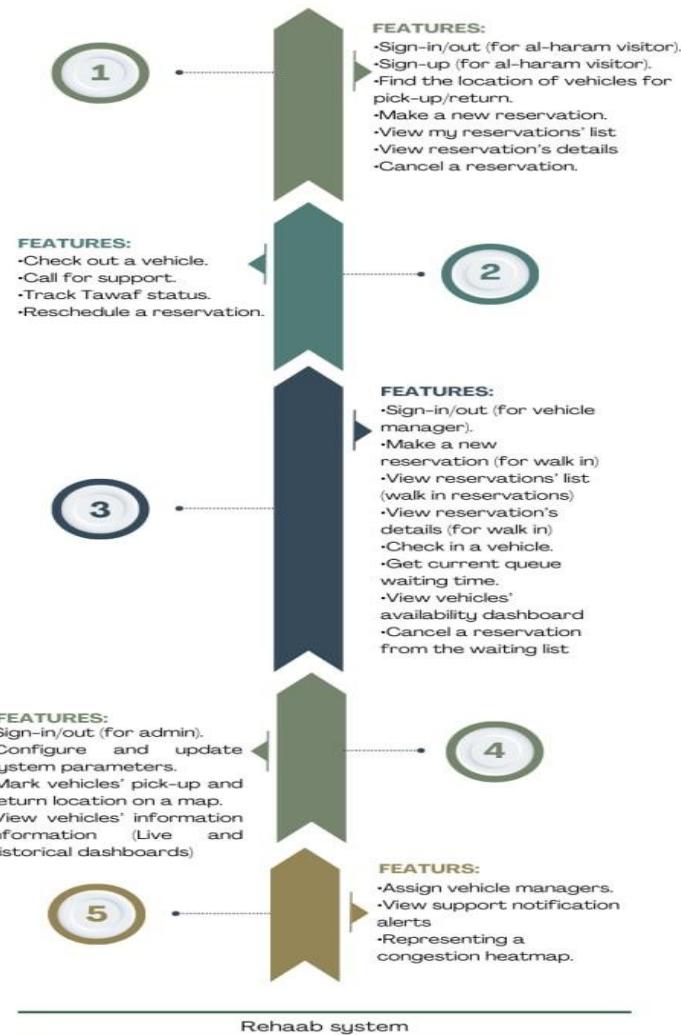


Figure 22. roadmap

**Table 2.Roadmap**

Sprint #	Release date	Features
Sprint 0	21/September/2023	The goal of sprint 0 is to study the background of the domain, search the literature review, study the system users, elicit the requirements, design the system architecture, and create the product backlog.
Sprint 1	19/October/2023	<ul style="list-style-type: none"> <li>•Sign-in/out (for al-haram visitor).</li> <li>Sign-up (for al-haram visitor).</li> <li>•Find the location of vehicles for pick-up/return.</li> <li>•Make a new reservation.</li> <li>•View my reservations' list</li> <li>•View reservation's details</li> <li>•Cancel a reservation.</li> </ul>
Sprint 2	30/November/2023	<ul style="list-style-type: none"> <li>•Check out a vehicle.</li> <li>•Call for support.</li> <li>•Track Tawaf status.</li> <li>•Reschedule a reservation.</li> </ul>
Sprint 3	15/February/2024	<ul style="list-style-type: none"> <li>•Sign-in/out (for vehicle manager).</li> <li>•Make a new reservation (for walk in)</li> <li>•View reservations' list (walk in reservations)</li> <li>•View reservation's details (for walk in)</li> <li>•Check in a vehicle.</li> <li>•Get current queue waiting time.</li> <li>•View vehicles' availability dashboard</li> <li>•Cancel a reservation from the waiting list</li> </ul>
Sprint 4	21/March/2024	<ul style="list-style-type: none"> <li>•Sign-in/out (for admin).</li> <li>Configure and update system parameters.</li> <li>•Mark vehicles' pick-up and return location on a map.</li> <li>•View vehicles' information (Live and historical dashboards)</li> </ul>
Sprint 5	21/May/2024	<ul style="list-style-type: none"> <li>•Assign vehicle managers.</li> <li>•View support notification alerts</li> <li>•Representing a congestion heatmap.</li> </ul>

Now we will present Rehaab system's product backlog:

Sprint 1					
ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledge acquisition)	Status (To do, in progress, or done)	Acceptance criteria (The conditions of satisfaction that must be met for that item to be accepted.)
1	As an al-haram visitor, I want to be able to sign up to the application so that I can reserve a vehicle and get benefits from the application's features.	3	Feature	Done	<p>As an al-haram visitor, If I use the application for the first time, then I should sign up in the sign-up page by filling in the following required information (Full name, Email, Password, Confirm Password) and click on "sign up" button.</p> <p>As an al-haram visitor, If I enter invalid information and click "sign up" button, then an error message should appear which indicates that the information is invalid. As an al-haram visitor, If I leave one of the fields empty and click on "sign up" button, then an error message should appear indicating that there are empty fields.</p>

## Sprint 1

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					<p>As an al-haram visitor, If I enter valid information with a strong password that contains (At least 8 characters, including one lowercase letter, one uppercase letter, one special character, and one digit) in the (sign-up page) and click on "sign up" button, then a verification message will be sent to my email to verify and to complete the signing up process.</p> <p>As an al-haram visitor, If I verified my email, then I am successfully signed up and able to use the application</p>
2	As an al-haram visitor, I want to be able to sign out from my account so that I can terminate my activity and close the application.	1	Feature	Done	As an al-haram visitor, If I click on "sign out" button in the (my profile), then a confirmation pop-up window must appear to confirm sign out process.

## Sprint 1

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					<p>As an al-haram visitor, if I click on "confirm" then I should be directed to the sign in page.</p> <p>As an al-haram visitor, if I click on "back" the sign out process will be terminated, and I will be returned to the in-process page (settings page).</p>
3	As an al-haram visitor, I want to be able to sign in the application so that I can access my information and use the application.	3	Feature	Done	As an al-haram visitor, If I am signed up user and go to the (sign in page) and enter valid information (email, password) and click on "sign in" button, then I should be directed to the (home page) and able to access my information.

## Sprint 1

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					<p>As an al-haram visitor, If I am signed up user and go to the (sign in page) and enter incorrect email or password and click on "sign in" button, then the sign in process fails and an error message should appear indicating that email or password is incorrect.</p> <p>As an al-haram visitor, If I am a signed-up user and go to the (sign in page) and did not enter an email or password, and click on "sign in" button, then the sign-in process fails, and an error message should appear indicating that email or password is missing.</p>

## Sprint 1

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					<p>As an al-haram visitor, If I am signed up user and forgot my password or want to change it and click on "forgot password" option, then "forgot password page" will open to enter my email then I click on "send email" button then an email message should be sent to enter the new password.</p> <p>As an Al-haram visitor, if I enter an unregistered email during sign-in, then the process should fail with a clear error message indicating the email is not registered.</p> <p>As an Al-haram visitor, if I did not verify my email and want to sign in and enter my email, then the process</p>

## Sprint 1

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					should fail with a clear error message indicating the email is not verified.
4	As an al-haram visitor, I want to be able to reserve a vehicle so that I can perform tawaf easily.	3	Feature	Done	<p>As an al-haram visitor, If I am in (home page) and click on "reserve vehicle" option, then I should be directed to (reserve vehicle page).</p> <p>As an al-haram visitor, If I am in (reserve vehicle page) and choose time (24 hours) and date (up to 3 months) and type of vehicle (single/double) and type of driving (self-driving) and click on "reserve" button, then a confirmation pop-up window should appear to confirm the reservation.</p>

## Sprint 1

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					<p>As an al-haram visitor, If I am in (reserve vehicle page) and choose the time (24 hours) and date (up to 3 months) and type of vehicle (single/double) and type of driving (with a driver) then I should choose gender type of driver (female/male) and click on "reserve" button, then a confirmation pop-up window should appear to confirm the reservation.</p> <p>As an al-haram visitor, if I click on "confirm" then the database should be updated, and a barcode should be generated.</p>

## Sprint 1

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					<p>As an al-haram visitor, if I click on "back" the reservation process will be terminated and I will be returned to the in-process page (reserve vehicle page).</p> <p>As an al-haram visitor, If I am in (reserve vehicle page) and don't choose time (24 hours) or date (up to 3 months) or type of vehicle (single/double) or type of driving (self-driving/with a driver) or type of driver (female/male) "in case choosing (with a driver)" and click on "reserve" button, then an error message should appear indicating that one of the options aren't choosed.</p>

## Sprint 1

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5	As an al-haram visitor I want to view my reservations details so that I can know the details of the reservation and make other choices which are cancellation and rescheduling.	3	Feature	Done	<p>As an al-haram visitor, if I am in (home page) and click on "my reservations " option in the navigation bar, then I should be directed to (my reservations page) then a list of my current and previous reservations should appear.</p> <p>As an al-haram visitor, if I am in (my reservations page) and click on "view details " button, then I should be directed to (reservation details page).</p> <p>As an al-haram visitor, If I am in (reservation details page), then I should be able to view my reservation information.</p>

## Sprint 1

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6	As an al-haram visitor I want to view my reservations list so that I can be able to view my current/previous reservations.	3	Feature	Done	<p>As an al-haram visitor, if I am in (home page) and click on "my reservations " option in the navigation bar, then I should be directed to (my reservations page).</p> <p>As an al-haram visitor, if I am in (my reservations page), then I should be able to see a list of my confirmed, completed, cancelled and active reservations.</p>
7	As an al-haram visitor, I want to be able to find vehicles pickup/return location so that I can pick up/return the vehicle easily.	2	Feature	Done	As an al-haram visitor, If I am in (home page) and click on "find location" option, then I should be directed to (vehicles location page).

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					<p>As an al-haram visitor, If I am in (vehicles location page), then I should be able to view vehicles pickup/return location.</p> <p>As an al-haram visitor, If I click on the vehicle marker on the map, then an information window should pop up indicating the description of the location.</p>
8	As an al-haram visitor, I want to be able to cancel my reservation so that I can change my reservation.	3	Feature	Done	As an Al-haram visitor, if I am in (home page) and click on "my reservations " option in the navigation bar, then I should be directed to (my reservations page) then a list of my current, upcoming, and previous reservations should appear.

## Sprint 1

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledge acquisition)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As an Al-haram visitor, If I am in (my reservations page) and click on "view details" button, then I should be directed to (reservation details page).</p> <p>As an Al-haram visitor, If I am in (reservation details page) and click on “cancel reservation” button - the cancellation is allowed only if it is requested at least 24 hours before the scheduled reservation time, then a confirmation pop-up window should appear to confirm cancellation.</p> <p>As an Al-haram visitor, if I click on "confirm" then the cancellation process will be done, and the database is updated.</p>

## Sprint 1

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					As an Al-haram visitor, if I click on "back" then the cancellation process will be terminated, and the system will return me to the in-process page (reservation details page).

## Sprint 2

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledge acquisition)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
9	As an al-haram visitor, I want to be able to reschedule my reservation so that I can postpone it to another time.	3	Feature	Done	<p>As an Al-haram visitor, if I am in (home page) and click on "my reservations " option in the navigation bar, then I should be directed to (my reservations page) then a list of my current, upcoming, and previous reservations should appear.</p> <p>As an Al-haram visitor, If I am in (my reservations page) and click on "view details" button, then I should be directed to (reservation details page).</p> <p>As an Al-haram visitor, If I click on "reschedule reservation" button - the rescheduling is allowed only if it is requested at least 24 hours before the scheduled reservation time-, then I should be directed to (reschedule page).</p>

## Sprint 2

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledge acquisition)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As an Al-haram visitor, If I am in (reschedule page) and choose a date (up to 3 months) and time (24 hours) and click on "reschedule" button, then a confirmation pop-up window should appear to confirm rescheduling.</p> <p>As an Al-haram visitor, If I click on "confirm", then the database should be updated, and a message appears indicating that the rescheduling process is done successfully.</p> <p>As an Al-haram visitor, If I click on "back", then the reschedule process will be terminated, and I will be returned to the in-process page (reschedule page).</p>

## Sprint 2

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledge acquisition)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
10	As an al-haram visitor, I want to be able to track my tawaf status so that I can know the approximate time left to finish and in which round I am.	5	Feature	Done	<p>As an al-haram visitor, If I am in (home page) and click on "track tawaf status" option, then I should be directed to (tawaf status page).</p> <p>As an al-haram visitor, If I click on "start tawaf" button, then a counter should be shown to know in which round I am.</p> <p>As an al-haram visitor, If I click on "start tawaf" button, and if I finished the first round, then a timer should be shown to know how much time is left to finish tawaf.</p> <p>As an al-haram visitor, if I click on “Pause” button, the counter and the timer should stop.</p>

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					As an al-haram visitor, If the application is not open or my phone is locked, then it should continue tracking.
11	As an al-haram visitor, I want to be able to call for support so that I can solve my problem.	3	Feature	Done	<p>As an Al-haram visitor, If I am in (home page) and click on "call support" button (with active reservation after checking in), then I should be directed to (support page).</p> <p>As an Al-haram visitor, if I am in (support page) and select one of the following buttons (empty battery/ sudden stop) as the problem type or describe the problem and click on “send” button, then my request with my location should be sent to the vehicle managers and admin. so, they can find me and offer me help.</p>

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ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledge acquisition)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As an Al-haram visitor, if I am in (support page) and did not select one of the following buttons (empty battery/ sudden stop) as the problem type or describe the problem and click on “send” button, then an error message should appear indicating that I did not enter the problem.</p> <p>As an Al-haram visitor, If I click on "confirm", then the database should be updated, and a message appears indicating that the call for support request is sent successfully.</p> <p>As an Al-haram visitor, If I click on "back", then the call for support process will be terminated, and I will be returned to the in-process page (support page).</p>

## Sprint 2

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					As an Al-haram visitor, if I am in (support page) and did not select one of the following buttons (empty battery/ sudden stop) as the problem type or describe the problem and click on “send” button, then an error message should appear indicating that I did not enter the problem.
12	As an Al-haram visitor, I want to be automatically checked out when my Tawaf ends so that I can have a convenient and efficient experience without the need for manual check-out procedures.	3	Feature	Done	As an Al-haram visitor, if my reservation has been activated by the vehicle manager and I finish my Tawaf and move away from the Tawaf area then I should be checked out automatically, and the database should be updated.

## Sprint 2

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c	As an al-haram visitor, I want to be able to reschedule my reservation so that I can postpone it to another time.	3	Feature	Done	As an Al-haram visitor, if I am in (home page) and click on "my reservations " option in the navigation bar, then I should be directed to (my reservations page) then a list of my current, upcoming, and previous reservations should appear.

## Sprint 2

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledge acquisition)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As an Al-haram visitor, If I am in (my reservations page) and click on "view details" button, then I should be directed to (reservation details page).</p> <p>As an Al-haram visitor, If I click on "reschedule reservation" button - the rescheduling is allowed only if it is requested at least 24 hours before the scheduled reservation time-, then I should be directed to (reschedule page).</p> <p>As an Al-haram visitor, If I am in (reschedule page) and choose a date (up to 3 months) and time (24 hours) and click on "reschedule" button, then a confirmation pop-up window should appear to confirm rescheduling.</p>

## Sprint 2

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					<p>As an Al-haram visitor, If I click on "confirm", then the database should be updated, and a message appears indicating that the rescheduling process is done successfully.</p> <p>As an Al-haram visitor, If I click on "back", then the reschedule process will be terminated, and I will be returned to the in-process page (reschedule page).</p>

### Sprint 3

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
13	As a vehicle manager, I want to be able to sign in so that I can use the application and its features.	3	Feature	Done	<p>As a vehicle manager, If I go to the (sign in page) and enter correct (email, password) and click on "sign in" button, then I should be directed to the home page and able to access my information.</p> <p>As a vehicle manager, If I go to the (sign in page) and enter incorrect (email or password) and click on “sign in” button, then the sign in process fails and an error message should appear indicating that email or password is incorrect.</p>

### Sprint 3

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As a vehicle manager, If I go to the (sign in page) and did not enter the email or password, and click on "sign in" button, then the sign-in process fails, and an error message should appear indicating that email or password is missing.</p> <p>As a vehicle manager, If I forgot my password or want to change it and click on "forgot password" option, then “forgot password page” will open to enter my email then I click on “send email” button then an email message should be sent to enter the new password.</p>
14	As a vehicle manager, I want to be able to sign out so that I can	1	Feature	Done	As a vehicle manager, If I am in (settings page) and click on “sign out” button, then a confirmation pop-up window must appear to confirm sign out process.

### Sprint 3

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	terminate my activity and close the application.				<p>As a vehicle manager, if I click on “confirm” then I should be directed to the sign in page.</p> <p>As a vehicle manager, if I click on “back” the sign out process will be terminated, and I will be returned to the in-process page (settings page).</p>
15	As a vehicle manager, I want to be able to reserve vehicles for walk-in people so that they can perform tawaf.	5	Feature	Done	As a vehicle manager, If I am in (home page) and click on “reserve vehicle” option, then I should be directed to (reserve vehicle page).

### Sprint 3

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As a vehicle manager, If I am in (reserve vehicle page) and choose type of vehicle (single/double) and driving type (self-driving) and enter valid (name, phone number [optional]), and click on “reserve” button, then a confirmation pop-up window should appear to confirm the reservation.</p> <p>As a vehicle manager, If I am in (reserve vehicle page) and choose type of vehicle (single/double) and driving type (with a driver) and then choose type of driver (female/male) and enter valid (name, phone number [optional]), and click on "reserve" button, then a confirmation pop-up window should appear to confirm the reservation.</p>

### Sprint 3

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As a vehicle manager, If I am in (reserve vehicle page) and do not choose type of vehicle (single/double) or type of driving (self-driving/with a driver) or type of driver(female/male) “in case of choosing (with a driver)” and click on “reserve” button, then an error message should appear indicating that one of the options are not chosen.</p> <p>As a vehicle manager, If I leave “name” field empty, then an error message should appear indicating that the field “name” is empty.</p>

### Sprint 3

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As a vehicle manager, if I click on “confirm,” then a reservation id should be generated, and the database should be updated (the reservation status in (reservations page) is updated).</p> <p>As a vehicle manager, if I click on “back” the reservation process will be terminated and I will be returned to the in-process page (reserve vehicle page).</p>
16	As a vehicle manager, I want to view the reservation details so that I can know the details of the reservation.	3	Feature	Done	As a vehicle manager, if I am in (home page) and click on “the reservations” option in the navigation bar, then I should be directed to (the reservations page) then a list of current and waiting walk-in visitors’ reservations should appear.

### Sprint 3

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					<p>As a vehicle manager, if I am in “current” tab in (the reservations page) and click on “view details” button, then I should be directed to (reservation details page).</p> <p>As a vehicle manager, If I am in (reservation details page), then I should be able to view the reservation information.</p>

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17	As a vehicle manager, I want to be able to view all current and waiting reservations for walk-in so that I can see their priorities to use the next available vehicle.	3	Feature	Done	<p>As a vehicle manager, if I am in (home page) and click on “the reservations” option in the navigation bar, then I should be directed to (the reservations page).</p> <p>As a vehicle manager, if I am in (the reservations page), then a list of current and waiting walk-in visitors’ reservations should appear.</p>
18	As a vehicle manager, I want to be able to cancel reservation from the waiting list for walk in so that they can change their reservation.	3	Feature	Done	<p>As a vehicle manager, if I am in (home page) and click on “the reservations” option in the navigation bar, then I should be directed to (reservations page) then a list of current and waiting walk-in visitors’ reservations should appear.</p>

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					<p>As a vehicle manager, If I am in “waiting” tab in (reservations page) and click on “remove” button, then a confirmation pop-up window should appear to confirm cancellation.</p> <p>As a vehicle manager, if I click on “confirm” then the database should be updated, and a message appears indicating that the cancellation process will be done.</p> <p>As a vehicle manager, if I click on “back” then the cancellation process will be terminated, and I will be returned to the in-process page (reservation details page).</p>

### Sprint 3

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					As a vehicle manager, if I didn't cancel a reservation from the waiting list within 5 minutes after the scheduled reservation time has passed, then the system will automatically cancel the reservation.
19	As a vehicle manager, I want to be able to view the expected finish time for the next available vehicle (in case all vehicles are occupied) so that I can inform walk-in people how much time they need to wait.	5	Feature	Done	<p>As a vehicle manager, if I am in (home page) and click on "Reserve vehicle" option , then I should be directed to (Reserve vehicle page).</p> <p>As a vehicle manager, If I am in (Reserve vehicle page), then I should be able to view the expected finish time for the next available vehicle (in case all vehicles are occupied).</p>

### Sprint 3

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20	As a vehicle manager, I want to be able to check in people who reserved vehicles so that they can use the vehicle and start tawaf.	5	Feature	Done	<p>As a vehicle manager, If I am in (home page) and click on “check in” option, then I should be directed to (check in page).</p> <p>// for people who reserved through the application.</p> <p>As a vehicle manager, If I am in (check in page) and put the QR code inside the scan area, then the scanning will start automatically.</p> <p>As a vehicle manager, If I scan correct reservation barcode, then a message should appear indicating that the checking in process done successfully, and</p>

### Sprint 3

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					<p>the database should be updated (the reservation status in al-haram visitor's interface (my reservation page) is updated to "active").</p> <p>As a vehicle manager, If I scan incorrect reservation barcode, then an error message should appear indicating that the QR code is invalid and the check in process will be terminated, and I will be returned to the in-process page (check in page).</p>

### Sprint 3

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria (The conditions of satisfaction that must be met for that item to be accepted.)
21	As a vehicle manager, I want to be able to view simple dashboard so that I know vehicles' availability information.	1	Feature	Done	As a vehicle manager, If I am in (home page) then I should be able to see a dashboard containing vehicles' availability information.

## Sprint 4

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
22	As an admin, I want to be able to sign in so that I can view and edit the system parameters.	3	Feature	Done	<p>As an admin, If I am in sign in page and enter valid (email, password) and click on “sign in” button, then I should be directed to the (home page) and able to access my information.</p> <p>As an admin, If I enter incorrect (email or password) and click on “sign in” button, then the sign in process fails and an error message should appear indicating that email or password is incorrect.</p> <p>As an admin, If I go to the sign in page and did not enter the email or password, and click on "sign in" button, then the sign-in process fails, and</p>

## Sprint 4

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>an error message should appear indicating that email or password is missing.</p> <p>As an admin, If I forgot my password or want to change it and click on “forgot password” option, then “forgot password page” will open to enter my email then I click on “send email” button then an email message should be sent to enter the new password.</p>
23	As an admin, I want to be able to sign out from my account so that I	1	Feature	Done	As an admin, If I click on "sign out" button in the sidebar menu, then a confirmation pop-up window must appear to confirm sign out process.

## Sprint 4

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
	can terminate my activity and close the application.				<p>As an admin, if I click on "confirm" then I should be directed to the sign in page.</p> <p>As an admin, if I click on "back" the sign out process will be terminated, and I will be returned to the in-process page.</p>
24	As an admin, I want to be able to change system parameters so that I can update them based on the season.	3	Feature	Done	As an admin, If I am in (update and configure page) and I want to update the “System information” form and change one of the following fields (number of vehicles for Al-haram visitors (single/double), number of vehicles for walk in (single/double), number of backup vehicles( single/double)) and click on “update” button, then a confirmation popup window should appear to confirm the update.

## Sprint 4

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
					<p>As an admin, if I click on “confirm” then the parameters will be updated successfully, and the database should be updated.</p> <p>As an admin, if I click on “back” then the update process will be terminated, and I will be returned to the in-process page (update and configure page).</p>
25	As an admin, I want to be able to mark vehicles’ pickup/return	3	Feature	Done	As an admin, If I am in (update and configure page) a map will be displayed and the admin can manually set the marker and click on “update” button, then a confirmation pop-up window should appear to confirm the update.

## Sprint 4

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
	location so that al-haram visitors can find the vehicles.				<p>As an admin, if I click on “confirm” then the mark on the map should change.</p> <p>As an admin, if I click on “back” then the process will terminate, and I will be returned to the in-process page (update and configure page).</p>
26	As an admin, I want to be able to view vehicles' information so that	3	Feature	Done	As an admin, If I am in (dashboard page), then I should be able to view a comprehensive dashboard (containing the vehicles' information) for the entire system.

## Sprint 4

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work, knowledg e acquisitio n)	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
	I can monitor the entire system.				

