



Sekkah | سِكّة

IT 497: Graduation Project Report
Product Release-2

Prepared by

Student Name	Student ID
Yara AlManea	441203522
Razan AlDhafian	441201359
Reema AlSaif	439200834
Najd AlNasrallah	439201287

Supervised by
Dr. Meriam Kefi

Third Semester 1444
2022/2023

TABLE OF CONTENTS

1	Introduction	9
2	Background	14
2.1	Public Transportation	14
2.2	Intelligent Public Transportation Systems	15
2.3	Web Application Development	16
2.4	Mobile Application Development	16
2.5	Google Maps API	17
2.6	Firebase	17
2.7	PayPal	17
2.8	Definitions	18
3	Literature Review	20
3.1	Competitive Product Analysis	22
4	System Design and Development	28
4.1	Methodology	28
4.2	System Requirements	30
4.2.1	System Users	30
4.2.2	Requirements Elicitation and Analysis	31
4.2.3	User Interactions	33
4.2.4	Roadmap and Product Backlog	34
4.3	System Design	53
4.3.1	Architectural Diagram	53
4.3.2	Class Diagram /DFD	54
4.3.3	Component Level Design	55
4.4	Data Design	60
4.4.1	Data Models	60
4.4.2	Data Collection and Preparation	61
4.5	Interface Design	62
4.6	Implementation	70
5	System Evaluation	87
5.1	Experimental Results	87
5.2	User Acceptance Testing	87
5.2.1	Demographics of Participants	87
5.2.2	Questionnaire/Interview Results	88
5.3	Quality Attributes (NFR testing)	95

5.4	Discussion	98
6	Conclusions and Future Work	101
7	Acknowledgements	107
8	References	109
9	Appendix A	114
10	Appendix B	119

TABLE OF FIGURES

<i>Figure 1 - Riyadh Bus App</i>	22
<i>Figure 2 - SAR App Logo</i>	22
<i>Figure 3 - S'hail App Logo</i>	22
<i>Figure 4 - TfL Go App</i>	23
<i>Figure 5 - Transit App logo</i>	23
<i>Figure 6 - User Interactions Diagram</i>	33
<i>Figure 7 - Product Roadmap</i>	34
<i>Figure 8 - Sekkah Architecture Diagram</i>	54
<i>Figure 9 - Sekkah Class Diagram</i>	54
<i>Figure 10 - View Stations FlowChart</i>	55
<i>Figure 11 - Find Nearest Stations FlowChart</i>	56
<i>Figure 12 - Update Availability FlowChart</i>	57
<i>Figure 13 - Activate Digital Card FlowChart</i>	58
<i>Figure 14 - Plan Route FlowChart</i>	59
<i>Figure 15 - ER Diagram</i>	60
<i>Figure 16 - Sekkah Data Model</i>	60
<i>Figure 17 - Splash Screen & Welcome page Interface Design</i>	62
<i>Figure 18 - Login & Register Interface Design</i>	62
<i>Figure 19 - View Map Interface Design</i>	63
<i>Figure 20 - View Map (Find Nearest Bus/Metro stations) Interface Design</i>	63
<i>Figure 21 - Plan Route Page Interface Design</i>	64
<i>Figure 22 - Plan Route Page (Detailed Route) Interface Design</i>	64
<i>Figure 23 - Plan Route Page (Purchase ticket) Interface Design</i>	65
<i>Figure 24 - Digital Card Page Interface Design</i>	65
<i>Figure 25 - Tickets Page Interface Design</i>	66
<i>Figure 26 - Profile Page (Edit page) Interface Design</i>	66
<i>Figure 27 - Profile Page (Change password) Interface Design</i>	67
<i>Figure 28 - Login (Admin) Interface Design</i>	67
<i>Figure 29 - HomePage (Admin) Interface Design</i>	68
<i>Figure 30 - Sekkah Site Map (Passenger)</i>	68
<i>Figure 31 - Sekkah Site Map (Admin)</i>	69
<i>Figure 32 – Participants' Demographics</i>	87

LIST OF TABLES

<i>Table 1 - Competitive Product Analysis</i>	24
<i>Table 2 - Product Backlog</i>	34
<i>Table 3 - Code snippet (1)</i>	73
<i>Table 4 - Code snippet (2)</i>	74
<i>Table 5 - Code snippet (3)</i>	75
<i>Table 6 - Code snippet (4)</i>	76
<i>Table 7 - Code snippet (5)</i>	79
<i>Table 8 - Code snippet (6)</i>	80
<i>Table 9 - Code snippet (7)</i>	82
<i>Table 10 - User Questionnaire Results</i>	89
<i>Table 11 - Admin Questionnaire Results</i>	93
<i>Table 12 - NFR</i>	95
<i>Table 13 - User Questionnaire Results</i>	119
<i>Table 14 - Admin Questionnaire Results</i>	123

Sekkah

Yara AlManea¹, Razan AlDhafian², Reema AlSaif³ and Najd AlNasrallah⁴

¹Information Technology Department, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia; 441203522@student.ksu.edu.sa