## Sprint 5

ID	PBIs (User Stories)	Size	Type (Feature, defect, technical work,	Status (To do, in progress, or done)	Acceptance criteria  (The conditions of satisfaction that must be met for that item to be accepted.)
----	---------------------	------	--	---	--

			knowledge acquisition)		
27	As an admin, I want to be able to track vehicles so that I can detect congestion.	8	Feature	Done	As an admin, If I am in (dashboard page), then I should be able to view a heatmap which shows the movement of the vehicles.
28	As an admin, I want to be able to assign vehicle managers so that they can use the application.	3	Feature	Done	<p>As an admin, If I am in (assign managers page) and I fill in the “assign managers” form with the following required correct information (Full name, Email, Task) and click on “Add” button, then a message appear that the adding process has been done successfully.</p> <p>As an admin, If I enter invalid email (already exist in database) and click on “Add” button, then an error message should appear which indicates that the email is already exist.</p> <p>As an admin, If I leave an empty field in the form and click on “Add” button, then an error message should appear which indicates that there is empty field.</p>

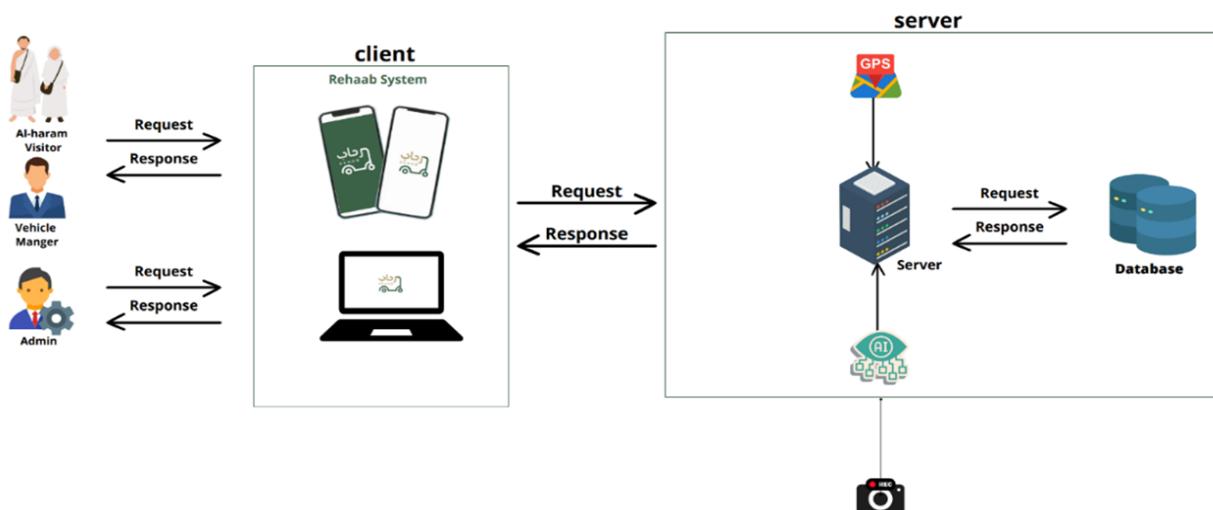
29	As an admin, I want to be able to view support notification alerts from al-haram visitors.	3	Feature	Done	As an admin, If I am in (dashboard page), then I should be able to view a map with list of support notifications. These notifications should indicate the time each support request was reported, the type of problem, the assigned vehicle manager and etc.
Non-functional requirements					
30	As a user I want to learn how to use the system in 30 minutes so that I can understand it easily and I can avoid doing something wrong. (usability)	3	Feature	Done	As a user, if I find out where the system's features are and how to deal with them easily after 30 minutes of training and my total number of errors did not exceed 20% then the system is easy to learn.
31	As a user, I want the system to load within 10 seconds so that I will not have to wait long for a specific page to load. (performance)	3	Feature	Done	As a user, if I tried to move from page to page and it took less than or equal to 10 seconds to load then the system is fast.

32	As a user, I want that system to be available 99% of the time, so that I can access it without any interruption or downtime. (availability)	3	Feature	Done	As a user, if I tried using the system at various times and the system was 99% available without any interruption or downtimes then the system is available.
33	As a user concerned about the security of my personal information, I want to ensure that the system enforces strong password requirements so that my account remains protected from unauthorized access. (security)	2	Feature	Done	As a user, if I created a new account and the system required a strong password (8 characters at least, at least one upper and lower letter, at least one numeric digit and at least one special character) then the system is secure.

## 4.2 System Design

### 4.2.1 Architectural Diagram

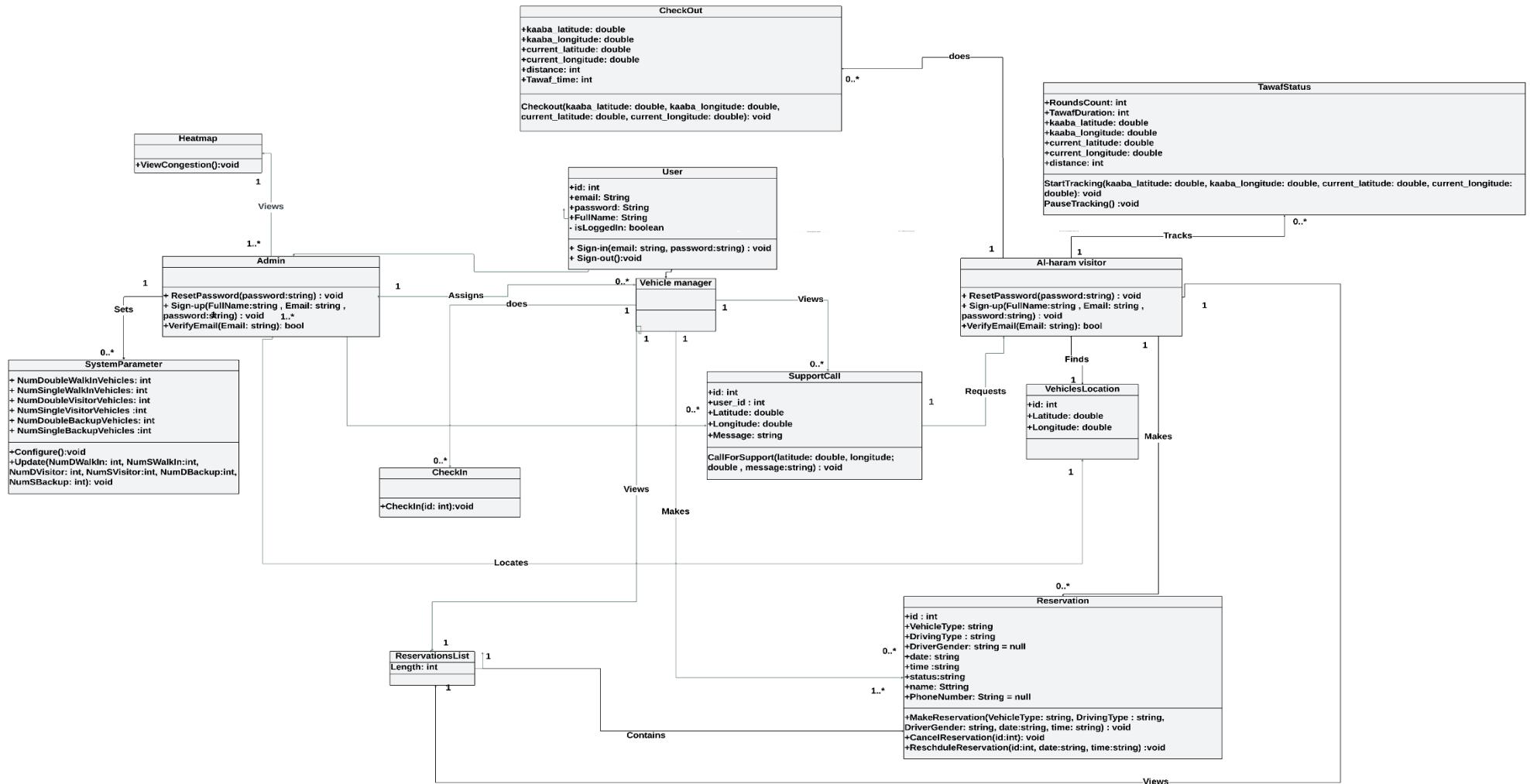
We chose client-server architecture for our system. "Rehaab" system depends on servers to respond to clients' requests, our clients are (Al-haram visitors, vehicle managers, and administrators). This architecture pattern is split into three parts: the client side, the server side, and the network. The client-side handles the user's interface and user's input while the server-side handles the database, APIs, and the GPS, and the network moves the data between them. The user will request a feature, (Al-haram visitors can request to sign in, sign up, sign out, make or cancel or reschedule a reservation, view the vehicles' location map, view its reservations list, and view its reservation details, call for support and track their tawaf status. Vehicle managers can request to sign in, sign out, make or cancel reservations (for walk-ins), view the walk-in reservations list, view reservation details (for walk-ins), check in a vehicle, and get the current queue waiting time. The administrator can request to sign in, sign up, sign out, configure, and update system parameters, mark vehicles' pick-up, and return location on a map, view vehicles' information, assign vehicle managers, view support notification alerts, and track vehicles and congestions by presenting heatmap). The client-side will send the request to the server side (the request can be a query, google map, coordinates by GPS or heatmap) the server side responds with the required data to the client side, and the client side will send the response to the user. We chose this architecture because of its scalability; additional clients can be easily added to the network without impacting the overall system. This makes it suitable for our system, which requires the ability to handle many users (al-haram visitors and vehicle managers). In this architecture, the server acts as a crucial point of control and management. This allows for easier administration, monitoring, and maintenance of the system. Also, it ensures that all users access the most up-to-date information which enables synchronization (in the reservations in our case).



**Figure 24. Architectural Diagram**

#### 4.2.2 Class Diagram /DFD

The class diagram for the Rehaab system, As shown in Figure 23, portrays the essential user classes: Al-haram Visitors, Administrators, and Vehicle Managers. Al-haram Visitors, representing users of the system, can perform account management tasks such as signing up, signing in, and resetting passwords. They also manage vehicle reservations, including actions like reserving, rescheduling, and canceling reservations, along with accessing reservation history and support features. Administrators possess similar user functionalities but hold additional administrative privileges, enabling them to oversee the entire system, configure parameters, and access live data. Vehicle Managers handle operational tasks related to vehicle reservations, ensuring smooth usage within the system. Overall, the class diagram delineates the roles and interactions of each user class, contributing to the efficient functioning of the Rehaab system.



*Figure 23. class diagram*

#### 4.2.3 Component Level Design

In this section, we present the component-level design using flowcharts for the following use cases:

For Al-haram visitors, we choose three use cases:

- Checking out a reservation.
- Track Tawaf status.
- Reserving a vehicle, including canceling, and rescheduling the reservation.

For the Vehicle manager, we choose one use case:

- Check in a reservation.

For Admin, we choose one use case:

- detect congestion through a heatmap.

A flowchart for checking out a vehicle shown in Figure 24.

Assuming that the distance between the Kaaba and Corridors/Roof Areas is between 90 and 120 meter [35].

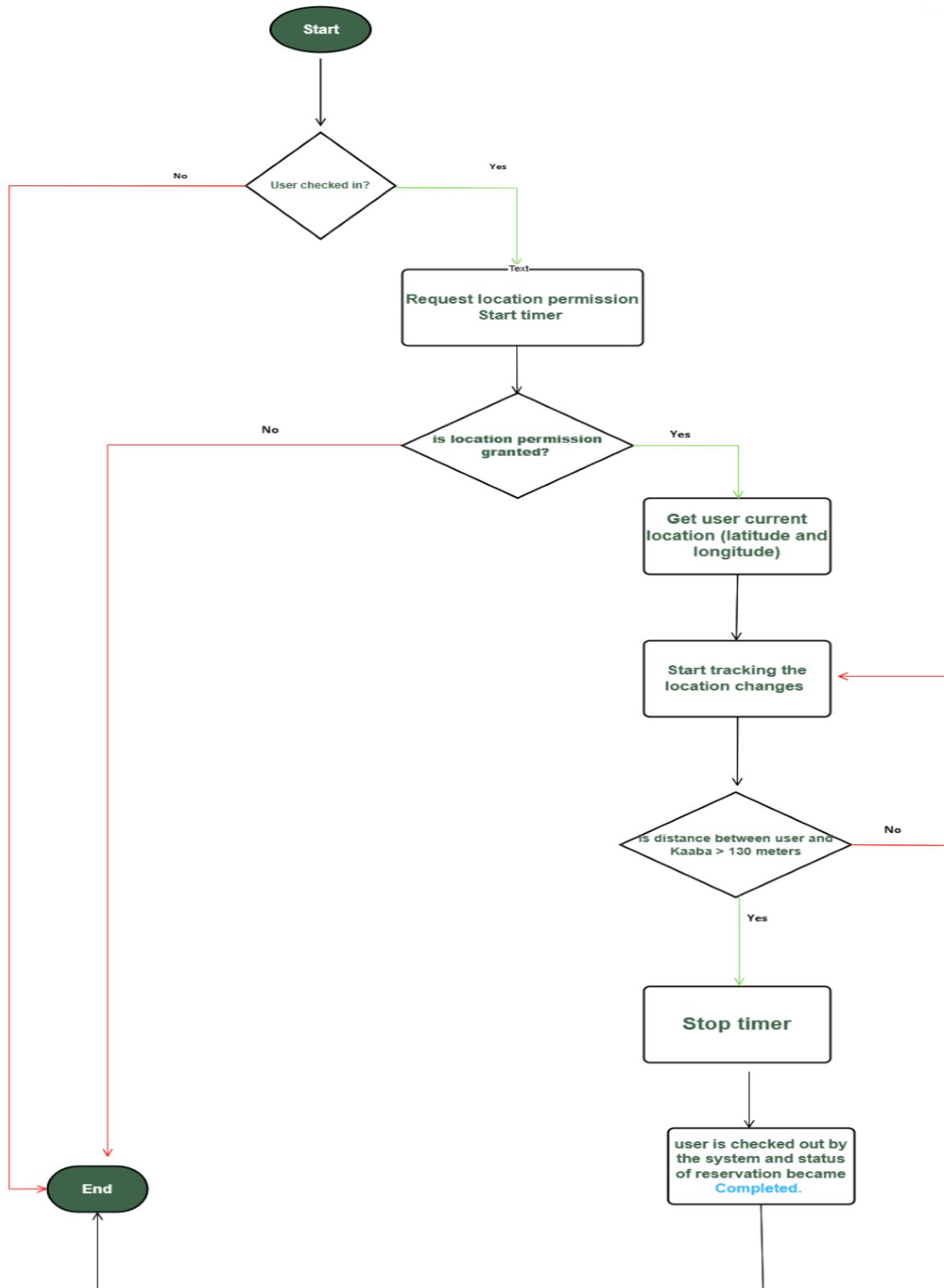


Figure 24. check out component level design

A flowchart for tracking the tawaf status process shown in Figure 25:

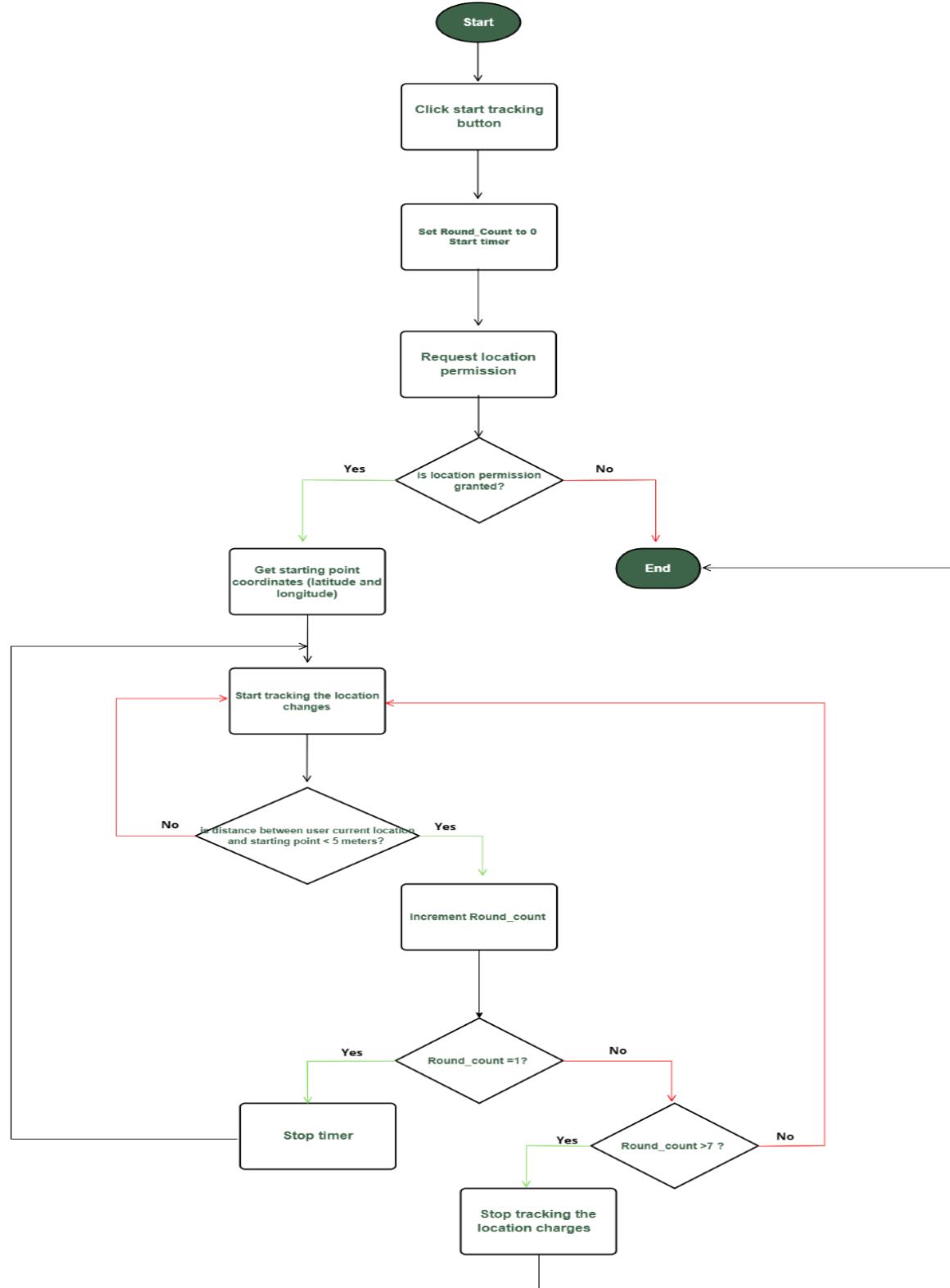
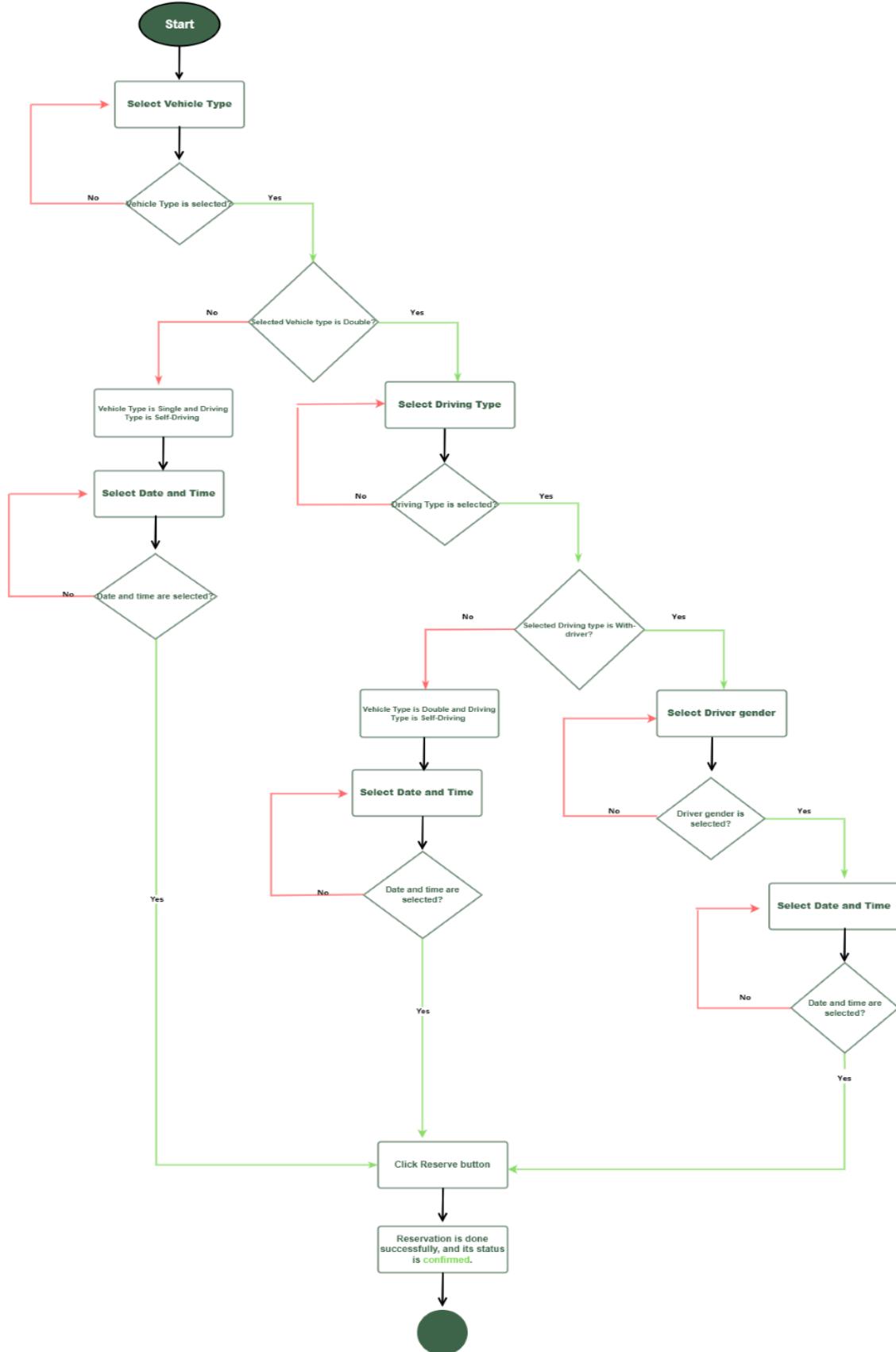
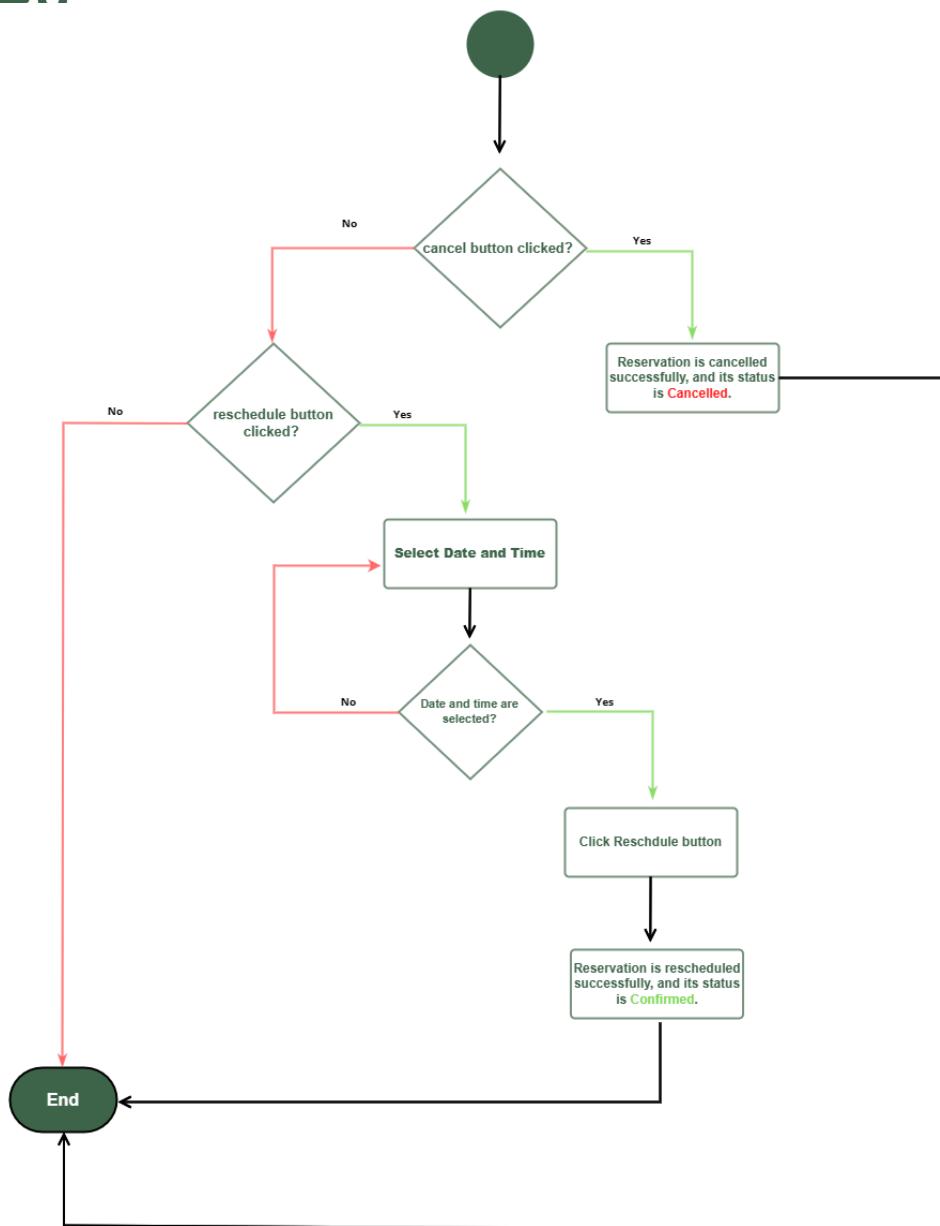


Figure 25. Track tawaf status component level design

A flowchart for reserving a vehicle, canceling, and rescheduling the reservation shown in Figure 26.





*Figure 26. reserve, cancel , and reschedule a reservation component level design*

A flowchart for checking in a reservation shown in Figure 27:

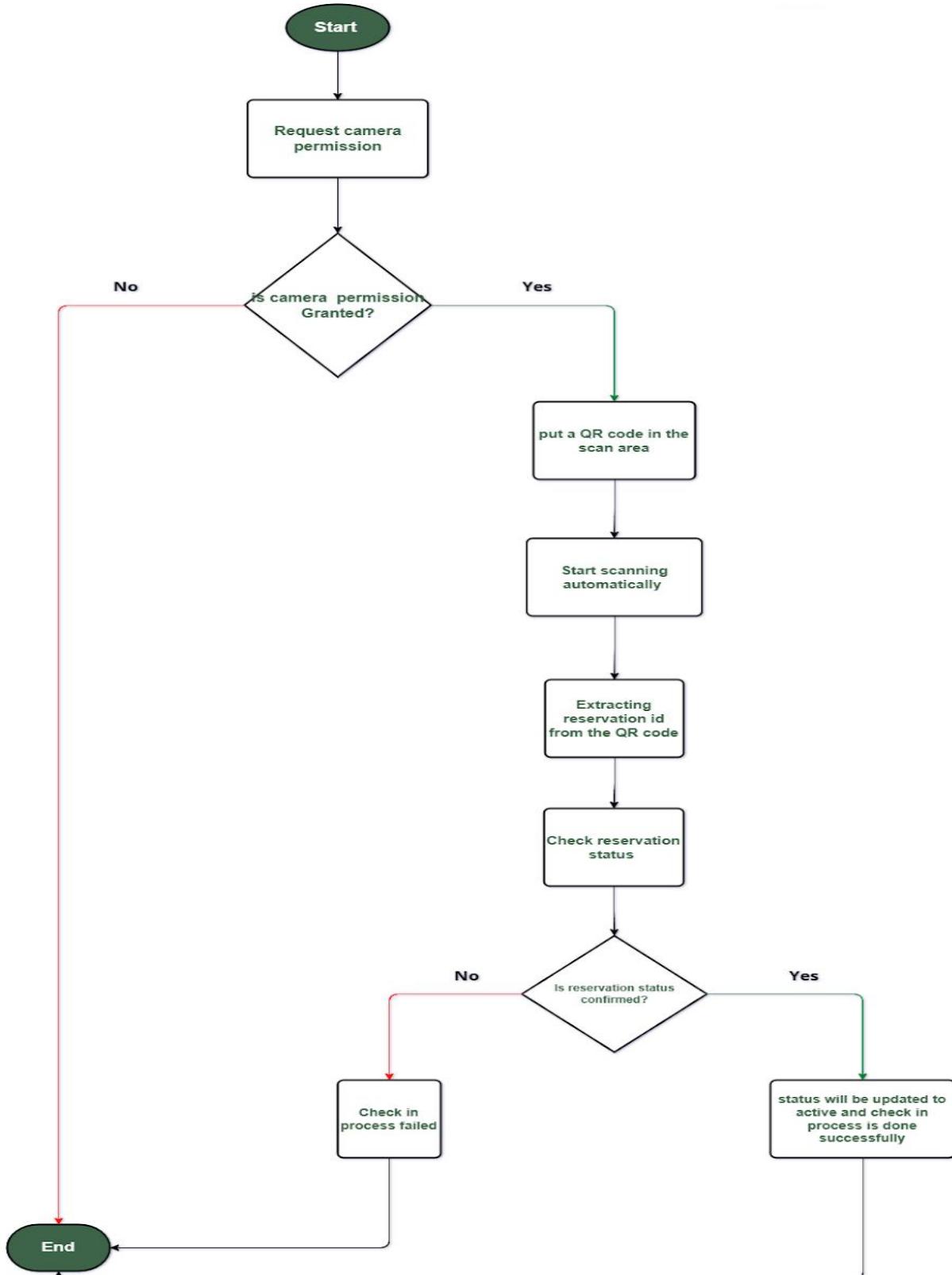
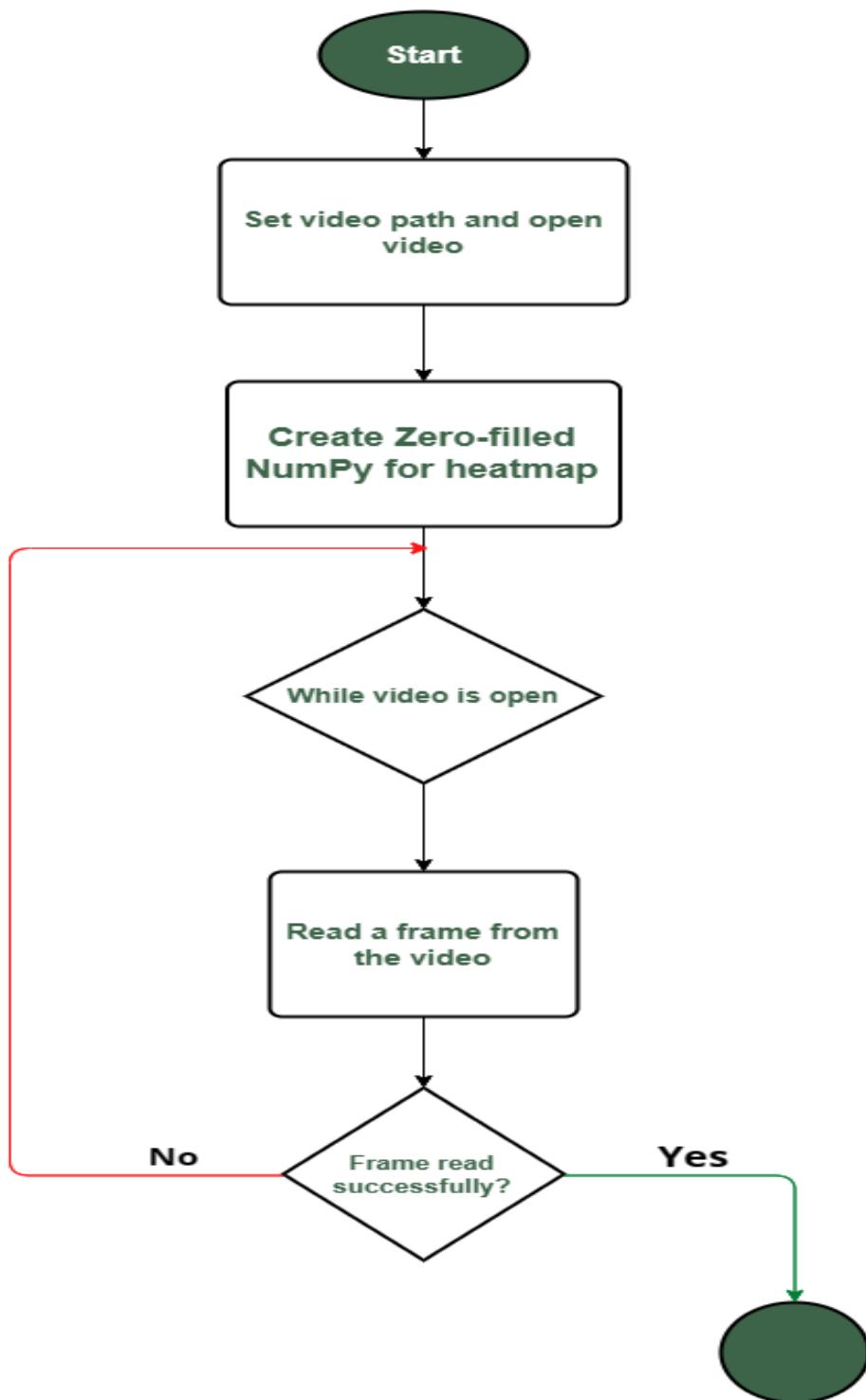
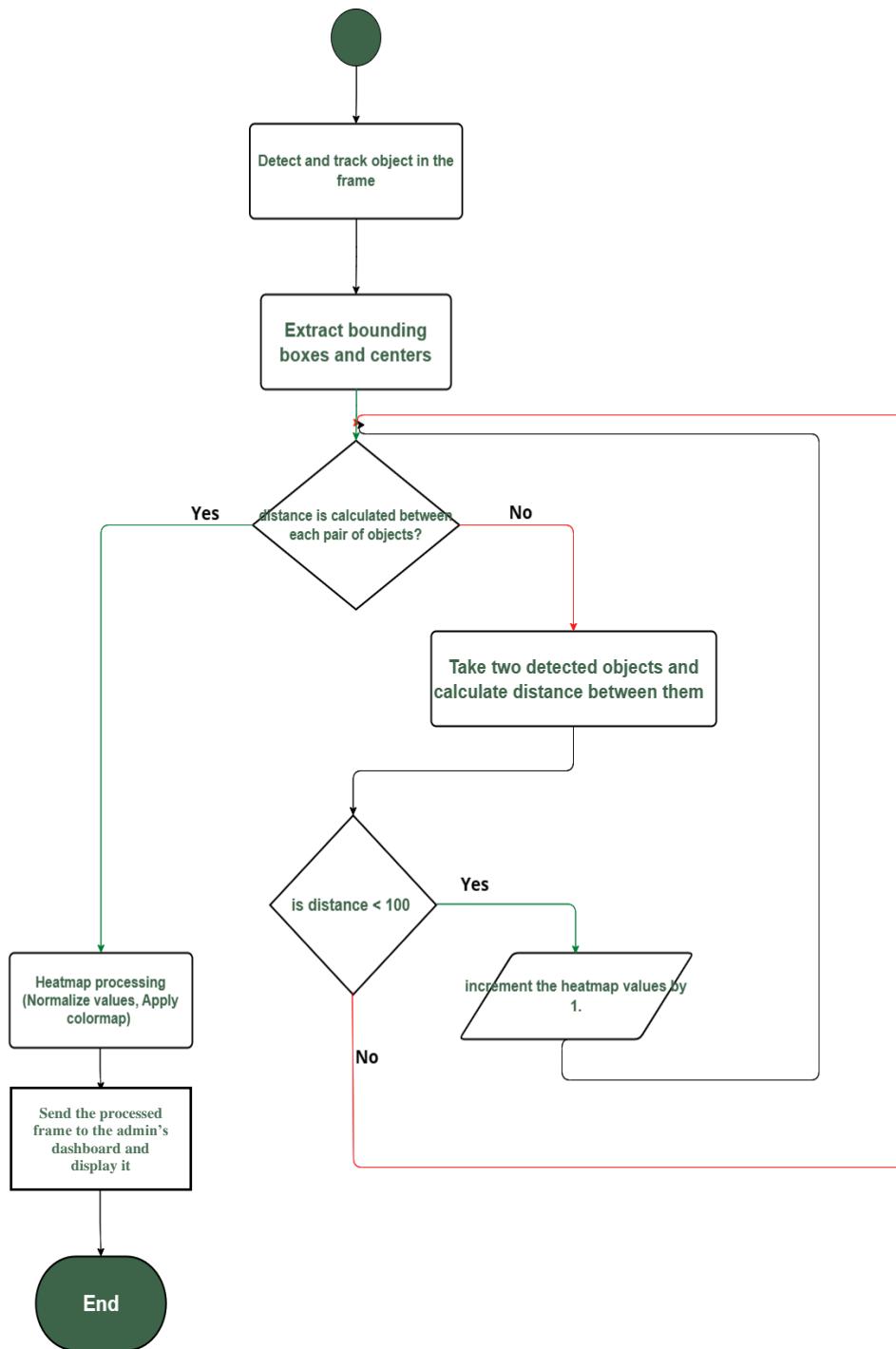


Figure 27. Checking in a reservation component level design

A flowchart for detecting congestion through a heatmap shown in Figure 28:





*Figure 28. Detecting congestion through a heatmap component level design*



### Model explanation:

The objective of this model is to detect and track motorcycles in video footage, visualizing high-density areas using an adaptive heatmap algorithm to identify congestion points and understand traffic patterns. The model comprises two main components: YOLO-based detection and tracking, and an adaptive heatmap algorithm. The YOLOv8 model, a state-of-the-art, pre-trained object detection model, identifies motorcycles (class 3) accurately and efficiently in real-time. The adaptive heatmap algorithm calculates distances between motorcycles to identify high-density areas, updates the heatmap based on motorcycle density, and introduces a decay factor to simulate traffic dispersion over time.

The algorithm follows these steps: First, it initializes the environment by importing necessary libraries, loading the YOLOv8 model, setting up video capture and writer, and initializing an empty heatmap. Next, it detects and tracks motorcycles by reading video frames, using YOLOv8 to detect motorcycles, and calculating the center of each bounding box [36]. Then, it updates the heatmap by calculating proximities between motorcycles and updating the heatmap accordingly, applying a decay factor to account for traffic dispersion. The visualization step smooths the heatmap, normalizes values, applies a color map, and blends it with the original video frames. Finally, the processed video with the heatmap overlay is saved, and frames are displayed in real time for feedback. This approach leverages the YOLOv8 model for accurate motorcycle detection, providing valuable insights into traffic density and patterns.

#### 4.2.4 Data Models

##### ER Diagram

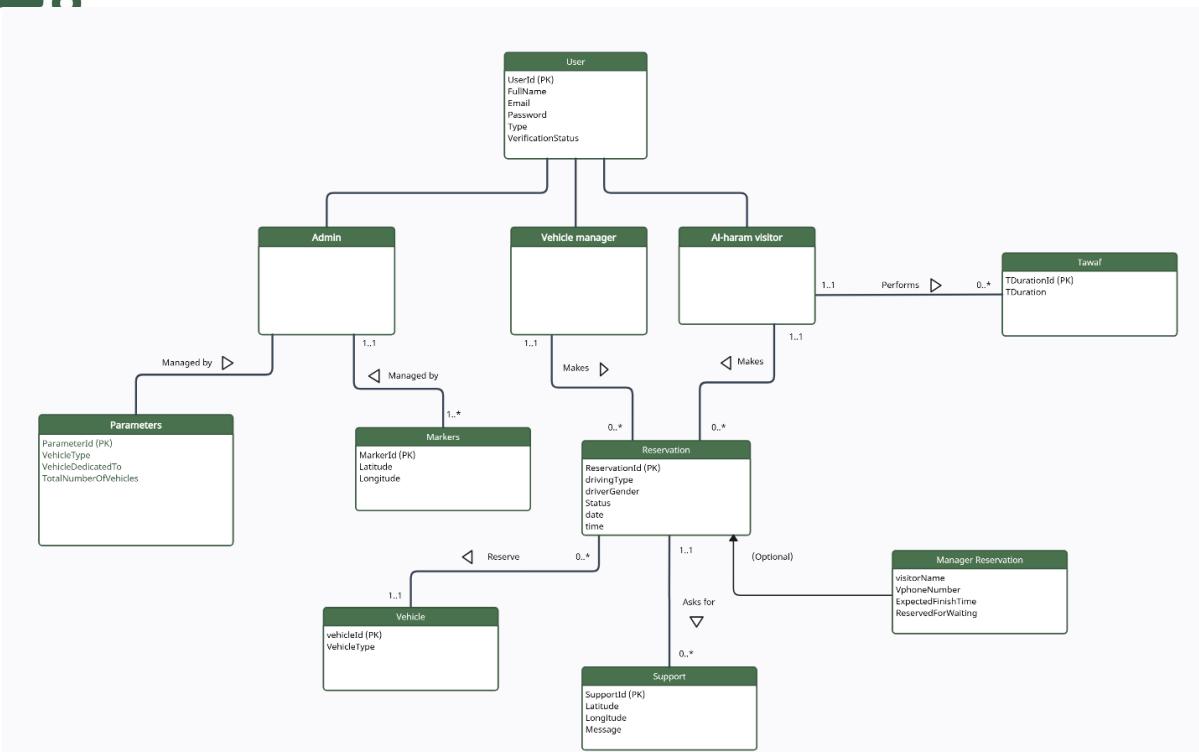


Figure 29.ER Diagram

## Relational Schema

User (UserId, FullName, Email, Password, Type, VerifyStatus)

Primary key: UserId

Reservation (ReservationId, time, date, VehicleId, drivingType, driverGender, ReservationStatus, visitorId, SlotId)

Primary key: ReservationId

Foreign key: visitorId references User (UserId)

Foreign key: SlotId references TimeSlots (SlotId)

Foreign key: VehicleId references Vehicle (vehicleId)

Vehicle (vehicleId, VehicleType)

Primary key: vehicleId

ManagerReservation (ReservationId, visitorName, VphoneNumber, ExpectedfinishTime, ReservedForWaiting)



Primary key and foreign key: ReservationId

Markers (MarkerId, Latitude, Longitude)

Primary key: MarkerId

Tawaf (TDurationId, TDuration, UserId)

Primary key: TDuarionId

Foreign key: UserId references User (UserId)

Support (SupportId, Latitude, Longitude, Message, ReservationId)

Primary key: SupportId

Foreign key: ReservationId references Reservation (ReservationId)

Parameters (ParametersId, VehicleType, VehicleDedicatedTo, TotalNumberOfVehicles)

Primary key: ParametersId

## Data Dictionary

**Table 3. Data dictionary for entities**

Entity name	Description	Occurence
<b>Al-haram visitor</b>	The user uses the application to reserve al-haram vehicle.	Al-haram visitor makes zero or more reservations.  Al-haram visitor asks for zero or more support.  Al-haram visitor performs zero or more tawaf.
<b>Vehicle Manager</b>	The manager who uses the application to reserve for walk-in.	Vehicle manager makes zero or more reservations.
<b>Admin</b>	The admin who uses the website to view the system as whole.	Admin manages parameters.  Admin manages markers.
<b>Reservation</b>	It is information about reservations for diverse types of vehicles made by users Al-haram visitor.	Each reservation belongs to only one Al-haram visitor.

<b>Markers</b>	The coordinates for the pickup and return locations of vehicles.	The markers are managed by the Admin.
<b>Tawaf</b>	It is the duration taken by Al-haram visitor to perform tawaf.	Each Tawaf is performed by only one Al-haram visitor.
<b>Support</b>	It is the support for which Al-haram visitor who has reservation can ask for.	Each support is asked by only one Al-haram visitor.
<b>Parameters</b>	It is information about number of vehicles.	Parameters managed by the Admin.
<b>Vehicle</b>	<p>It is the vehicle that can be reserved from users.</p> <p>Each vehicle is reserved by only one Al-haram visitor.</p> <p>Each vehicle is reserved by only one Vehicle manager.</p>	

**Table 4. Data dictionary for relationships**

Entity name	Multiplicity	Relationship	Entity name	Multiplicity
Al-haram visitor	1..1	Performs	Tawaf	0.. *
Al-haram visitor	1..1	Asks for	Support	0.. *
Al-haram visitor	1..1	Makes	Reservation	0.. *
Vehicle manager	1..1	Makes	Reservation	0.. *
Markers	1.. *	Managed by	Admin	1..1
Reservation	1..1	Reserve	Vehicle	1..1
Reservation	1..1	Optional, and	ManagerReservation	1..1
Parameters	1.. *	Managed by	Admin	1..1

Table 5. Data dictionary for attributes

Entity name	Attribute	Description	Data type	Length	Nulls	Multi-valued	Default value	PK	FK
User	UserId	Uniquely identifies user	Integer	11				Yes	
	FullName	User's fullname	String	30					
	Email	User's unique email	String	200					
	Password	String of characters, numbers, symbols	String	255					
	Type	User type (Admin/ Al-haram visitor/ Vehicle manager)	String	30			Al-haram visitor		
	VerificationStatus	User's authentication	Integer	11			0		
Reservation	ReservationId	Uniquely identifies reservation	Integer	20				Yes	
	visitorId	Uniquely identifies users	Integer	20					Yes
	VehicleType	Type of vehicle (single/double)	String	6					
	drivingType	Type of driving the vehicle (self-driving/with-driver)	String	20					
	driverGender	Gender of driver	String	20	Yes				
	ReservationStatus	Status of the reservation	String	20					
	Date	Reservation date (dynamic taken from api calendar in the system)	String	10					
Tawaf	TDurationId	Uniquely identifies tawaf duration	Integer	11				Yes	
	UserId	Uniquely identifies user	Integer	11					Yes
	TDuration	The duration of performing Tawaf	Decimal	10,0					

Entity name	Attribute	Description	Data type	Length	Nulls	Multi-valued	Default value	PK	FK
Support	SupportId	Uniquely identifies support	Integer	11				Yes	
	ReservationId	Uniquely identifies reservation	Integer	11					Yes
	Latitude	Latitude of user's location (Al-haram visitor)	Double						
	Longitude	Longitude of user's location (Al-haram visitor)	Double						
	Message	User's support message	String	200					
Markers	MarkerId	Uniquely identifies marker	Integer	11				Yes	
	Latitude	Latitude of vehicles' pickup/return location	Double						
	Longitude	Longitude of vehicles' pickup/return location	Double						
ManagerReservation	reservationId	Uniquely identifies reservation	Integer	20				Yes	Yes
	visitorName	Walk-in's name	String	20					
	VphoneNumber	Walk-in's phone number	String	10					
	ExpectedFinishTime	Expect finish tawaf time	String	10	Yes		NULL		
	ReservedForWaiting	The walk-in's reservation Id that is waiting	Integer	15			0		
Vehicle	vehicleId	Vehicle's id	Integer	20				Yes	
	VehicleType	Vehicle's type (Single/Double)	String	6					
Parameters	ParametersId	Parameter's id	Integer	20				Yes	

Entity name	Attribute	Description	Data type	Length	Nulls	Multi-valued	Default value	PK	FK
	VehicleType	Vehicle type (Single/Double)	String	6					
	VehicleDedicatedTo	Vehicle dedicated to (Backup/visitor/walk-in)	String	10					
	TotalNumberOfVehicles	The total number of the vehicles	Integer	20					

### 4.3 Interface Design

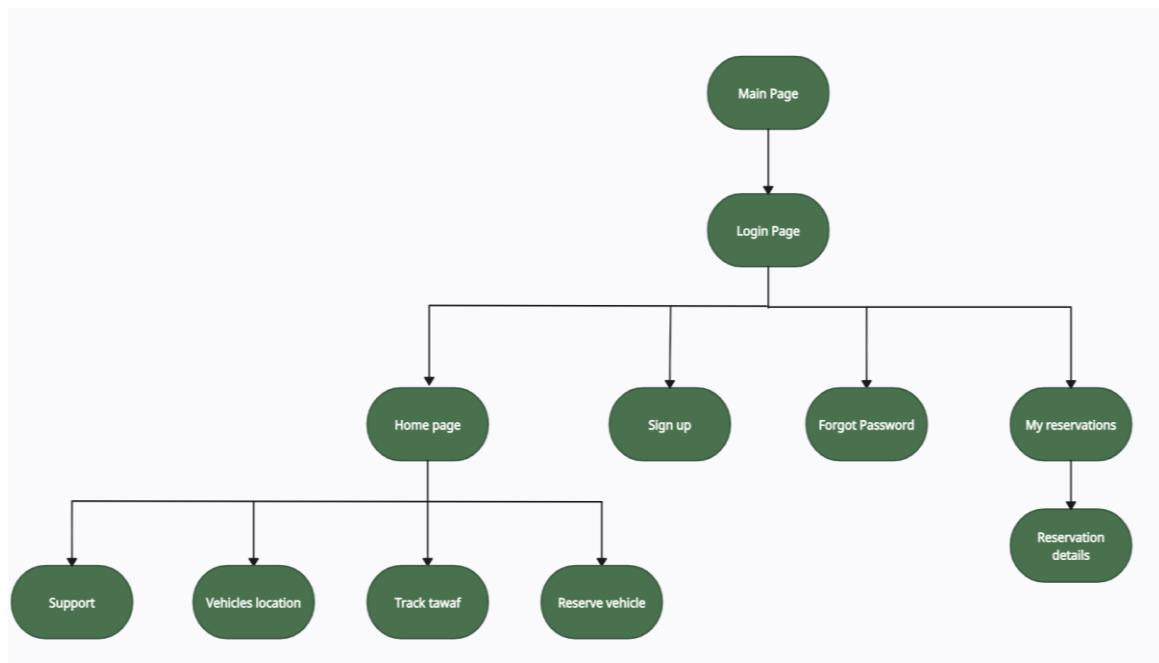
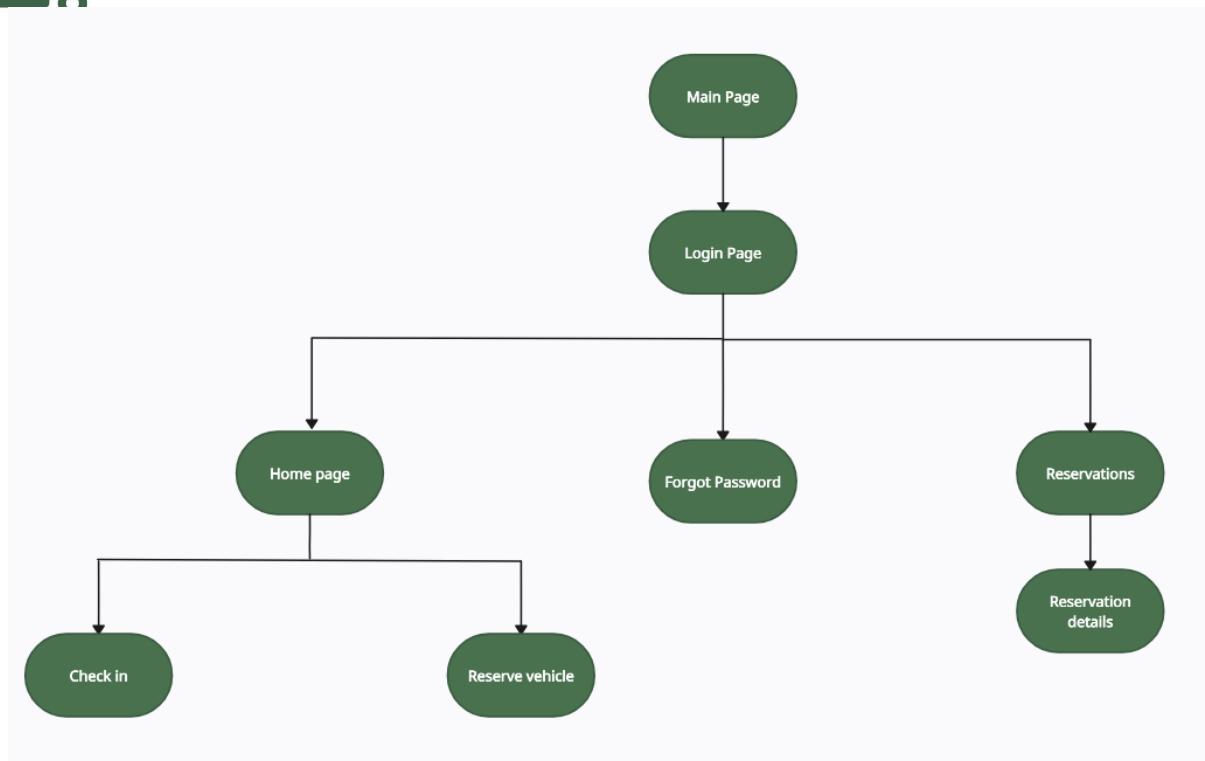
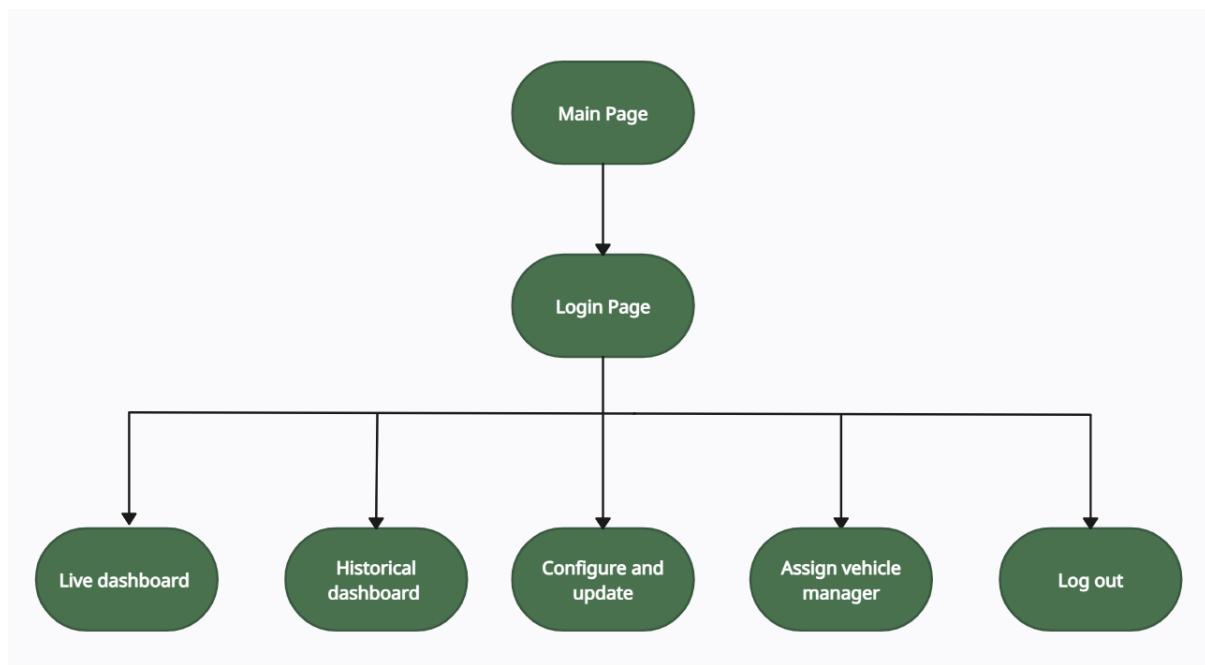


Figure 30. Al-haram visitor Site map



*Figure 31. Vehicle Manager Site map*



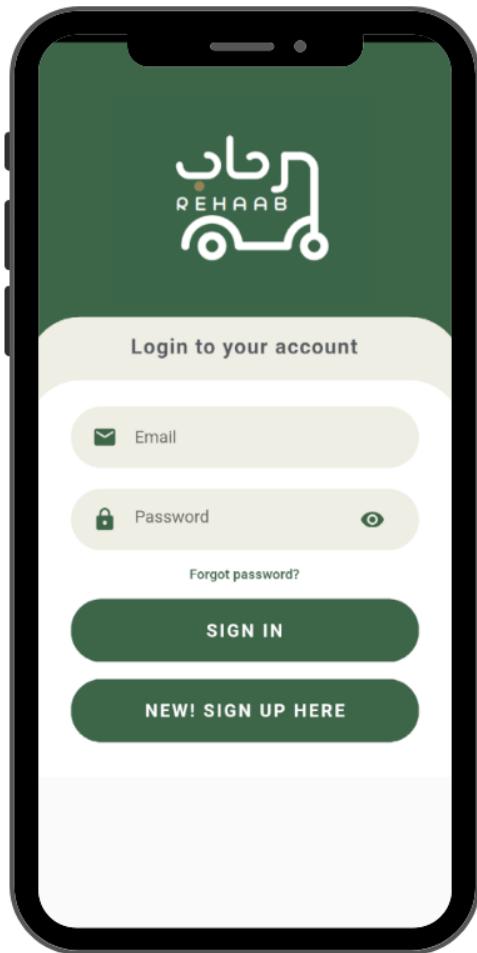
*Figure 32. Admin Site map*

- **Consistency and standards**

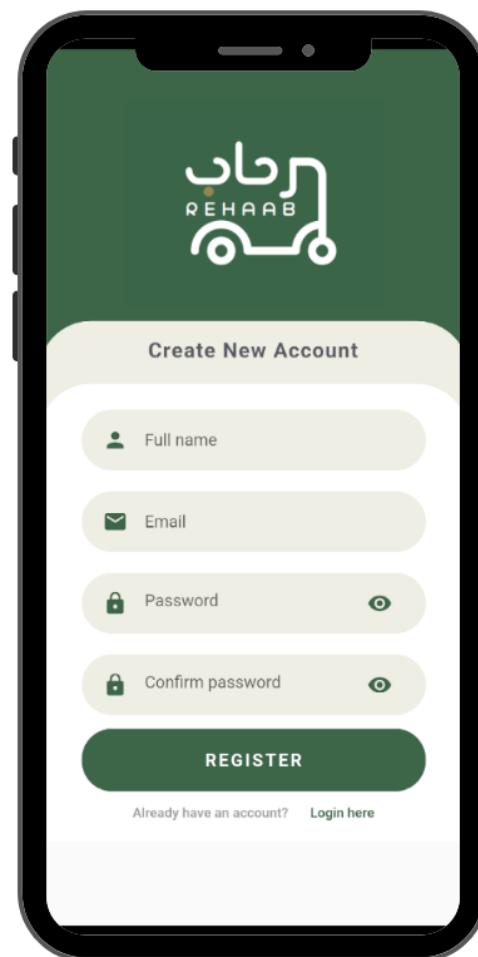
Design consistency is what ties UI elements together with distinguishable and predictable actions [37]



As shown in Figure 33 and 34, similar actions like entering data have consistent design across different pages.



*Figure 33. Login screen*

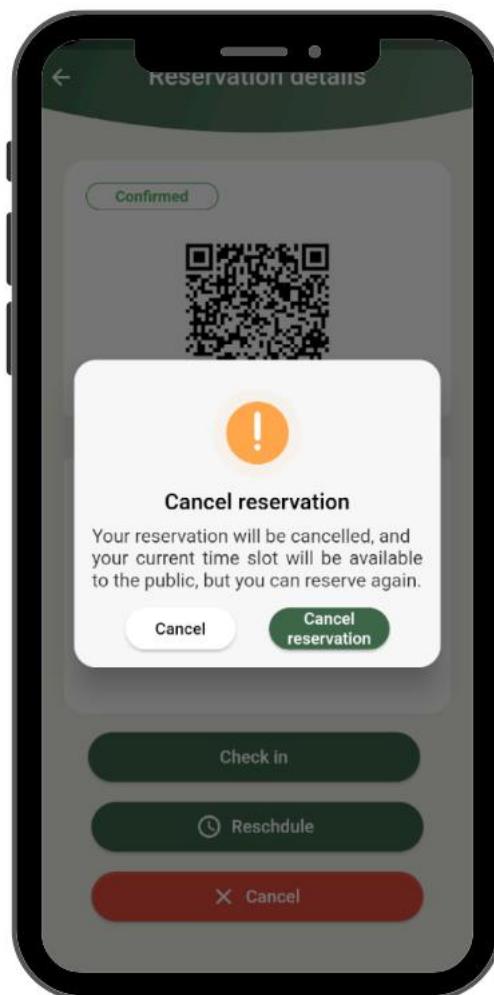


*Figure 34. Sign up screen*

- **Error prevention**

Error prevention is preventing the occurrence of errors or any situation that leads the user to make a false or any unwanted decision. [38]

As shown in Figure 35, The system displays a confirmation message when clicking on cancel button stating that the reservation will be cancelled.



*Figure 35. Confirmation message*

- **Recognition rather than recall**

Minimize the user's memory load by making visible objects, actions, and options.[39]

As shown in Figures 36 and 37, the system displays previous/current reservations buttons so that users can reach their reservations easily.

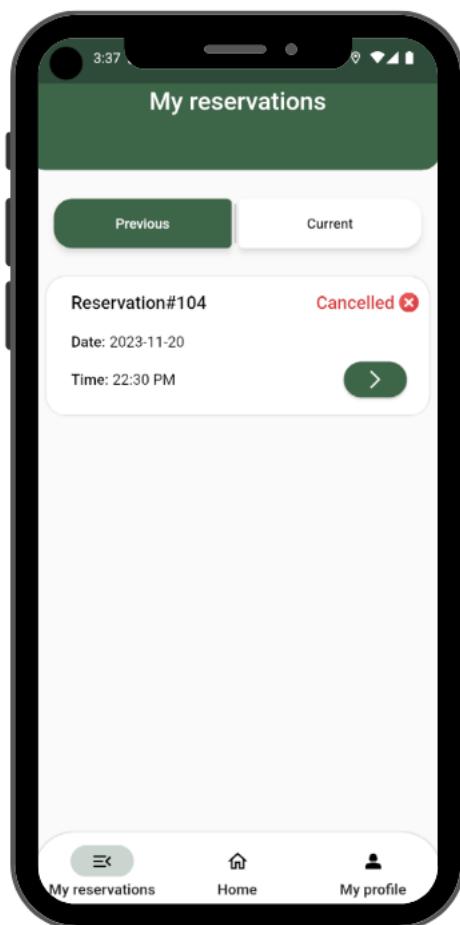


Figure 36. My reservations screen (previous reservations)

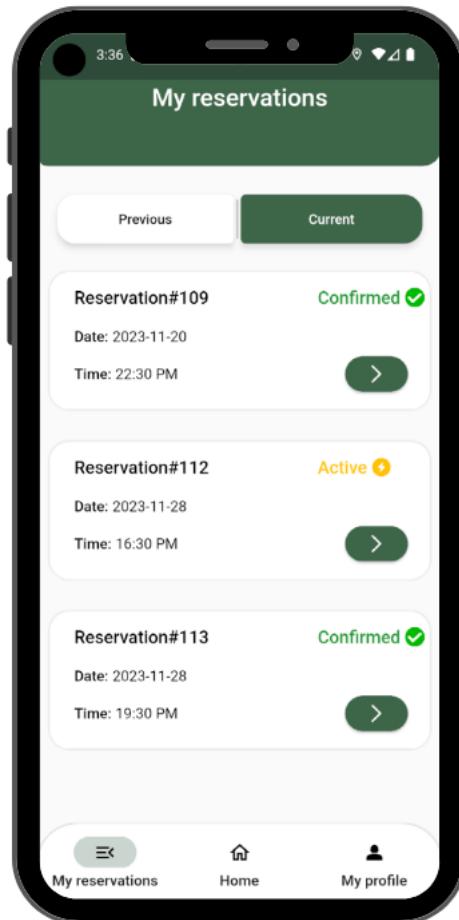
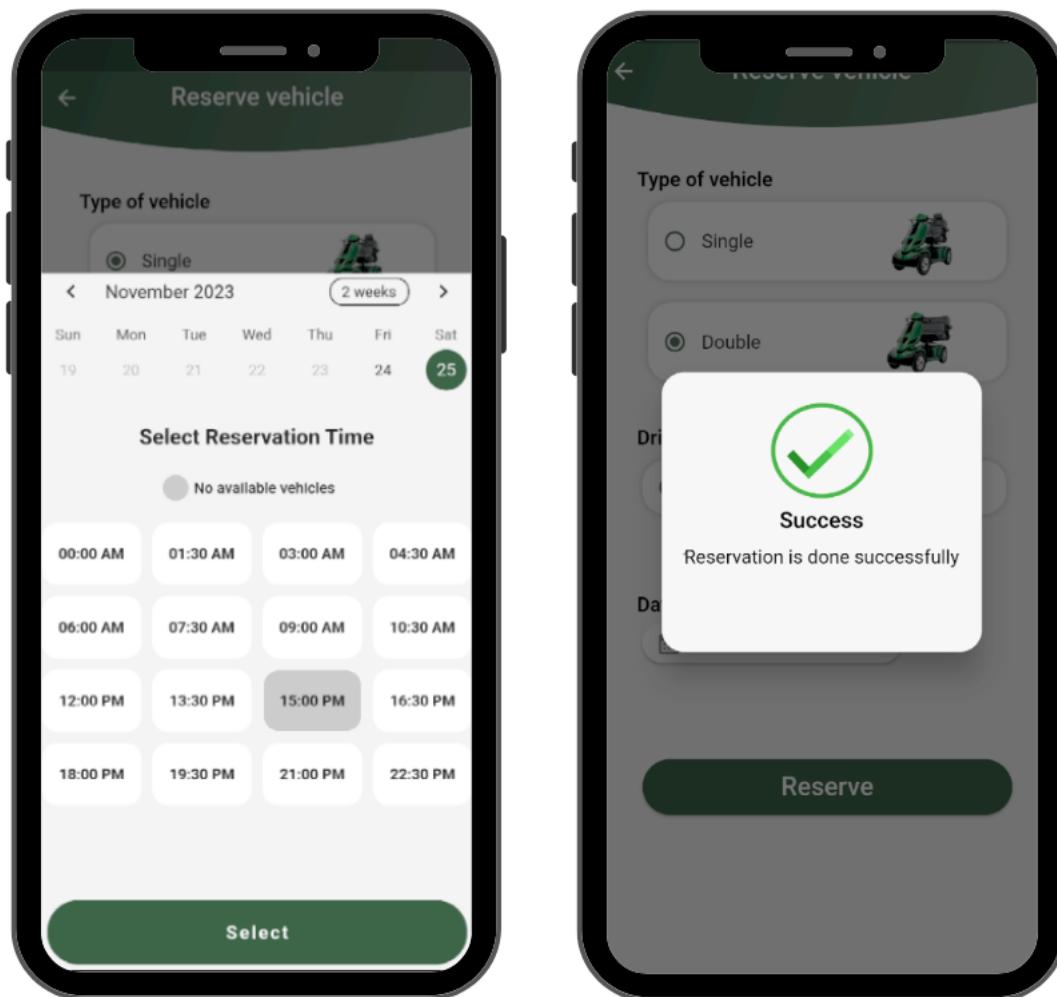


Figure 37. My reservations screen (current reservations)

- **Visibility of system status**

The visibility of system status refers to how well the system's state is conveyed to its users. Ideally, systems should always keep users informed about what is going on, through appropriate feedback within a reasonable time [40].

As shown in Figure 38 and 39, the system tells the user which timeslots are not available and after the user select the available time and reserve, completion feedback going to be displayed confirm to users that their reservation has been successfully completed.



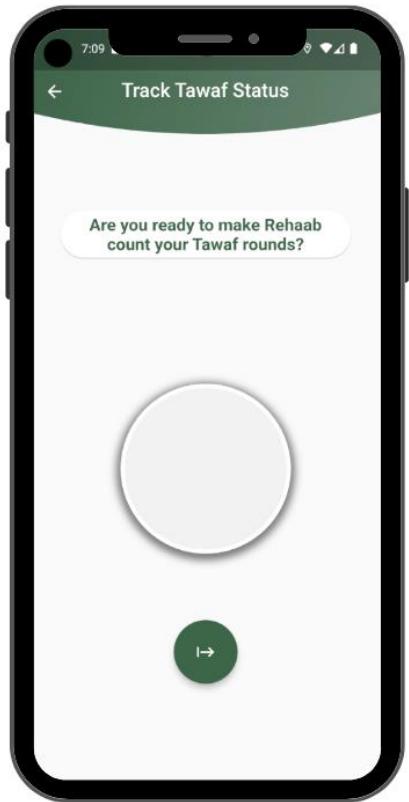
*Figure 38. Reservations time*

*Figure 39. Success message*

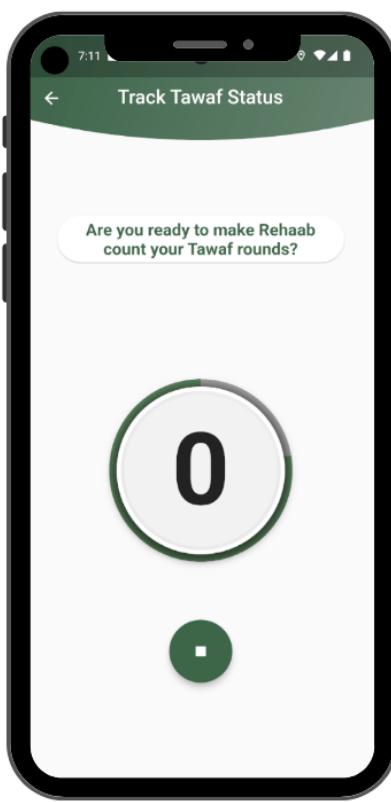
- **Familiarity**

Familiarity refers to the degree to which users feel comfortable and at ease with the design of a product or service.[41]

As shown in Figure 40 and 41, The system uses familiar icons which are start and pause button for tawaf so that users can easily interpret their purpose without requiring additional explanations.



*Figure 40. Track tawaf page (Start button)*



*Figure 41. Track tawaf page (Pause button)*

We have also incorporated design rules to design confirmation dialog [42]. As shown in Figure 42, the dialog avoids asking a question and presents the data in a readable format. The title clearly indicates the relevant task, and the buttons are direct responses that align with the confirmation task.

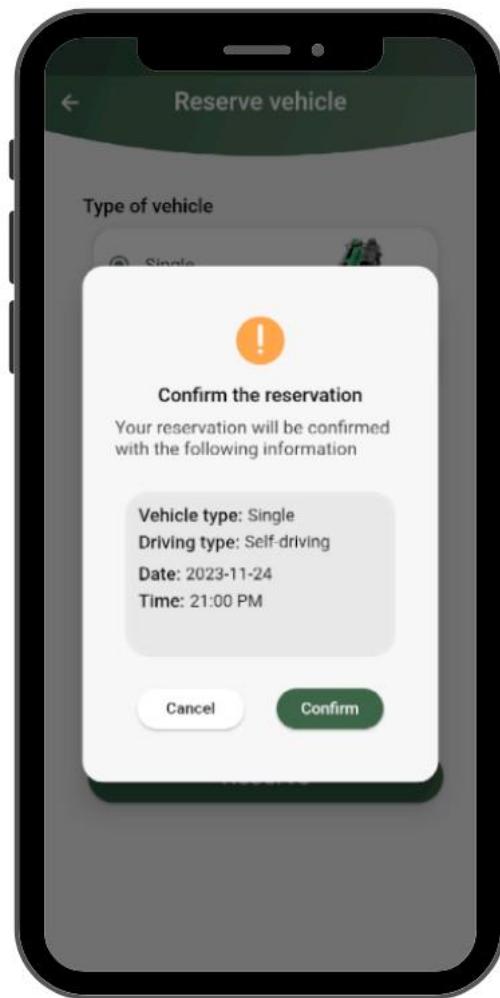


Figure 42. Confirmation dialog



## 4.4 Implementation

### 4.4.1 Software Tools

Table 6 shows the software tools used to implement Rehaab.

**Table 6. Software tools**

Software type	Version
Flutter	3.13.1
Dart	3.1.0
Visual studio code	1.84.0
Android studio	2022.3.1
phpMyAdmin	5.2.1
Php	8.2
Python	3.12.3
Django	4.1.13
GitHub	2.42.0
Jira	9.11.2

### 4.4.2 Database

In this section, we describe the process of choosing the database type and the process of database connection.

- Database type

First, we conducted extensive research on the advantages and disadvantages of the two types of the database (SQL and no-SQL), and we noticed that SQL is often used in reservation systems due to its ability to handle complex relationships. In our case, we connect each vehicle (single or double) with a time slot, and then we link it to the reservations table to determine how many reservations are available for a specific date and time, with each reservation associated with a specific user. Also, SQL supports all the features we require and is considered powerful. We also consulted with Help Desk, and they confirmed that both models are suitable for our system, so we chose MySQL database server.



We used MySQL database and phpMyAdmin tool to handle the administration of MySQL database server.

- Database connection

Here are the steps to connect Rehaab system with the database:

- 1- Downloading Visual studio code.
- 2-Downloading xampp server.
- 3-Creating a new database called “Rehaab” in phpMyAdmin.
- 4-Inserting php file in our GP’s folder called “connect.php” inside Visual studio code.
- 5-Calling “mysqli” function in “connect.php” with localhost, username, password, database name parameters to establish the connection with the database.
- 6-Including “connect.php” file in any other php file to deal with the database.

#### 4.4.3 Google API Connection

Google Maps is hosted on cloud servers, and to access these maps, the Flutter application must request them. Each application has an API key it provides to the Google server to receive the map. The following are the steps to generate this API key:

- 1- Open [console.cloud.google.com](https://console.cloud.google.com)
- 2- Create project
- 3- Enable maps on the project
- 4-Enable map sdk for android
- 4>Create credential for API key
- 5-API key value will be generated
- 6-Put the API key value in AndroidManifest.xml file that is in our GP folder.

Finally, the google map API will be connected to our application and can be used easily.

#### 4.4.4 System Implementation

This section describes the process of implementing Rehaab system along with the components and code-fragments of the major functions.

We used visual studio code with Flutter framework (Dart language) to design and develop the code of Rehaab mobile application, and Django framework (Python language) to design and develop the code of Rehaab web application. We set up an emulator and physical device to run the code. The following code-segments As shown in Table 7 are for the special methods created to be called while implementing the major functions such sign-in, make a reservation, track Tawaf status, check in a vehicle, get current queue waiting time and represent a congestion heatmap.

**Table 7. Major parts of the code**

<b>Function</b>	Sign-in
<b>Description</b>	This function enables the user to enter the application with his own account.
<b>Functions' flow</b>	<p>For the application, the <code>_SigninScreenState</code> class will store the values entered in sign-in page fields in variables then the <code>signin()</code> function will send these values to the <code>signin.php</code> page As shown in Figure 43. <code>signin.php</code> page will take the values, validate them if everything goes right (the email exists, correct, and verified, the password is correct) a success message will be sent to the dart otherwise an error message indicating the type of error will be sent As shown in Figure 44.</p> <p>For the web, A view called <code>signin</code> As shown in Figure 45, will receive the required data (the email and the password) from the sign in html page and will validate them if everything goes right (the email exists and correct and the password is correct) a success message will be shown and the user will be</p>

redirect to the dashboard page otherwise an error message indicating the type of error will be shown.

## Code

```

18
19 class SigninScreen extends StatefulWidget {
20   const SigninScreen({Key? key}) : super(key: key);
21
22
23   @override
24   State<SigninScreen> createState() => _SigninScreenState();
25
26   class _SigninScreenState extends State<SigninScreen> {
27     TextEditingController email = TextEditingController();
28     TextEditingController Password=TextEditingController();
29     bool _isSecurePassword=true;
30     Future signin() async{
31       var url ="http://10.0.2.2/phpfiles/signin.php";
32       final response= await http.post(Uri.parse(url),body: {
33         "Email":email.text,
34         "Password":Password.text});
35       var data =json.decode(response.body);
36
37       if(data[0]=="Success"){
38         GlobalValues.id=data[1];
39         GlobalValues.Fullname=data[2];
40
41         showDialog(
42           context: context,
43           builder: (context)
44             {
45               Future.delayed(Duration(seconds:2), () =>
46                 Navigator.push(
47                   context,
48                   MaterialPageRoute(
49                     builder: ((context) =>
50

```

Figure 43. Sign in Dart code

```
files > signin.php > ...
1  <?php
2   include 'connect.php';
3
4   $Email = $_POST['Email'];
5   $Password = $_POST['Password'];
6
7   $stmt = $conn->prepare("SELECT * FROM users WHERE Email = ? AND status = 1");
8   $stmt->bind_param("s", $Email);
9   $stmt->execute();
0   $result = $stmt->get_result();
1   $count = $result->num_rows;
2
3
4   $stmt1 = $conn->prepare("SELECT * FROM users WHERE Email = ? AND status = 0");
5   $stmt1->bind_param("s", $Email);
6   $stmt1->execute();
7   $result1 = $stmt1->get_result();
8   $count1 = $result1->num_rows;
9
0   if (empty($Password) || empty($Email)) {
1     echo json_encode("empty");
2   }
3   else if ($count == 1) {
4     $row = $result->fetch_assoc();
5     $pw = $row['Password'];
6     $id = strval($row['userID']);
7     $name = $row['FullName'];
8
9     if (password_verify($Password, $pw)) {
0       echo json_encode([0 => "Success", 1 => $id, 2 => $name]);
1     }
2     else {
3       echo json_encode("Fail");
4     }
5   }
6
7
8
9
```

*Figure 44. Sign in PHP code*

```
def signin(request):
    request.session['is_authenticated'] = False
    if request.method == 'POST':
        email = request.POST.get('email')
        password = request.POST.get('Password')
        try:
            user = User.objects.get(Email=email)
            if user.check_password(password):
                if user.Type == 'Admin':
                    messages.success(request, 'You have been signed in successfully!')
                    request.session['is_authenticated'] = True
                    return redirect(('index'))
                else:
                    messages.error(request, 'Invalid email or password!')
        except User.DoesNotExist:
            messages.error(request, 'Email does not exist!')
        return redirect('sign-in')
    else:
        return render(request, 'sign-in.html')
```

**Figure 45.** Sign in view code (for web)

<b>Function</b>	Make a reservation
<b>Description</b>	This function enables the user to reserve a vehicle at a specific date and time.

## Functions' flow

The insert() function will send the values required to reserve a vehicle to reservation.php page after validating them and making sure that they are not empty As shown in Figure 46. reservation.php page will receive the values and insert it to “reservation” table in the database As shown in Figure 47.

## Code

```

16 String _driverGender = "";
17 String _vehicleType = "";
18 String _drivingType = "Double";
19 String getDate = "";
20 String getTime = "";
21 String label = "";
22 Color labelColor = Colors.white;
23
24 class ReserveVehicle extends StatefulWidget {
25   const ReserveVehicle({super.key});
26
27   @override
28   State<ReserveVehicle> createState() => _ReserveVehicleState();
29 }
30
31 class _ReserveVehicleState extends State<ReserveVehicle> {
32   bool isVisibleGender = false;
33   bool isVisibleDriving = false;
34
35   Future insert() async {
36     var url = "http://10.0.2.2/phpfiles/reservation.php";
37     final res = await http.post(Uri.parse(url), body: {
38       "id": GlobalValues.id,
39       "date": getDate,
40       "time": getTime,
41       "VehicleType": _vehicleType,
42       "DrivingType": _drivingType,
43       "DriverGender": _driverGender
44     });
45     var resp = json.decode(res.body);
46     print(resp);
47   }
48
49   void initState() {
50     setState(() {
51       _vehicleType = "";
52       _drivingType = "";}
53     );
54   }
55 }
```

Figure 46. Make a reservation Dart code

```

iphiles > reservation.php > ...
1  <?php
2  include 'connect.php';
3  $id=$_POST['id'];
4  $date= $_POST['date'];
5  $time= $_POST['time'];
6  $VehicleType= $_POST['VehicleType'];
7  $DrivingType= $_POST['DrivingType'];
8  $DriverGender= $_POST['DriverGender'];
9
10 $slots = "SELECT slotId FROM timeslots WHERE time='".$time."'";
11 $slotIdResult = mysqli_query($conn, $slots);
12 $row = mysqli_fetch_assoc($slotIdResult);
13 $slotId = $row['slotId'];
14
15 $s ="INSERT INTO reservation (date,VehicleType,drivingType,driverGender,status,visitorId,slotId) VALUES ('".$date."','".$$VehicleType."','".$$DrivingType."','".$DriverGender."','".$status."','".$visitorId."','".$slotId"')";
16
17 $result2 = mysqli_query($conn, $s);
18

```

*Figure 47. Make a reservation PHP code*

<b>Function</b>	Track Tawaf status
<b>Description</b>	This function enables the users to track their tawaf rounds (automatically).
<b>Functions' flow</b>	In _TrackTawatstate class As shown in Figure 48, we declared variables to store information such as the coordinates of the Kaaba, current position, stopwatch, rounds counter, etc. We defined requestPermission() function to handle location permission checks and requests, if “Location services” was enabled getCurrentPosition() function will get the starting point coordinates and store it in a variable, then it will listen to the position stream and update the current position and the rounds counter based on the users movements. A timer shown to the user telling her/him when she/he will approximately finish her/his tawaf, by counting how much it takes from the user to end this round multiplied by the remaining rounds (the timer is changing in each round depending on how each round takes from the user). EndStream() function is called if counter reached 7, its stops the position streaming and shows



	a message indicating that the user finished his/her tawaf.
--	--

## Code

```

Future<bool> requestPermission() async {
    final permission = await location.requestPermission();
    return permission == PermissionStatus.granted;
}

Future<LocationData> getCurrentLocation() async {
    setState(() {
        _isVisible = !_isVisible;
    });
    _isVisible = true;
    final serviceEnabled = await location.serviceEnabled();
    if (!serviceEnabled) {
        final result = await location.requestService;
        if (result == true) {
            print('Service has been enabled');
        } else {
            throw Exception('GPS service not enabled');
        }
    }
    final position = await location.getLocation();
    var DistanceCenter = distance(
        position.latitude, position.longitude, kaaba_lat, kaaba_lon)
        .floor(); //////////the distance between the starting point and the center

    locationSubscription =
        location.onLocationChanged.listen((LocationData currentLocation) {
    Distance = distance(position.latitude, position.longitude,
        currentLocation.latitude, currentLocation.longitude)
        .floor();
});
}

```

Figure 48. Track Tawaf status Dart code

<b>Function</b>	Check in a vehicle
<b>Description</b>	This function enables the manager to check in a confirmed reservations for Al-Haram visitors so they can take their vehicles and start their tawaf.
<b>Functions' flow</b>	In checkin class As shown in Figure 49, The _requestCameraPermission() function will check if the camera access for this device (Vehicle manager devive) is granted or not, if yes it will call

\_initializeCamera() function which will set up the camera controller to scan the QR code, after the QR scanning is done StartTawaf() function will be called, this function will decrypt the reservation id and will send it to StartTawaf.php, in StartTawaf.php As shown in Figure 50, will check the reservation status, if it is “Confirmed” it will update it to “Active” so the user can take its vehicle and start its tawaf, Also a success message will be shown to the manager, otherwise an error message will be shown “invalid QR code” and the user can't take its vehicle or start its tawaf.

## Code

```

bool isVisibleInvalid=false;
Future<void> _requestCameraPermission() async {
  final status = await Permission.camera.request();
  if (status.isGranted) {

    initializeCamera();
    print("Camera permission granted.");
  } else if (status.isDenied) {
    print("Camera permission denied.");
  } else if (status.isPermanentlyDenied) {
    print("Camera permission permanently denied.");
  }
}

Future<void> initializeCamera() async {
  try {

    await controller.start();

  } catch (e) {
    print('Error initializing camera: $e');
  }
}

Future<void> StartTawaf(String code) async {
  try {
    // Decrypt the QR code
    final key = enc.Key.fromUtf8("3159a027584ad57a42c03d5dab118f68");
    final iv = enc.IV.fromUtf8("e0c2ed4fbcc3e1fb6");
    final encrypter = enc.Encrypter(enc.AES(key, mode: enc.AESMode.cbc));
    final decrypted = encrypter.decrypt64(code, iv);

    var url = "http://10.0.2.2/phpfiles/startTawaf.php";
  }
}

```

Figure 49. Check in Dart code

```
<?php

include 'connect.php';

$Rid = $_POST['Rid'];
$select = "SELECT Status FROM reservation WHERE reservationId=$Rid";
$result1 = mysqli_query($conn, $select);
$row = mysqli_fetch_assoc($result1);

if ($row["Status"] == "Confirmed") {
    $update = "UPDATE `reservation` SET `Status`='Active' WHERE reservationId=$Rid";
    $result = mysqli_query($conn, $update);

    if ($result) {
        $response = json_encode("Tawaf started successfully");
    } else {
        $response = json_encode("Error in starting Tawaf");
    }
} else {
    $response = json_encode("Reservation status is not confirmed");
}

echo $response;
```

Figure 50. Start Tawaf php code

<b>Function</b>	Get current queue waiting time
<b>Description</b>	This function shows to the vehicle manager when the next vehicle will be available in case if all vehicle are occupied to inform the walk-in visitors.
<b>Functions' flow</b>	In Reserve_walkInVehicle class, when the manager arranges a reservation for a walk-in visitor and selects the vehicle type (Single or Double), the system verifies if the chosen vehicle type is available, if it is not available, the system will call the NearestTime() function As shown in Figure 51, this function takes the selected vehicle type and sends it to NearestTime.php, and As shown in Figure 52 this will check all active reservations of that type, it will choose the active reservation with the nearest ExpectedFinishTime (it is calculated by adding the average tawaf time on the start time for this reservation) and a ReservedForWaiting value of 0

(indicating that there is no waiting reservation associated with it) then displays its ExpectedFinishTime as the time this walk-in visitor should wait to.

## Code

```

class _Reserve_WalkInVehicleState extends State<Reserve_WalkInVehicle> {
  Future insert() async {
    Status status;
  });

  if (res.statusCode == 200) {
    var respo = json.decode(res.body);
  }
}

Future<void> Check() async {
  var url = "http://10.0.2.2/phpfiles/checkVehicles.php";
  final res = await http.post(Uri.parse(url), body: {
    "VehicleType": _vehicleType,
  });

  if (res.statusCode == 200) {
    respo = json.decode(res.body);
    print(respo[0]);
    if (respo[0] == "UnavailableSingle") {
      setState(() {
        unAvailableSingle = true;
      });
      NearestTime();
    } else if (respo[0] == "UnavailableDouble") {
      setState(() {
        unAvailableDouble = true;
      });
      NearestTime();
    } else {
      unAvailableSingle = false;
      unAvailableDouble = false;
    }
  }
}

```

Figure 51. NearestTime() function being called when there is no available vehicles

```

<?php
include 'connect.php';
// Get the VehicleType value from the request
$vehicleType = $_POST['VehicleType'];

// Query to find nearest time for reservations
$query = "
SELECT reservation.reservationId, MIN(managerreservation.ExpectedFinishTime) AS nearestTime
FROM reservation
LEFT JOIN managerreservation ON reservation.reservationId = managerreservation.reservationId
WHERE (
    (reservation.Status = 'Active' AND managerreservation.ReservedForWaiting = 0)
    OR (reservation.Status = 'Waiting' AND managerreservation.ReservedForWaiting = 0)
)
AND reservation.VehicleId IN (
    SELECT VehicleId
    FROM vehicle
    WHERE VehicleType = '$vehicleType'
)
GROUP BY reservation.reservationId
ORDER BY nearestTime ASC
LIMIT 1
";

$result = mysqli_query($conn, $query);

if ($result) {
    $response = array();

    if (mysqli_num_rows($result) > 0) {
        $row = mysqli_fetch_assoc($result);
        $nearestTime = $row['nearestTime'];
        $reservationId = $row['reservationId'];

        $response['success'] = true;
        $response['nearestTime'] = $nearestTime;
        $response['reservationId'] = $reservationId;
    }
}
  
```

Figure 52. NearestTime php code

<b>Function</b>	Represent a congestion heatmap
<b>Description</b>	This function enables the administrator to view a heat map of the current vehicles tawaf place, enabling him/her to make decisions based on the current situation.
<b>Functions' flow</b>	As shown in figure 53, generate_frames(vidpath) function takes the path of the video we want to process as a parameter then it initializes a YOLO model (yolo version 8) using <a href="#">yolov8s.pt</a> file, the code opens the video then takes its width and height. After that it creates an empty heatmap with the same dimensions as the video, represented as a two-dimensional array of zeros. We defined 3 functions inside the generate_frames(vidpath), calculate_distance calculates the Euclidean distance between two points, calculate_vertical_distance calculates the vertical distance between two points, calculate_horizontal_distance calculates the

horizontal distance between two points. The code then enters a loop to read frames from the video, it passes the frame to the YOLO model to detect vehicles, the model. Track function that takes the frame, class value (a pretrained models ex: class 3 means that the objects are motorcycles, class 0 means that the objects are people and etc.) and a Boolean persist value as parameters and returns the detected results and for each detected vehicle, it retrieves the bounding box coordinates and calculates the center point of the box then it compares the distances between different vehicles and updates the heatmap accordingly based on the conditions. If two vehicles are close together (within a distance of 100), the corresponding area in the heatmap is incremented. If two vehicles are close vertically or horizontally (within a distance of 100) and have a specific relative position, the corresponding area in the heatmap is incremented. After processing each frame, it blurs the heatmap using a Gaussian blur filter, normalizes the values in the heatmap to a range of 0-255 and applies a color map (specifically the "JET" colormap) to convert the heatmap into a color image, finally it blends the original frame with the heatmap overlay using cv2.addWeighted function creating a combined image, this combined image is encoded as a JPEG image and converted to a base64 string, these combined images will be sent using yields keyword, this keyword allows each combined image to be return as a server-sent event (SSE) response, SSE allows the images to be streamed to the client in real-time.

**Code**

```

def generate_frames(vidpath):
    model = YOLO('yolov8x.pt')
    video_filename = vidpath
    videopath = os.path.join(os.path.dirname(__file__), 'static', 'RehaabWeb', video_filename)
    cap = cv2.VideoCapture(videopath)
    width = int(cap.get(3))
    height = int(cap.get(4))
    heatmap = np.zeros((height, width), dtype=np.float32)
    def calculate_distance(p1, p2):
        return np.sqrt((p1[0] - p2[0]) ** 2 + (p1[1] - p2[1]) ** 2)

    def calculate_vertical_distance(p1, p2):
        return abs(p1[1] - p2[1])

    def calculate_horizontal_distance(p1, p2):
        return abs(p1[0] - p2[0])

    rectangle_height_increment = 360
    while cap.isOpened():
        success, frame = cap.read()
        if success:
            results = model.track(frame, persist=True, classes=[3])
            for result in results:
                if result.bboxes.xyxy.cpu() is not None and result.bboxes.id.cpu() is not None:
                    boxes = result.bboxes.xyxy.cpu().numpy().astype(int)
                    centers = [(int((box[0] + box[2]) / 2), int((box[1] + box[3]) / 2)) for box in boxes]

                    for i in range(len(centers)):
                        for j in range(i + 1, len(centers)):
                            euclidean_distance = calculate_distance(centers[i], centers[j])
                            vertical_distance = calculate_vertical_distance(centers[i], centers[j])
                            horizontal_distance = calculate_horizontal_distance(centers[i], centers[j])

                            if euclidean_distance < 100:
                                x1, y1 = centers[i]
                                x2, y2 = centers[j]

                                top_left_x = min(x1, x2)
                                top_left_y = min(y1, y2) - rectangle_height_increment // 2
                                bottom_right_x = max(x1, x2)
                                bottom_right_y = max(y1, y2) + rectangle_height_increment // 2

                                top_left_x = max(0, top_left_x)
                                top_left_y = max(0, top_left_y)
                                bottom_right_x = min(heatmap.shape[1], bottom_right_x)
                                bottom_right_y = min(heatmap.shape[0], bottom_right_y)

                                heatmap[top_left_y:bottom_right_y, top_left_x:bottom_right_x] += 1

                            if vertical_distance < 100 and centers[i][1] < centers[j][1]:
                                x1, y1 = centers[i]
                                x2, y2 = centers[j]
                                top_left_x = min(x1, x2)
                                top_left_y = min(y1, y2) - rectangle_height_increment // 2
                                bottom_right_x = max(x1, x2)
                                bottom_right_y = max(y1, y2) + rectangle_height_increment // 2

                                top_left_x = max(0, top_left_x)
                                top_left_y = max(0, top_left_y)
                                bottom_right_x = min(heatmap.shape[1], bottom_right_x)
                                bottom_right_y = min(heatmap.shape[0], bottom_right_y)

                                heatmap[top_left_y:bottom_right_y, top_left_x:bottom_right_x] += 1

                heatmap_blurred = cv2.GaussianBlur(heatmap, (15, 15), 0)
                heatmap_norm = cv2.normalize(heatmap_blurred, None, 0, 255, cv2.NORM_MINMAX, dtype=cv2.CV_8U)
                heatmap_color = cv2.applyColorMap(heatmap_norm, cv2.COLORMAP_JET)

                overlay = cv2.addWeighted(frame, 0.3, heatmap_color, 0.7, 0)
                _, buffer = cv2.imencode('.jpg', overlay)
                frame_base64 = base64.b64encode(buffer).decode('utf-8')
                yield f"data: {frame_base64}\n\n"
            else:
                break
        cap.release()
        cv2.destroyAllWindows()

```

Figure 53. HeatMap view code

#### 4.4.5 System Integration

We used GitHub as a collaboration hosting platform so that we can upload our code and commit latest changes and resolve any conflicts. First, we created a repository called “2023-GP1-2” in GitHub, then selected “Collaborations” in the setting and invited all the team members’ and the supervisor’s accounts. In Visual studio code, we copied the repository URL from GitHub then pasted it in “clone repository” in the source control, by doing these steps all the members could work together easily and commit changes without conflicts. Also, GitHub provides a feature to know who is responsible for the commit.



#### 4.4.6 Challenges

First, we encountered difficulties in selecting the database type, but this issue was resolved after conducting extensive research and seeking advice from the Help Desk. Once we started writing the code, we faced several challenges. For example, we needed to pass a variable from one Dart page to another. However, we solved this problem by using global variables, which are variables accessible across all Dart pages. Another issue we faced was that the time slots on the vehicle reservation page did not change when the date was changed. They remained the same for all dates, which was a significant error. We resolved this problem by modifying the implementation. Now, whenever the user selects a new date, the time slots' function is called again, and the old time slots for the previous date are removed.

#### 4.4.7 GitHub Repository

The GitHub repository link is provided in reference [43].



## 5 System Evaluation

This chapter includes the entire user acceptance testing process and experimental results of Rehaab system.

### 5.1 Experimental Results

In this section, we present the results of our experiments utilizing the YOLOv8 model to detect the congestion of electric vehicles within the Tawaf area of Al-Haram. Leveraging the model advanced object detection capabilities, our goal was to evaluate the model's accuracy in identifying and quantifying the congestion of electric vehicles in this specific region of Al-Haram.

#### Experiment 1: Mobility Scooter Detection

In this initial experiment, we utilized a dataset from the "Carleton University" project on Roboflow, containing various images annotated with bounding boxes indicating the presence of mobility scooters. Our goal was to train the YOLOv8 model to effectively identify mobility scooters. Below are examples of images depicting mobility scooters from the dataset, as shown in Figures 54 and 55:



*Figure 54. Mobility scooter from the dataset*



*Figure 55 . Mobility scooter from the dataset*

The YOLOv8 object detection algorithm, known for its real-time performance and accuracy, was central to our approach. As an evolution of the original YOLO architecture, YOLOv8 includes significant improvements in model architecture and training methodologies. It divides



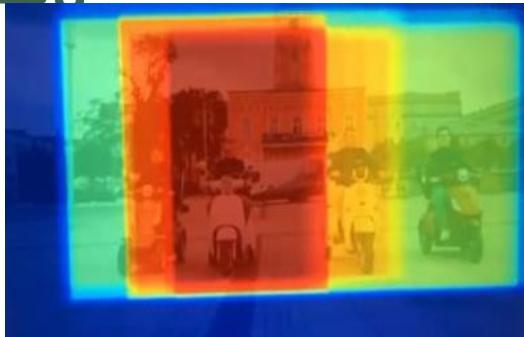
the input image into a grid, generating predictions for bounding boxes and class probabilities within each grid cell, enabling rapid inference by utilizing a single neural network to make predictions directly from the entire image.

During training, YOLOv8 iteratively refines its parameters, optimizing a custom loss function to enhance accuracy in predicting bounding boxes. Despite these advancements, our evaluation showed that the model struggled to accurately identify mobility scooters. Reviewing the model's predictions on the test set revealed instances where it failed to reliably detect mobility scooters.

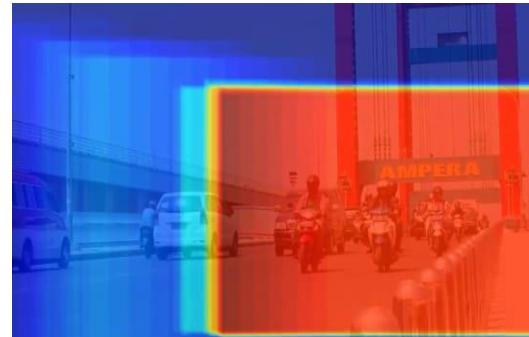
The primary reason for the model's failure to learn to detect mobility scooters was the poor quality of the training data. The dataset did not provide sufficient quality and variety for the model to learn effectively, resulting in an accuracy of 0.24% (0.00241) mAP in detecting mobility scooters. This highlights the critical importance of high-quality, representative training data for the effective training of object detection models like YOLOv8.

## Experiment 2: Real-Time Vehicle Tracking

YOLOv8 exhibited a robust performance in object detection and tracking, achieving an accuracy rate of 85% [44]. Experiment 2 shifted focus to real-time vehicle tracking using YOLOv8. The algorithm tracked vehicles, particularly motorcycles, in a video sequence by associating detections across consecutive frames. This involved a combination of object detection and motion estimation techniques. During tracking, YOLOv8 first detected vehicles in each frame and assigned unique identifiers to them. The algorithm then utilized motion prediction to estimate the future positions of tracked vehicles based on their current trajectories. By associating detections across frames and updating the vehicle's position over time, YOLOv8 facilitated real-time monitoring of vehicle movement. However, accurately estimating vehicle density solely from tracked trajectories proved challenging. Variations in vehicle sizes, occlusions, and complex traffic scenarios could lead to inaccuracies in density estimation. Below are some image examples to provide visual insights into the model's performance in various environments and conditions as shown in Figures 56-59:



**Figure 56.** An image of model performance.



**Figure 57.** An image of model performance



**Figure 58.** An image of model performance

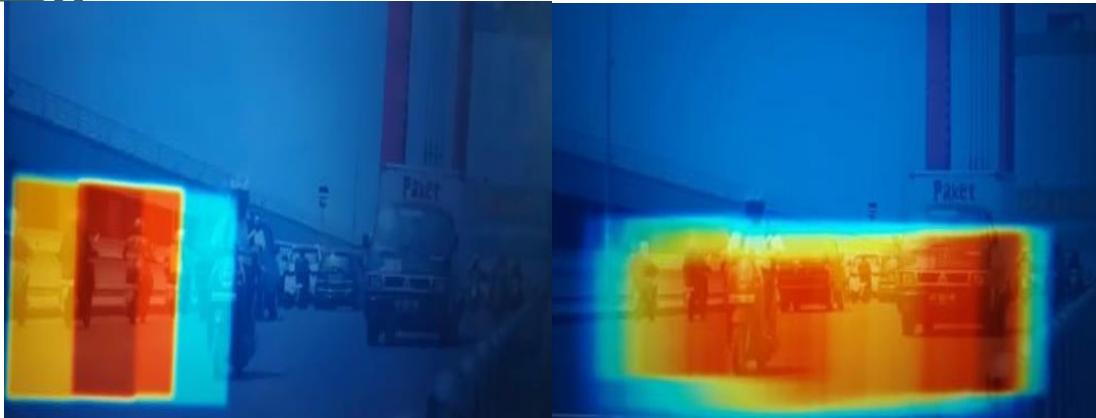


**Figure 59.** An image of model performance

As a result, Experiment 2 highlighted the limitations of traditional object-tracking methods for quantifying traffic density accurately.

### Experiment 3: Vehicle Proximity Analysis

YOLOv8 maintained a commendable accuracy rate of 85% in object detection and tracking[44]. Experiment 3 introduced a novel approach to traffic density estimation based on vehicle proximity analysis. Instead of relying solely on object detection and tracking, this approach focused on analyzing the spatial relationships between detected vehicles to infer traffic density indirectly. The algorithm calculated the distances between detected vehicles and utilized proximity metrics to estimate traffic density levels. By analyzing the distribution of vehicle distances within the scene, the algorithm could infer congestion levels and traffic flow patterns. This approach offered a more nuanced understanding of traffic dynamics by considering the interactions between vehicles. Below are some image examples to provide visual insights into the model's performance as shown in Figures 60 and 61:



**Figure 60.** An image of model performance

**Figure 61.** An image of model performance

Accurately quantifying vehicle proximity and translating it into meaningful density metrics necessitated sophisticated analysis techniques and algorithmic refinement. Experiment 3 was designed to tackle some of the shortcomings associated with traditional object detection and tracking methods by harnessing proximity-based analysis to achieve more precise traffic density estimations. This innovative approach facilitated a more nuanced understanding of traffic dynamics by encompassing not only the presence of vehicles but also their spatial arrangements and interactions. Leveraging YOLOv8's prowess in object detection and spatial analysis, Experiment 3 aimed to furnish precise and comprehensive insights into traffic density patterns.

#### Experiment 4: Real-Time Al-Haram Electric Vehicles Detection and Annotation Using YOLOv8

In this experiment, YOLOv8 demonstrated an impressive accuracy rate of 85% in detecting and tracking objects [44]. We focused on real-time detection and annotation of Al-Haram electric vehicles using the YOLOv8 model (this model is trained on detecting motorcycles). The primary objective was to leverage the advanced capabilities of YOLOv8 for accurately identifying and annotating Al-Haram electric vehicles in a video feed. We processed the video frame by frame to detect the vehicles, annotating the detected vehicles with bounding boxes and labels in real-time. Key steps included setting up video capture, processing the video frame by frame, and utilizing the YOLOv8 model to detect and annotate the vehicles. The video properties such as frame rate and resolution were considered to ensure smooth processing and accurate annotation. The annotated frames were then saved to a new video file. Below are some

image examples to offer visual insights into the model's performance as shown in Figures 62 and 63:



*Figures 62. An image of model performance*

*Figures 63. An image of model performance*

As a result, the model successfully detected and annotated Al-Haram electric vehicles in real-time, providing valuable insights for further refinement and application in real-world scenarios. This experiment illustrated that our algorithm could detect electric vehicles, but due to changing camera angles, displaying a heatmap accurately was not feasible.

In conclusion, the experiments underscored the complexities of mobility scooter detection, electric vehicle detection, and traffic density estimation. While Experiments 1 and 2 using YOLOv8 showcased shortcomings in object detection and tracking, Experiment 3 introduced a promising proximity-based strategy. Moreover, Experiment 4 successfully demonstrated the detection of Al-Haram electric vehicles. Despite initial setbacks, these findings offer valuable lessons for refining algorithms and advancing research in this field.

## 5.2 User Acceptance Testing

In this section, user acceptance testing was conducted and documented to assess the performance of the Rehaab System's second release. The testing focused on evaluating the tasks outlined in Table 8 to ensure that the system meets the specified requirements. A total of 20 end users participated in the testing, including 11 Al-Haram visitors, 6 Vehicle managers, and 3 administrators who met the project users' criteria. To gather feedback, a questionnaire was created consisting of 29 questions. The questionnaire was divided into three sections :11 questions for Al-Haram visitors of, 7 questions for vehicle managers, and 9 questions for admin . The questionnaire covered aspects such as the system's interface, functionality, and ease of use. At the conclusion of the testing phase, participants completed the listed tasks from Table



8 and provided their responses to the questionnaire to evaluate the system's performance. For the questionnaire itself, please refer to Appendix C.

**Table 8. Tasks**

Task number	Task
Al-Haram Visitor	
1	Sign-in
2	Sign-up
3	Sign-out
4	Find the location of vehicle for pick-up/return
5	Make a new reservation
6	View my reservation's list
7	View my reservation's details
8	Cancel a reservation
9	Check out a vehicle
10	Call for support
11	Track Tawaf status
12	Reschedule a reservation.
Vehicle Manager	
1	Sign-in
2	Sign-out
3	Make a new reservation
4	view vehicles' availability dashboard
5	View walk-in current/waiting reservations list
6	View walk-in reservation's details
7	Check in a vehicle
8	Get current queue waiting time

Admin	
1	Sign-in
2	Sign-out
3	Configure and update system parameters
4	Mark vehicles' pick-up and return location on a map
5	View vehicles' information
6	Assign vehicle managers
7	View support notification alerts
8	Representing a congestion heatmap

## Demographics of Participants

Table 9 describes the end users who tested the second release of Rehaab system.

*Table 9.Demographics of Participants*

Participants	Gender	Age	Al-haram visitor/Vehicle manager/Admin	Basic English	Basic Technical Experience
1	Female	25	Al-haram visitor	Yes	Yes
2	Female	22	Al-haram visitor	Yes	Yes
3	Male	28	Al-haram visitor	Yes	Yes
4	Female	23	Al-haram visitor	Yes	Yes
5	Female	34	Al-haram visitor	Yes	Yes
6	Male	33	Al-haram visitor	Yes	Yes
7	Male	20	Al-haram visitor	Yes	Yes
8	Male	40	Al-haram visitor	Yes	Yes
9	Male	37	Al-haram visitor	Yes	Yes
10	Male	39	Al-haram visitor	Yes	Yes
11	Female	22	Al-haram visitor	Yes	Yes
12	Female	21	Vehicle manager	Yes	Yes

13	Male	26	Vehicle manager	Yes	Yes
14	Male	45	Vehicle manager	Yes	Yes
15	Male	55	Vehicle manager	Yes	Yes
16	Male	49	Vehicle manager	Yes	Yes
17	Male	26	Vehicle manager	Yes	Yes
18	Male	47	Admin	Yes	Yes
19	Male	38	Admin	Yes	Yes
20	Male	32	Admin	Yes	Yes

### 5.2.1 Questionnaire/Interview Results

**Table 10. Questionnaire Results**

Question number	Question	Summary of Results
		Al-haram visitor
1	I was able to register	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
2	I was able to log in	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
3	I was able to log out	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
4	The application assisted me in locating the electric vehicles pick-up and return point	Strongly agree 72.7% Agree 27.3% Neutral 0% Disagree 0% Strongly disagree 0%

		Vehicle manager
5	I was able to reserve an electric vehicle and reschedule my reservation through the application	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
6	The application provides clear enough details about my reservation	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
7	The application can accurately calculate the number of circumambulation cycles and the expected time to complete the circumambulation	Strongly agree 72.7% Agree 27.3% Neutral 0% Disagree 0% Strongly disagree 0%
8	The application helped me report an electric vehicle issue quickly	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
9	The app's design makes it easy to find what you need.	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
10	How satisfied are you with the current features of the application?	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
11	Do you have any additional comments or suggestions for improving the app?	All users very satisfied But some user suggest pay on the app when they are reserved the electric vehicle, Live broadcast of prayers

1	I was able to log in	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
2	I was able to log out	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
3	I was able to make vehicle reservation for <i>walk-in Al -Haram visitors</i> (those who did not make reservation through the app)	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
4	The application provides clear enough reservation details for walk-in visitors' reservations	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
5	I was able to know the estimated time for the next available vehicle in case all vehicles are occupied to inform Al-Haram visitors of the queue waiting time	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
6	I was able to view vehicles' availability dashboard	Strongly agree 83.3% Agree 16.7% Neutral 0% Disagree 0% Strongly disagree 0%
7	How satisfied are you with the current features of the application?	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%

Admin			
1	I was able to log in	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%	
2	I was able to log out	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%	
3	I was able to configure and update system parameters	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%	
4	I was able to mark vehicles' pick-up and return location on a map	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%	
5	I was able to view vehicles' information	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%	
6	I was able to assign vehicle managers	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%	
7	I was able to view support notification	Strongly agree 100% Agree 0% Neutral 0% Disagree 0%	

		Strongly disagree 0%
8	I was able to detect vehicles' congestion by presenting a vehicle heatmap, which shows areas of congestion	Strongly agree 100% Agree 0% Neutral 0% Disagree 0% Strongly disagree 0%
9	How would you describe your experience with the website?	All user satisfied , they see good and comprehensive website.

### 5.3 Quality Attributes (NFR testing)

During the testing phase, we conducted evaluations to assess the non-functional aspects of the system. We took into consideration the non-functional requirements and tested each requirement based on its specific measurement, as outlined in Table 11. Additionally, we accounted for the surrounding environment, including factors such as the internet connection and the testing device. This was important as these factors can influence the results and simulate real-life situations. By considering these aspects during testing, we aimed to ensure that the system performs effectively and meets the specified non-functional requirements under realistic conditions.

Table 11. Quality Attributes

User story	Quality Attribute	Measure	Results
As a user I want to learn how to use the system in 30 minutes so that I can understand it easily and I can avoid doing something wrong.	(Usability)  How much time a user takes to perform main tasks once they see the interface?	Compute the time the users spend performing the main tasks (Task completion time).  The task completion time should not exceed 6 minute.	<ul style="list-style-type: none"> <li>•First, set a timer</li> <li>•Run the application on Android phone</li> <li>•Start the timer once the users start to test and stop when the users submit the order</li> <li>•First testing: minimum time was (2min and 20s),</li> </ul>

			<p>maximum time was (5 minute and 35s), and the average time was (4 min and 33s)</p> <p>we tested on 3 different devices with different internet connection</p> <p>all user pass the test.</p>
As a user concerned about the security of my personal information, I want to ensure that the system enforces strong password requirements so that my account remains protected from unauthorized access.	(Security)  What are the requirements of the password when registering in the app?	Check the requirement of the password when creating an account in the app. The password must be strong (8 characters at least, at least one upper and lower letter, at least one numeric digit and at least one special character)	<ul style="list-style-type: none"> <li>First, let users create an account at the beginning of the test</li> <li>Validate the password requirements when users choose one password</li> <li>Make sure that none is able to create account without satisfying the requirements.</li> </ul> <p>we tested on 3 different devices with different internet connection</p>

			all user pass the test.
As a user, I want the application to load within 10 seconds so that I will not have to wait long for a specific page to load. (performance)	How responsive is the system and its components?	Compute the response time for displaying application pages. Pages need at most 10 seconds to be fully displayed.	<ul style="list-style-type: none"> <li>• First ,Run the application on Android mobile</li> <li>• Recorded the time the pages take to be displayed</li> <li>• The minimum time was (5s), maximum time was (10s), and the average time was (8s)</li> <li>we tested on 3 different devices with different internet connection</li> </ul> <p>all user pass the test.</p>

## 5.4 Discussion

After collecting and analyzing the questionnaire responses from the end users, it is possible to describe how well Rehab application has performed for serving its users: Al-haram visitors, vehicle managers and administrators.

For Al-haram visitors, it is evident that the application evaluation is very good. The results show a high level of satisfaction, with 100% of the users strongly agreeing that they were able



to register, log in, and log out successfully. Additionally, all users strongly agreed that the application assisted them in locating the electric vehicles' pick-up and return points, reserving and rescheduling their reservations, providing clear details about their reservations, reporting electric vehicle issues quickly, and having an app design that makes it easy to find what they need. Moreover, 27.3% of the users strongly agreed, and 73.7% agreed that the application accurately calculates the number of circumambulation cycles and the expected time to complete the circumambulation. While there is a chance for improvement in this aspect, overall satisfaction remains high.

For vehicle manager, it is evident that the application evaluation is also satisfactory. The evaluation of the vehicle manager application yielded excellent results, with 100% of users strongly agreeing that they were able to register, log in, and log out successfully. All users also strongly agreed that the application provided clear reservation details for walk-in visitors and allowed them to know the estimated waiting time for the next available vehicle. The majority (83.3%) strongly agreed that they could view the vehicles' availability dashboard.

As for administrators, they had a highly positive experience with the website. They were able to log in, log out, configure system parameters, mark vehicle pick-up and return locations on a map, view vehicle information, assign vehicle managers, receive support notifications, and detect vehicle congestion through a heatmap with satisfaction.

In general, the users' experiences with the system were described as positive, all users expressed high satisfaction with the current features of the system. Based on these results, it can be concluded that the system performs exceptionally well, with high user satisfaction across various aspects. The feedback indicates that the system is user-friendly, efficient, and provides a positive user experience, we also recognized from the first NFR usability testing, we found that users were able to complete the process faster than expected. This was a good surprise because it meant they could easily finish their tasks without wasting time. When it came to security, all users successfully created accounts with strong passwords. This made sure that their personal information stayed safe and protected from unauthorized access. Users appreciated this extra level of security.

In terms of performance, the application performed well, pages loaded quickly, usually within 8 seconds or less. This means users didn't have to wait long for the content to appear. We tested the application on different devices (Samsung Galaxy A35, Samsung A73 5G, Samsung Galaxy S2) and internet connections to make sure it worked well in various situations.



## 6 Conclusions and Future Work

To conclude, the Rehaab system comprises a mobile application and a website. The mobile application serves both Al-Haram visitors and vehicle managers, enhancing the visitors' experience by providing easy reservation of electric vehicles, as well as the ability to reschedule and cancel reservations. Visitors can also track their tawaf rounds, locate pick-up and return points for the vehicles, and more. For vehicle managers, the mobile application streamlines their job and management tasks by allowing them to check-in reservations of Al-Haram visitors, make reservations for walk-in visitors who do not have access to the application, inform walk-in people how much time they need to wait and add them to a waiting list (when all vehicles are occupied).

The management of the Rehaab system will be conducted through the website. The admin will have access to various functionalities such as viewing a congestion heatmap, vehicles information, support notifications, and updating or changing system parameters, such as the number of backup vehicles. Additionally, the admin will have the ability to assign vehicle managers.

This report describes the design and development of Rehaab. It started with an introduction chapter that outlines the core concept of the Rehaab application. The following chapter, the background, explains location-based services (LBS) and computer vision, and covers the integration of the Google Maps API and queue analysis. Additionally, the background chapter included a definition related to Al-Masjid al-Haram and provided a brief introduction to the vehicles used within Al-Masjid al-Haram.

To meet the market requirements and define Rehaab's features, thorough research and analysis of competing applications were conducted in the literature review chapter. The system design and development chapter shows the system use case diagram and system features described in the product backlog. With a comprehensive understanding of the system's infrastructure and key features, it also defined Rehaab's components and their interactions. This was followed by translating user stories into diagrams and flow charts to aid implementation.

The implementation chapter began by developing Rehaab's user stories using the Flutter framework and Django and testing them against defined acceptance criteria. In the end, the Rehaab system successfully achieved its objective of improving reservation services and contributing to society.



## 6.1 Local and Global Impact

### 6.1.1 Local Impact

The Rehaab system will have a few implications on the local level. The app streamlines the process of reserving vehicles for Tawaf in Al-Masjid al-Haram. This improves the efficiency of managing vehicle resources and reduces waiting times for users, resulting in a smoother and more organized experience for local visitors. It also has a positive economic impact on the local community, as it can create employment opportunities for individuals involved in managing and operating the vehicle fleet, as well as in providing customer support services. Additionally, the app can attract more visitors to the area, which enhances the overall experience and satisfaction of individuals performing religious rituals in Al-Masjid al-Haram.

### 6.1.2 Global Impact

The Rehaab System has a significant global impact in several key areas. Firstly, it strengthens the reservation mechanism for Al-Masjid al-Haram, the holiest site in Islam, by providing a convenient and efficient app for users to reserve vehicles for Tawaf. This improves the overall management and organization of the site, reducing overcrowding, minimizing waiting times, and facilitating a smoother flow of visitors.

Furthermore, the Rehaab System contributes to digital transformation efforts, driving economic growth by fostering innovation, improving efficiency. By leveraging technology and embracing digital solutions, the System creates a digital ecosystem that has wide-ranging implications for mobility and accessibility solutions. This not only benefits individuals with disabilities or the elderly but also has broader societal implications.

Moreover, the Rehaab System promotes the expansion of access to Al-haram services, making them more inclusive and accessible to a larger audience. This expansion of access has positive social and economic impacts, allowing more people to participate in religious practices and rituals, fostering a sense of community and cultural exchange.

From an environmental perspective, the Rehaab System has the potential to contribute to sustainability efforts. By enabling more efficient use of resources through technologies such as smart vehicle allocation and optimized transportation routes, the System can reduce energy consumption and minimize environmental impact. This aligns with global sustainability goals and encourages responsible resource utilization.



## 6.2 Limitations

Currently, the Rehaab application is only available in English and exclusively supports Android users. In its initial version, the system focuses on vehicle management for Tawaf, excluding Sa'i (another ritual in Hajj and Umrah). Payment services are not included at this stage but will be incorporated in future updates of the application.

## 6.3 Main Contributions

The Rehaab system provides several key features for customers. These include the ability to sign up, sign in, and log out of the application. Customers (Al-Haram visitors) can make new reservations for vehicles specifically for Tawaf and can view a list of their reservations (Their current and previous reservations). They can access the details of their reservation and have the option to cancel or reschedule a reservation if needed. For convenience, Al-Haram visitors can utilize the map feature within the application to find the location of vehicles for both pickup and return. In case of any assistance required during Tawaf, there is a support feature that allows visitors to call for support. Furthermore, the application enables them to track their Tawaf status, which indicates the count of rounds completed while circumambulating around the Kaaba and provide estimated finish time. Finally, once Tawaf is completed, they will be checked-out automatically if they leave the tawaf area. For vehicle managers, the system offers an application to manage walk-in reservations, monitor vehicle availability, and communicate wait times. At the administrative level, the Rehaab system provides controls to configure parameters, view vehicle information, and detect congestion through a vehicle heatmap. By integrating customer convenience, operational efficiency, and administrative oversight, the Rehaab System has transformed the way devotees connect with the Kaaba during Tawaf.

## 6.4 Challenges

During the implementation phase of building the Rehaab System, we have faced several challenges. Firstly, we lacked prior knowledge of the Flutter and Django framework, Dart and Python programming languages, and mobile application development in general and website development. This posed a challenge as they invested time in learning these technologies from scratch. Moreover, we faced limited resources specifically related to using Flutter with SQL. To overcome these challenges, we dedicated a significant amount of time to learn and



familiarize themselves with the Dart and Python programming language and the Flutter and Django framework . In addition, we delved into effective management principles, particularly in reservation management. We extensively researched and studied various strategies and techniques to address the challenges we encountered in this area. By effectively managing our time and allocating resources to learning and problem-solving, we successfully overcame these challenges and continued the development of the Rehaab app. Also, one of the challenges we faced was not being present in Mecca, especially since Rehaab system has several features that would be better tested there, such as track Tawaf status, check out, and also the process of searching for vehicle managers within Al-Haram to benefit from their expertise, opinions, suggestions, and understanding of the organization process there. Additionally, it was hard to search for sources of information, such as the average time visitors use the vehicles and the battery life of the vehicles, as well as the distance between the circumambulation area and the Kaaba, and so on. We also faced difficulties in representing a congestion heatmap feature. We were unable to find a high-quality video with the right angle of Al-Haram vehicles during the Tawaf that could serve our purpose, we tried to ask the visitors to Al-Haram to take videos of Al-Haram vehicles during the Tawaf, but they said it was prohibited by the guards there. Furthermore, we encountered several problems with the availability of models trained on Al-Haram vehicles, we attempted to train a new model, but unfortunately, the dataset for Al-Haram vehicles was very small, and its quality was not suitable.

## 6.5 Future Work

The Rehaab system team will continue to expand and keep working to make the system better, starting with adding support for iOS operating system. Also, the system will be expanded to support additional languages, enabling a wider range of users to interact with the app in their preferred language, and it will support the online payment service to make the user experience easier and faster. Also, the app will incorporate vehicle management for Sa'i, in addition to Tawaf. Moreover, the app will introduce the option for manual vehicle reservations, providing users with the flexibility to choose between automated and manual vehicles for their Tawaf and Sa'i. Lastly, the admin's dashboard will be enhanced to display comprehensive statistics and analytics regarding reservations made by Al-Haram visitors. This will provide valuable insights and data to help manage and optimize the app and vehicle management system's operations.



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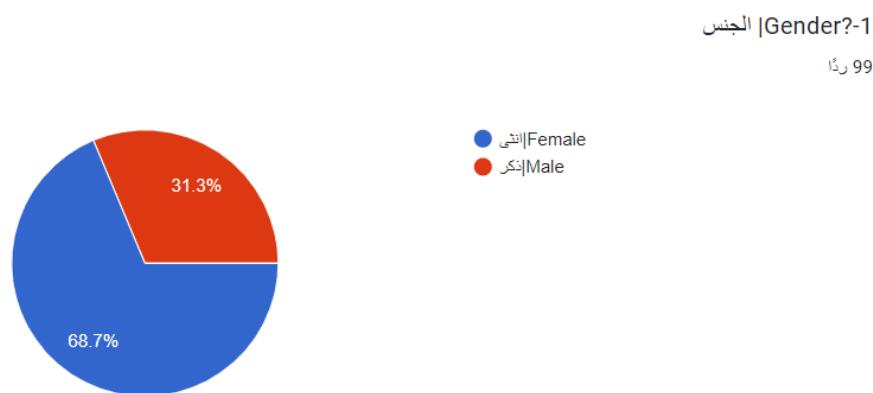
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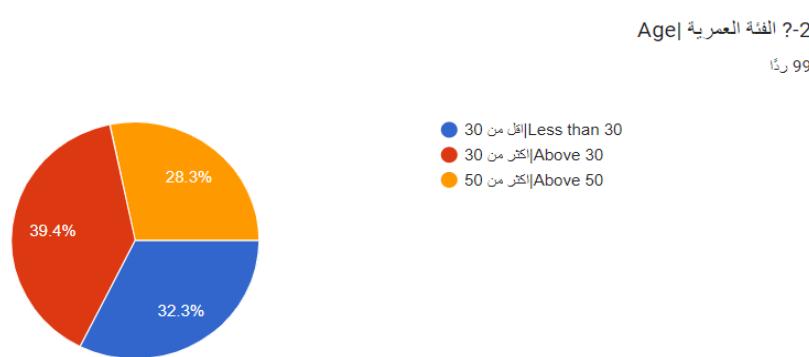
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## 9.1 Appendix A: Survey questions



**Figure 64. Survey questions**



**Figure 65. Survey questions**

Have you ever used al-haram electric vehicles? -3

هل سبق لك أن استخدمت حربات الحرم الكهربائية؟

رداً 99

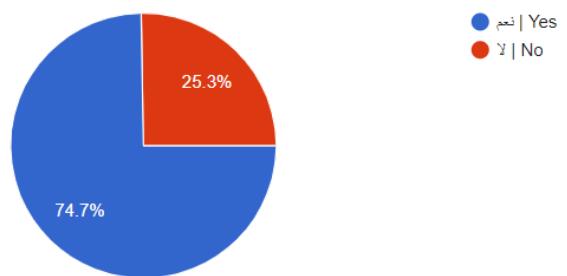


Figure 66. Survey questions

?If yes, then what is the method you use to reserve the vehicle -4

إذا كان الجواب نعم، فما هي الطريقة التي تستخدمها لحجز العربة؟

رداً 74

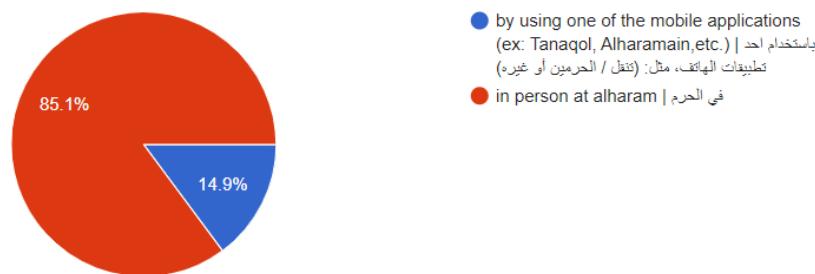


Figure 67. Survey question

?What is the acceptable time to wait in queue for receiving the vehicle -5

ما هو الوقت المقبول بالنسبة لك لانتظار في الصف لإستلام العربة الكهربائية؟

رداً 99

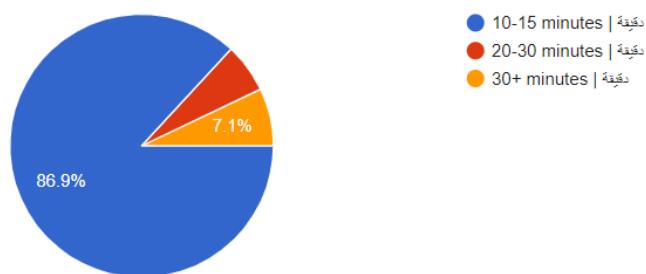


Figure 68. Survey questions

?Do you usually take your mobile phone with you while performing tawaf -6

هل عادة ما تحمل هاتفك أثناء أداء الطواف؟

رداً 99

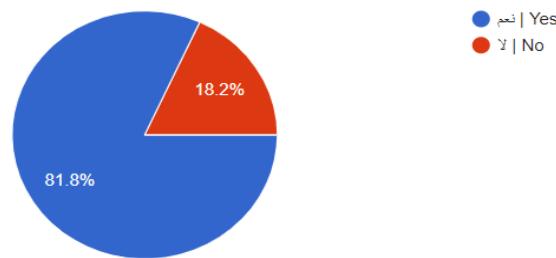


Figure 69. Survey questions

?Have you ever encountered issues with electric vehicles -7

هل سبق لك وأن واجهت مشاكل مع العربات الكهربائية؟

رداً 74

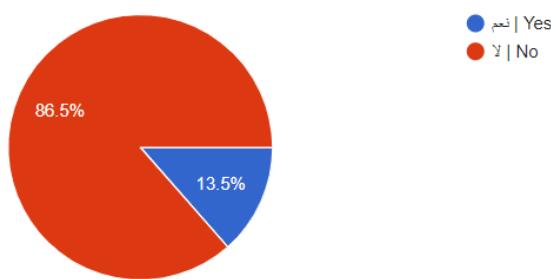


Figure 70. Survey questions

If yes, indicate the issue -8

إذا كانت الإجابة نعم، فاذكر المشكلة.

رداً 21

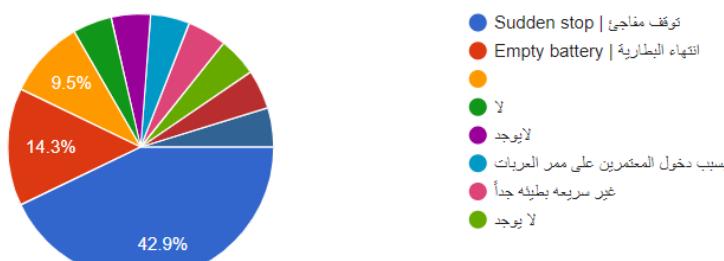


Figure 71. Survey questions

How did you ask for help? (ignore if your answer is no) -9

كيف طلبت المساعدة؟ (تجاهل اذا كانت اجابتك لا)

10 ردود

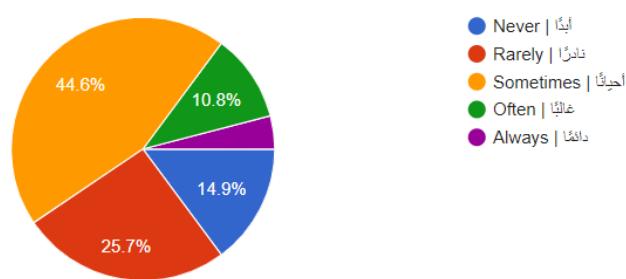
اطلب المساعدة بسبب وجود العربات الكهربائية في الدور الثاني الافضل موقعها في الدور الارضي تسهيلا على مستخدميها	اتصال بالرقم
	استبدلها
رحت وطلبت من المسؤول عن العربات بغير لي العربية	رجال أمن الحرم يساعدونني
	الاتصال بخدمة العملاء
طلبت التغيير فغيروها ونفس المستوى	الاموره سهلة
	لا

**Figure 72. Survey questions**

?How often do you encounter congestion while using the electric vehicle -10

كم مرة تواجه ازدحاماً أثناء استخدام العربات الكهربائية؟

74 ردًّا



**Figure 73. Survey questions**



Does congestion have a negative effect on worship performance? If yes, mention the effect - 11

هل لازدحام تأثير سلبي على أداء العبادة؟ إذا كانت الإجابة نعم، اذكر التأثير.

رداً 23

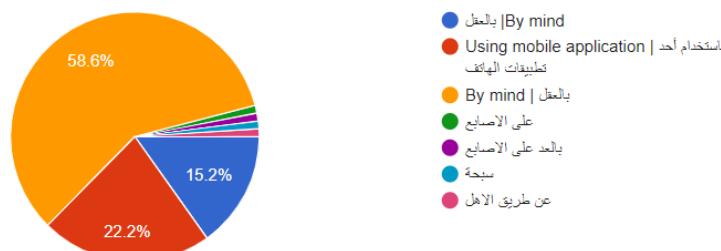
لا
نعم
نعم، عدم التركيز بـ أداء العبادة
أشغل في التركيز بالازدحام عن أداء العبادة بشكل كامل
نعم تشتت الواحد مايعد الله زين
نعم ، التشتت وعدم التركيز أثناء العبادة
نعم ممكن تصدام السيارات يتغير فلق بسيط
نعم الازدحام يؤثر على في اطالة الوقت وكذلك اصابة الادعية والتعب الجسدي
نعم تشتت المعتمر وتصبىع الوقت
احسن ايه ياخذ لانه يأخذ من وقتهم ومسكن يتاخروا عن اصحابهم اذا كان عندهم جدول او موعد محدد
نعم صعوبة التنقل
نعم عدم الخشوع في الدعاء وادا المناسب
نعم ، استغلال العبادة
الخروف واللثخير في الإزدحام والتصادم بدلاً من التركيز والإخلاص في العبادة
يأخذ الوقت ويستنزف مجهد النساء العبادة
عدم الخشوع / الاصابات الغير مقصودة بسبب الزحام/ارتفاع درجة الحرارة
الملل من الانتظار
تنقطع الدعاء و حل الأذكار

*Figure 74. Survey questions*

?What methods do you use to keep track of Tawaf rounds -12

ما هي الطرق التي تستخدمها لعد أشواط الطواف؟

99 ردًّا

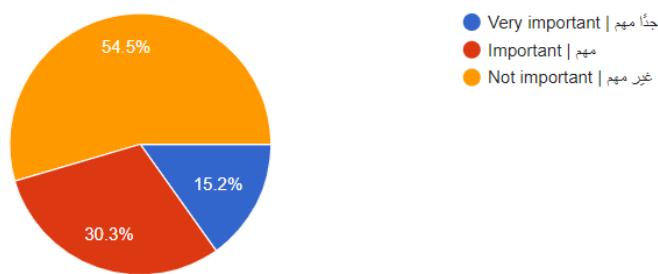


**Figure 75. Survey questions**

?How important is it to know the exact time to finish the Tawaf -13

ما مدى أهمية معرفة الوقت الدقيق لانتهاء الطواف؟

99 ردًّا



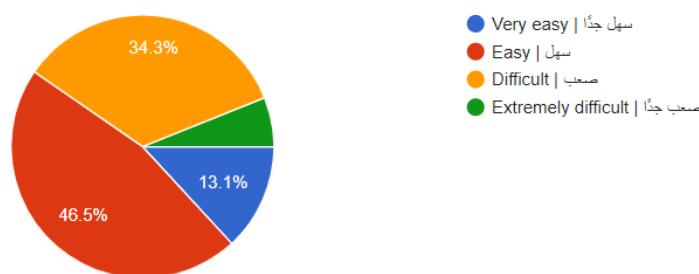
**Figure 76. Survey questions**

How easy is it to find electric vehicles' pickup/return location as a new guest to al- -14

?haram

ما مدى سهولة العثور على موقع استلام/إعادة العربات الكهربائية كضيف جديد في الحرمين؟

99 ردًّا



**Figure 77. Survey questions**

Mention your challenges when you want to reserve electric vehicles ?(optional) -15

اذكر التحديات التي تواجهك عندما ترغب في حجز عربة كهربائية (اختياري)

ردود 9

الازدحام عند صف الحجر
بعد مكانتها
خل
نورها عند بوابة واحدة
احيان في المواسم مثل رمضان والحج واجهتني مشكلة الانتظار لوقت طويل فقط
سؤال أكثر من شخص لوصف مكان حجوزات العربات
الازدحام لمستخدمين العربات
الحدلة
معرفة المكان المسافة البعيدة الازدحام

**Figure 78. Survey questions**

What are your recommendations to enhance organizing reservation system? (optional) -16

ما هي اقتراحاتك لتحسين نظام الحجوزات ؟ (اختياري)

ردود 11

باستحدث تطبيق يحدد وجود العربة مثل تطبيق غزاله حق السكوترات بحيث لما احمل التطبيق وابحث احصل العربة في اقرب مكان بدل ما تكون محجوزه عند بوابة واحدة

مdry والله بس ممكن انو نسووا تطبيق للحجر

وضع شاشات تشير لموقع مكان الحجر

ابلكيشن يسهل طريقه الحجر ويسهل الاستخدام للعربه

زياده عدد العربات وزياده مواقع تواجهها

ماك سمعت في نظام الحجوزات المصراوه ولكن الله يوفقكم يا اهلى مهندسات ❤️

زياده اماكن الحجوزات

سيطه

**Figure 79. Survey questions**



## 9.2 Appendix B: Interview questions

1. ماهي التحديات اللي تواجهك عند إدارة حجوزات العربات الكهربائية خلال أوقات النزوة مثل موسم الحج؟
2. كيف يمكنكم معرفة وجود ازدحام العربات الان؟ وهل تستعملون تقنيات معينة لاكتشاف الزحام؟
3. كم عدد العربات الكهربائية اليومية التي تتعرض لقطع، وهل هناك عربات احتياطية متاحة؟
4. هل سبق وان ثركت العربات الكهربائية في أماكن عشوائية لفترات طويلة بعد استخدامها من قبل اشخاص لم يُعيدها الى المواقف المخصصة لها أو تم استخدامها مرتين دون الدفع؟ وكيف يمكنكم معرفة ذلك؟
5. ماهي اقتراحاتك لتحسين نظام الحجوزات.

## 9.3 Appendix C: UAT

This part provides the questions of the user acceptance testing questionnaire, and the responses of the questionnaire in form of charts.

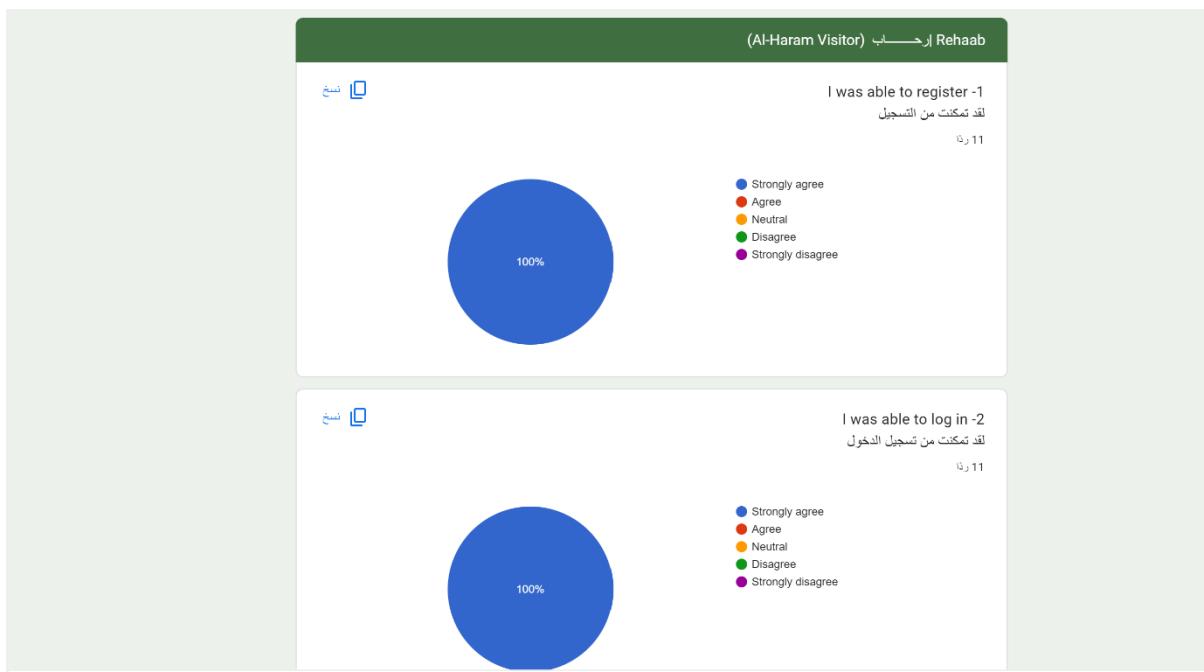


Figure 80.UAT

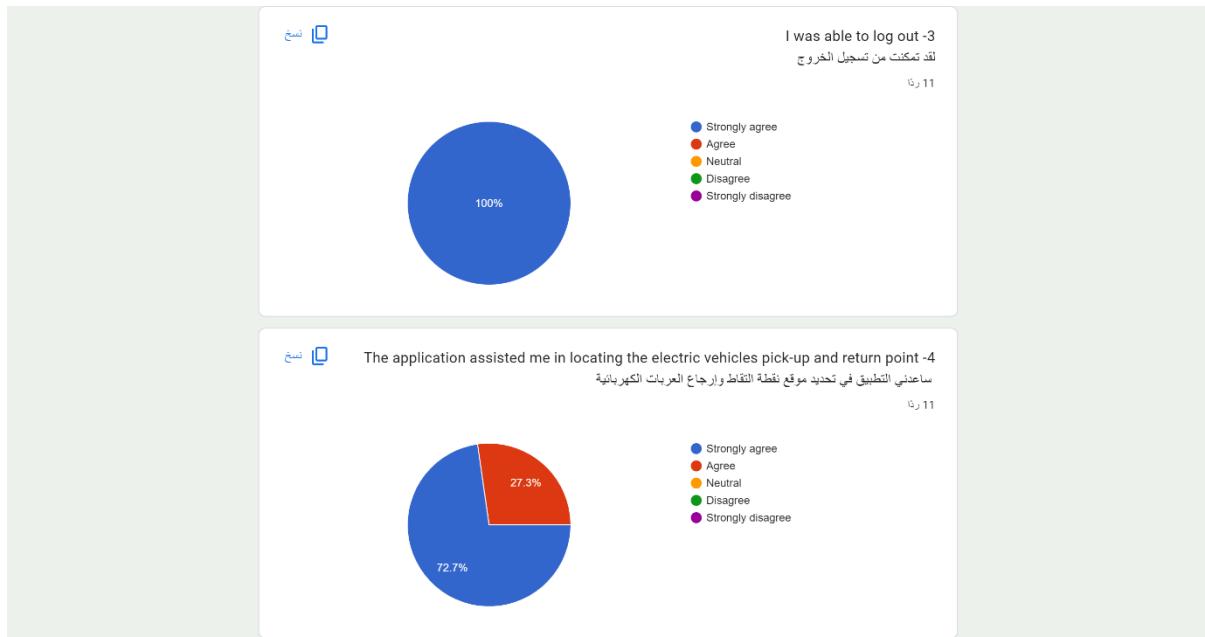


Figure 81.UAT

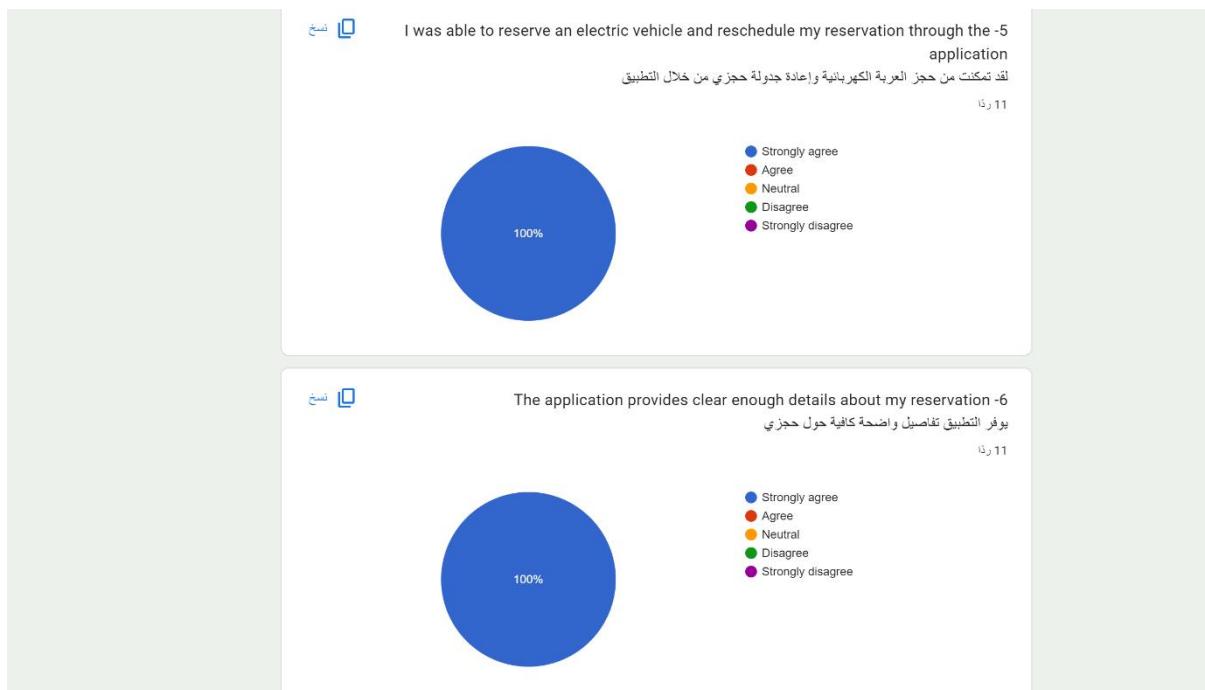
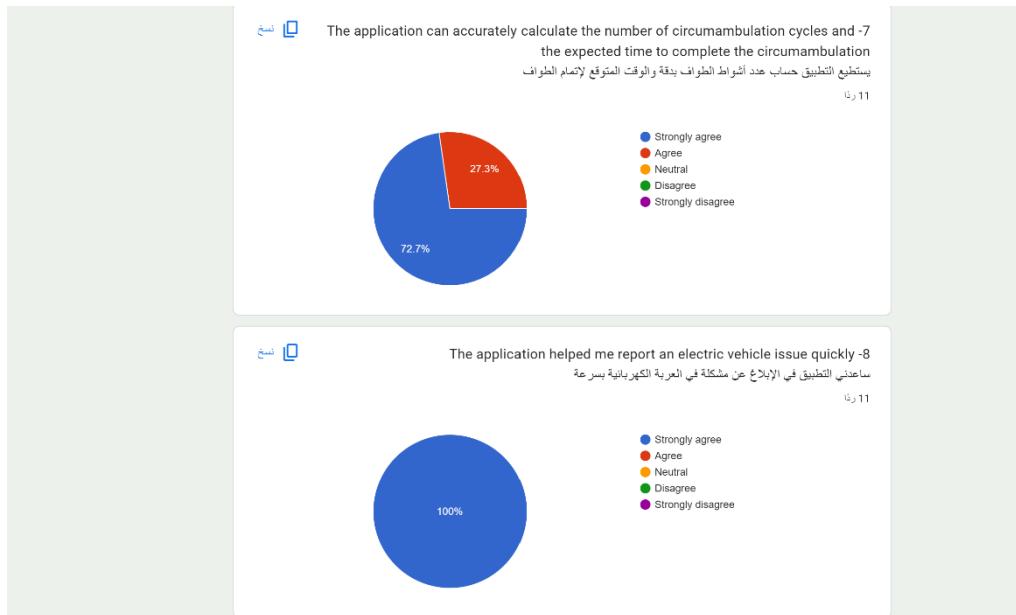
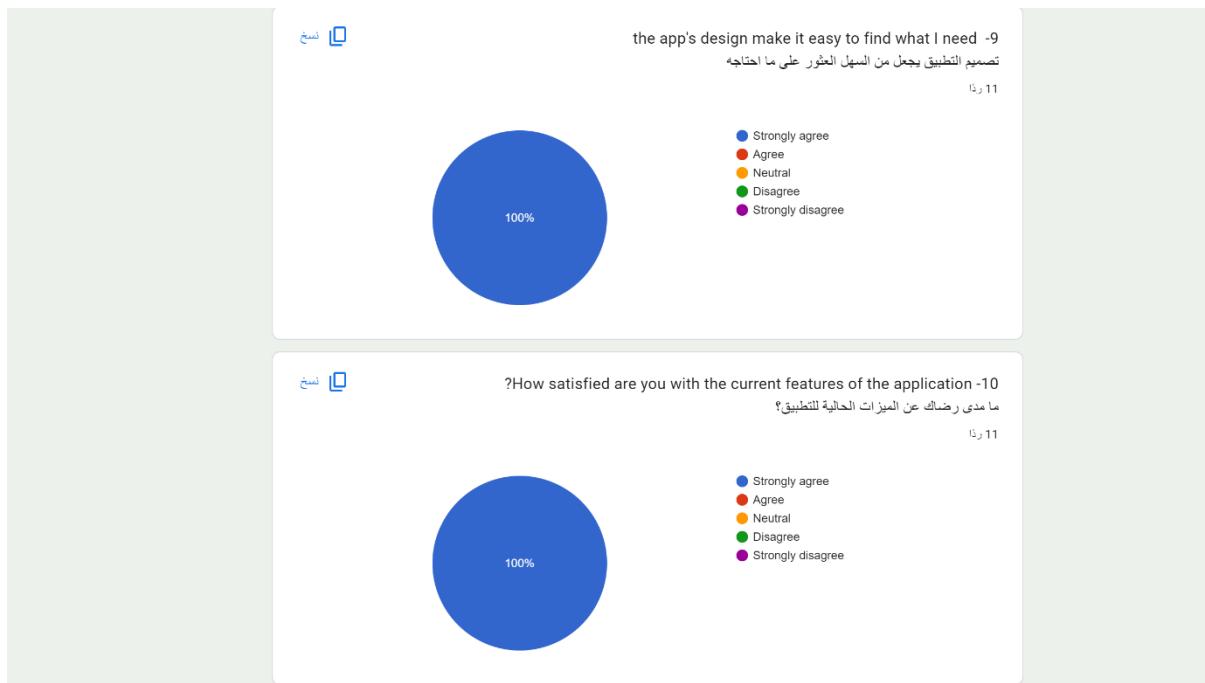


Figure 82.UAT



**Figure 83.UAT**



**Figure 84.UAT**

?Do you have any additional comments or suggestions for improving the app -11  
هل لديك اي تعليقات او اقتراحات اضافية لتحسين التطبيق؟

5 ردود

No
I want to pay on the app when I reserve electric vehicle
Live broadcast of prayers feature missing in your app
-

Figure 85.UAT

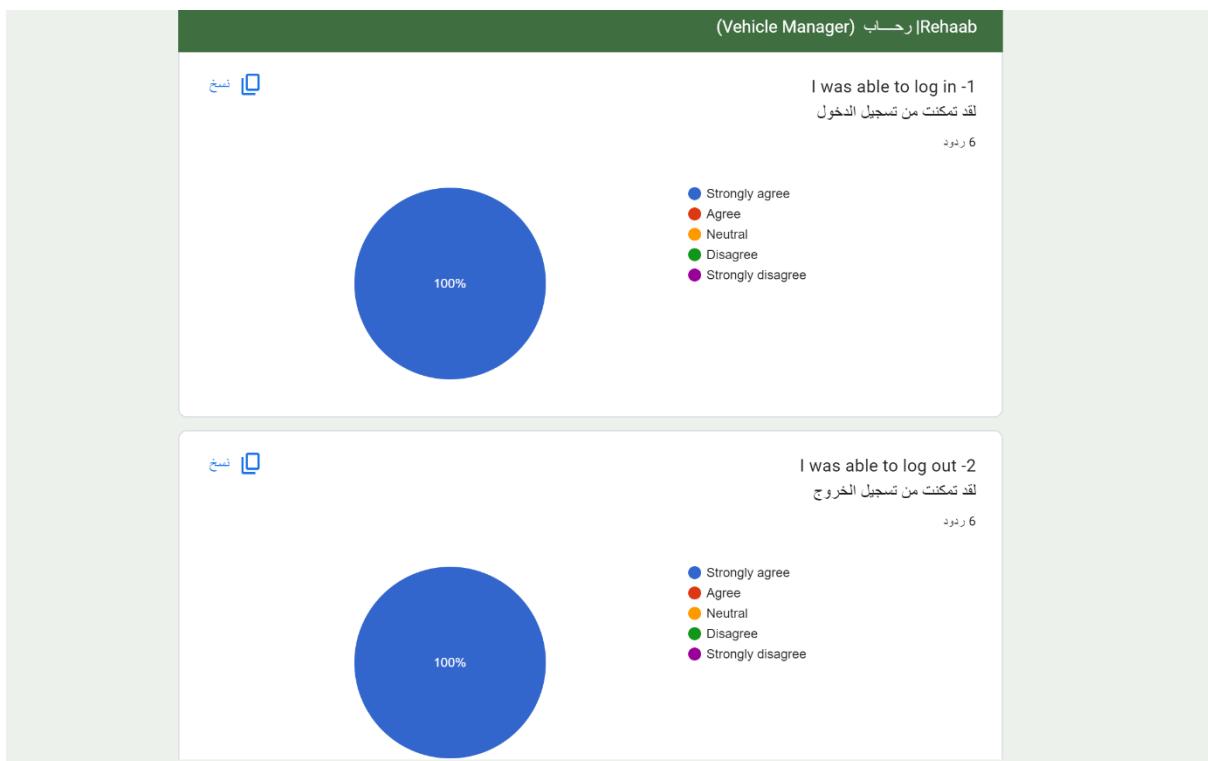


Figure 86.UAT

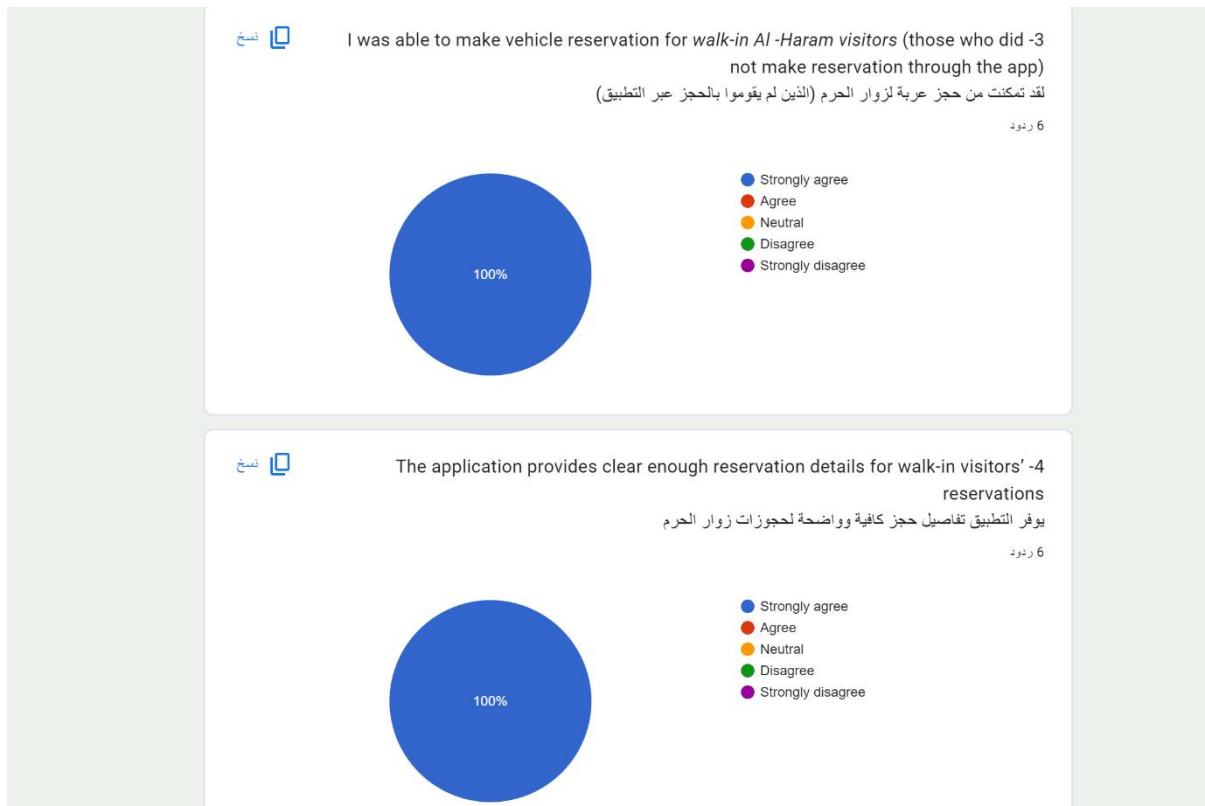
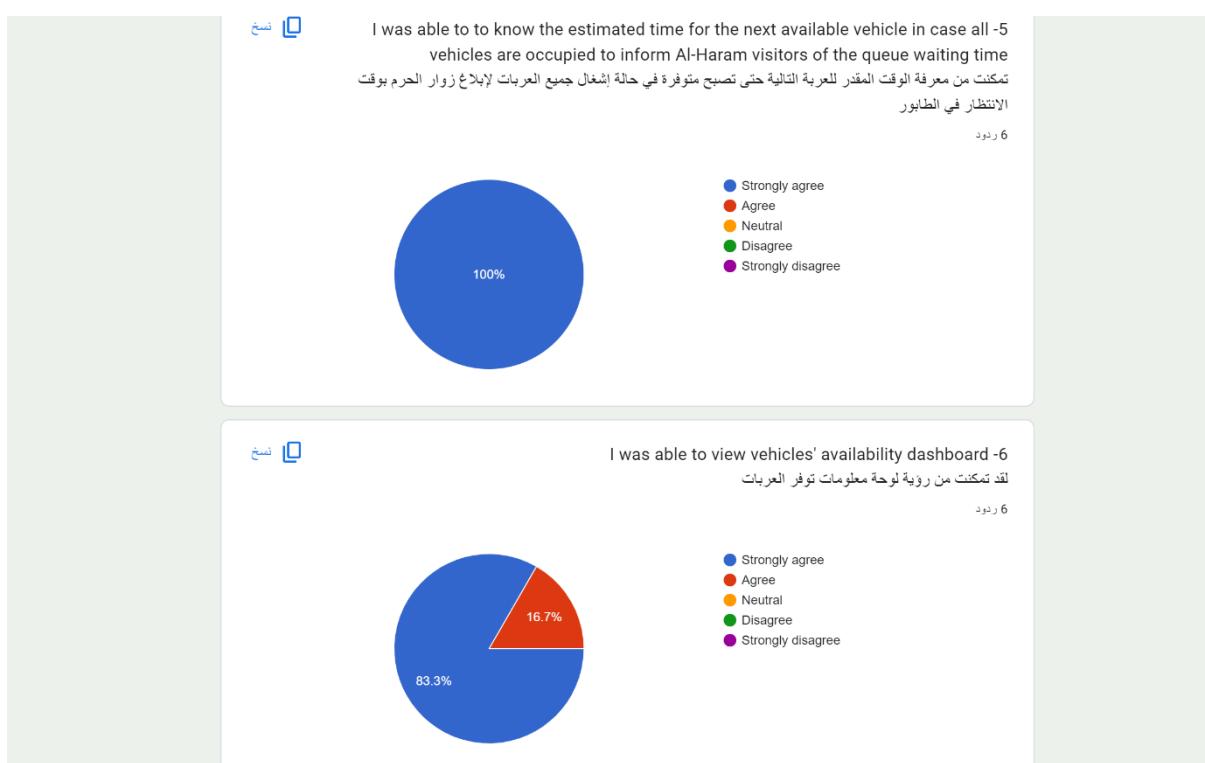
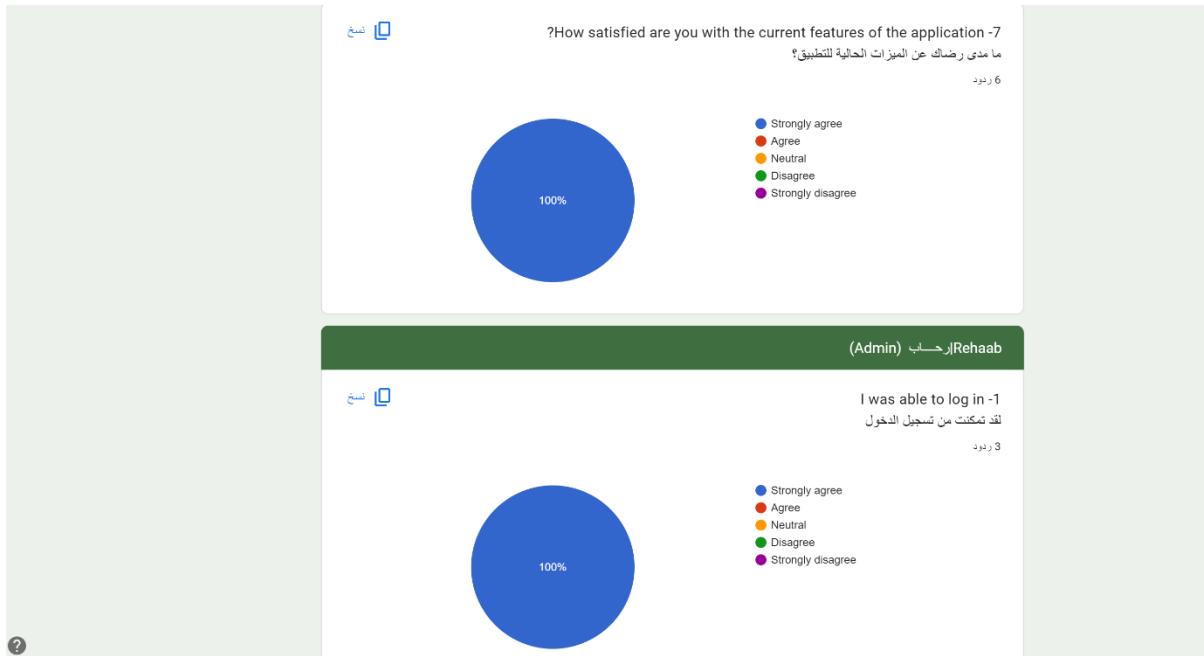


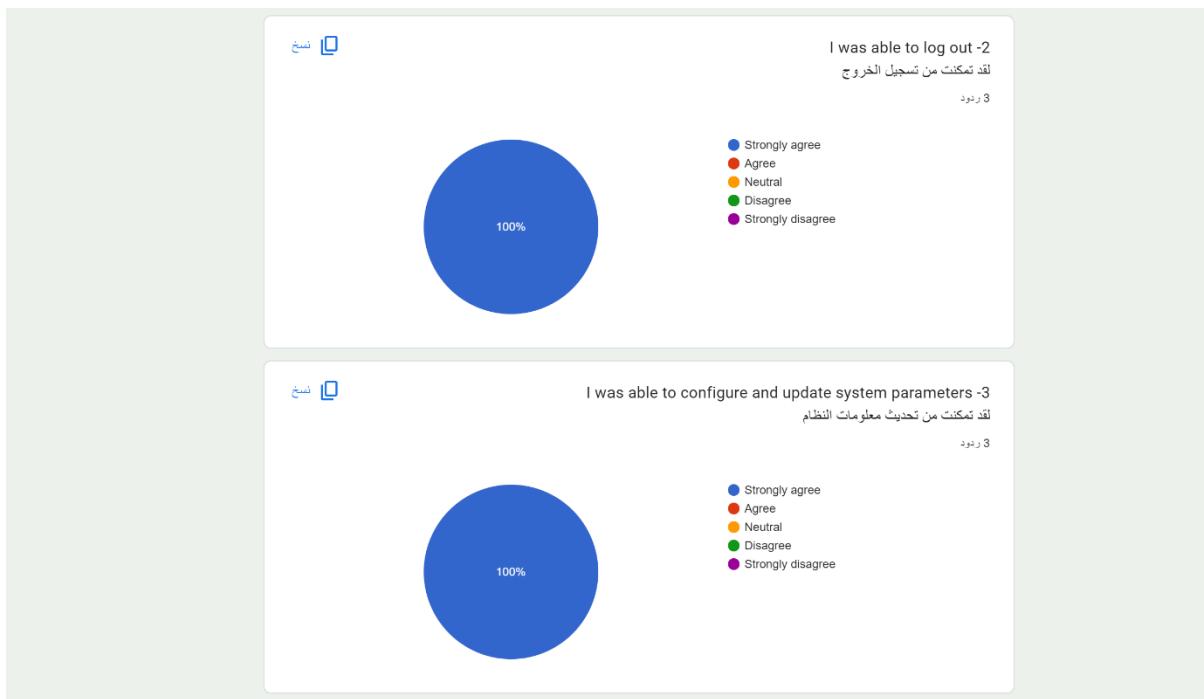
Figure 87.UAT



**Figure 88.UAT**



**Figure 89.UAT**



**Figure 90.UAT**

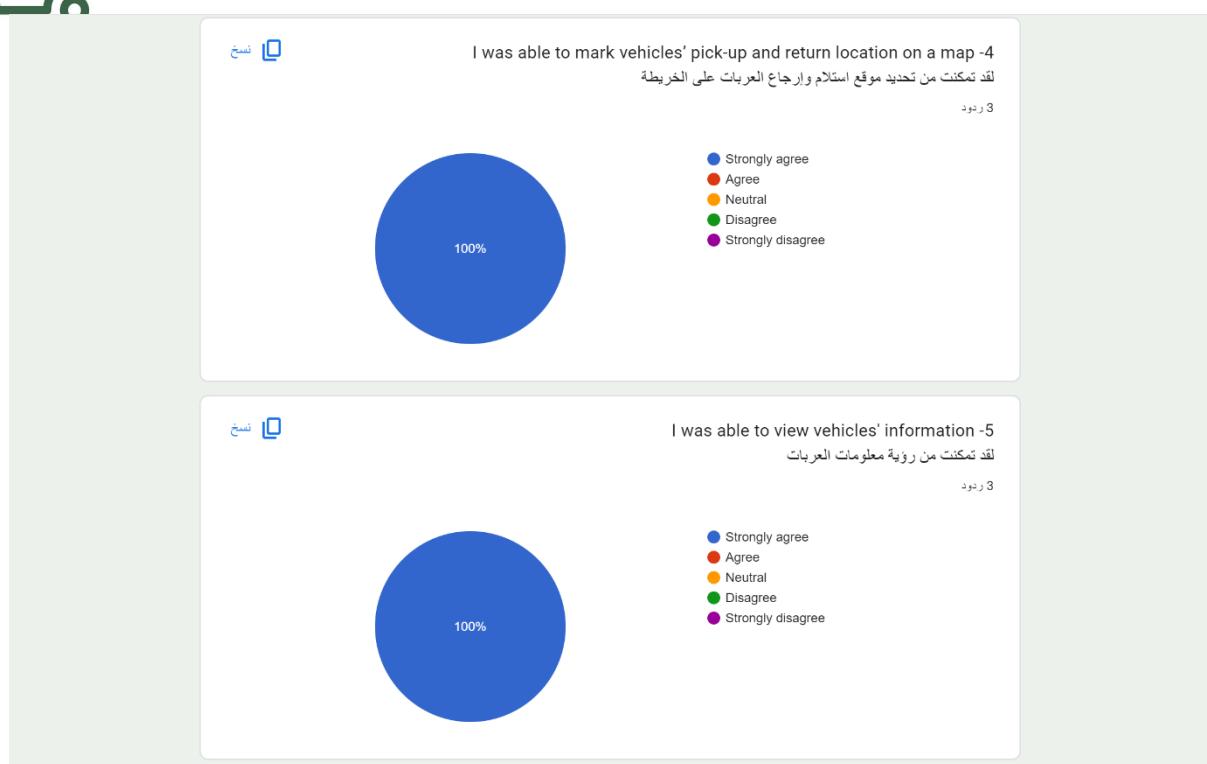


Figure 91.UAT

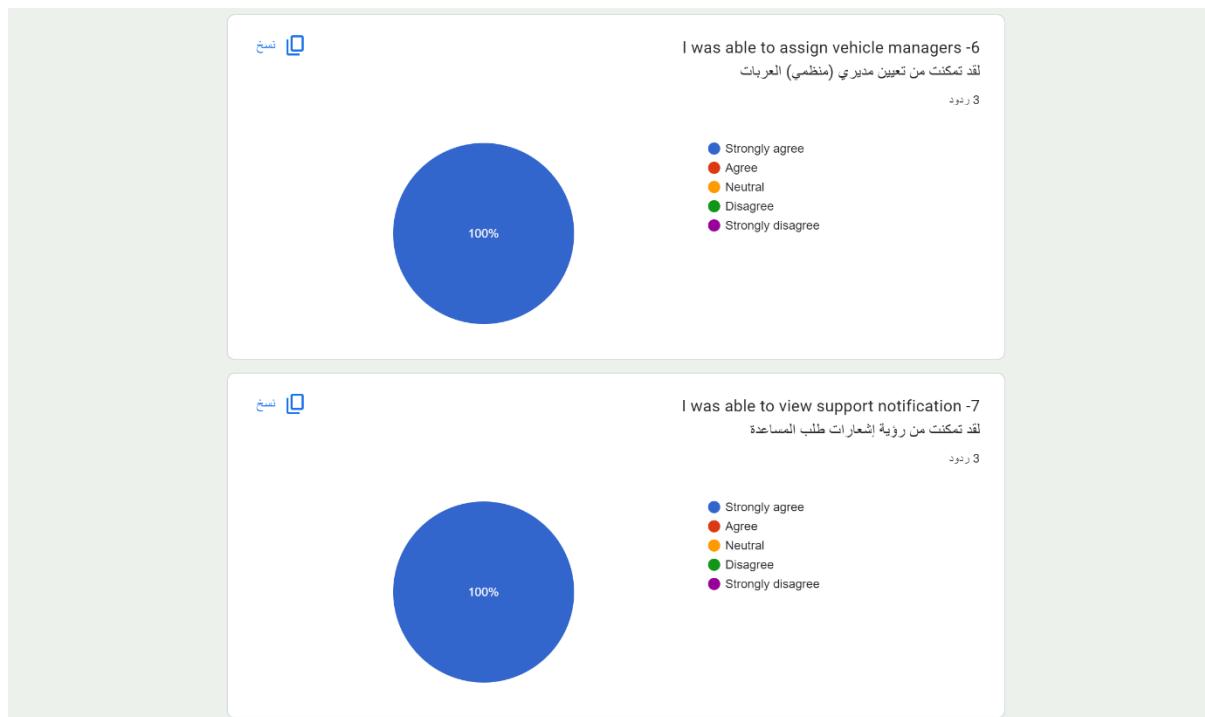


Figure 92.UAT

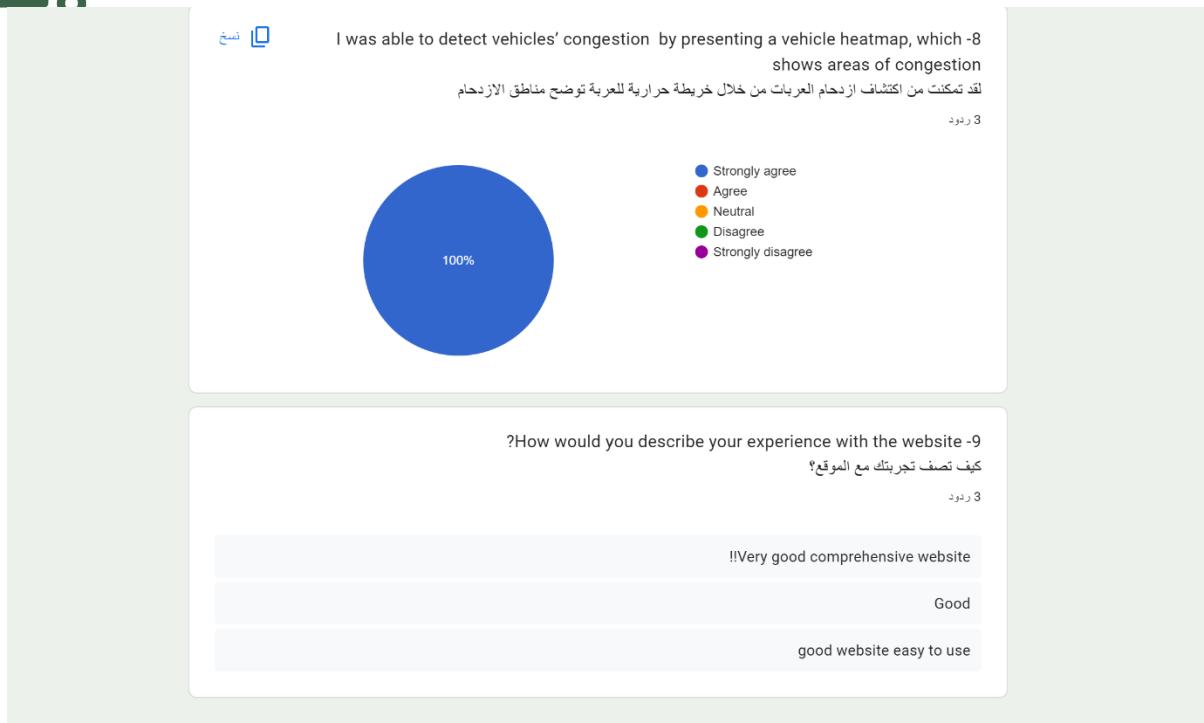


Figure 93.UAT