²Information Technology Department, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia; 441201359@student.ksu.edu.sa

³Information Technology Department, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia; 439200834@student.ksu.edu.sa

⁴Information Technology Department, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia; 439201287@student.ksu.edu.sa

Abstract (English):

As population growth accelerates, a significant challenge is increased traffic congestion. Utilizing public transportation thereby minimizes the time lost in traffic. Fortunately, the Riyadh Public Transport Authority is launching its metro. However, developing the metro's infrastructure is insufficient. Thus, integrating new technologies, like developing a mobile application with automated services, is becoming essential. In this project, we propose "Sekkah," a hybrid mobile application targeting Riyadh's public transportation passengers. It offers interactive maps that enable passengers to find nearby stations and effortlessly plan their journey. Moreover, an online ticket purchase option is available, along with a real-time journey tracking option. To build "Sekkah," we used the Scrum agile methodology, which takes an iterative approach to product development. To automate processes, if a station is temporarily closed or there is a slight delay by bus, an admin dashboard website is developed to push synchronized updates directly to "Sekkah". The main purpose of "Sekkah" is to give passengers a means to efficiently utilize public transportation, which is achieved by optimizing the journey planning process. To do so, we need to compute journey routes dynamically; hence, we built our algorithm based on the Dijkstra algorithm essentials, our logic, and the Google Maps API. After testing Sekkah with a group of users, results revealed that the numerous app features were efficient for users. Moreover, most users expressed satisfaction with the accuracy of the planning but hoped for some improvements in several aspects. Fortunately, almost all users encountered no problems; however, a few users reported that the system crashed. As a result, we will endeavor to improve all system use scenarios.

Abstract (Arabic):

مع تسارع نمو السكان أصبح الازدحام المروري تحدي تواجهه عاصمة المملكة العربية السعودية، ولذلك تحمت استخدام وسائل النقل العام لحل هذه المشكلة، فأطلقت الهيئة الملكية لمدينة الرياض مشروع الملك عبدالعزيز للنقل العام وبالتالي أصبح من الضروري دمج تقنيات جديدة وتطوير تطبيق جوال مزود بخدمات آلية لتساهم في سهولة استخدام وسائل النقل العام

فاقتربنا تطبيق "سكة" وهو تطبيق جوال يعمل على أكثر من نظام تشغيل يستهدف ركاب وسائل النقل العام في الرياض، يوفر التطبيق خرائط تفاعلية تمكّن الركاب من العثور على المحطات القريبة منهم وتخطيط رحلاتهم بكل سهولة ويوفّر خيار شراء التذاكر عبر الإنترنت، بالإضافة إلى خاصية تتبع للرحلة. وقد تم استخدام إطار عمل scrum لبناء التطبيق.

وفي حالة إغلاق المحطة مؤقتاً أو حدوث تأخير في موعد وصول الحافلة فقد تم تطوير لوحة تحكم تمكّن المسؤول من ارسال التحديثات مباشرة الى التطبيق "سكة"

والهدف الرئيسي من تطبيق "سكة" هو توفير وسيلة للركاب للاستفادة من وسائل النقل العام بكفاءة، والتي يتم تحقيقها من خلال تحسين عملية البحث عن الرحلات ولتحقيق هذا الهدف فإنه يتبعنا حساب مسارات الرحلة بشكل ديناميكي، وبالتالي فقد قمنا بتطوير خوارزمية خاصة بنا استناداً على أساسيات خوارزمية Dijkstra ومنطقنا الخاص وواجهة برمجة تطبيقات Google maps

بعد اختبار "سكة" مع مجموعة من المستخدمين كشفت النتائج أن العديد من المستخدمين أعربوا عن اعجابهم في دقة البحث واقتراح خطط سير الرحلات لكنهم أيضاً يأملون ان تتحسن بعض مميزات التطبيق، لحسن الحظ لم يواجه أغلب المستخدمين أي مشكلات أثناء استخدام التطبيق بينما واجه البعض منهم توقف التطبيق عن العمل، لذلك سنسعى جاهدين لتحسين التطبيق.

Keywords:

Mobile application development; Riyadh metro/bus network; Intelligent transportation systems; Route optimization; Location-based services; Mobile payments; automated services; google maps API.

CHAPTER 1

- INTRODUCTION -

1 Introduction

The general industry we are addressing is the transportation industry in Riyadh. The Riyadh Metro is a proposed rapid transit system that would serve as Riyadh's public transportation backbone. Whether a country is developed or not, traffic congestion has been rising significantly all around the world, with statistics showing that road traffic will only get worse as the years pass, especially if no effort is made for a public transport initiative, posing a risk to the quality of life. [1]

Riyadh is considered one of the world's fastest-growing metropolitan areas, as it rapidly advances day by day.[1] A living proof of that is the Riyadh Metro, which is one of the biggest projects Riyadh is currently constructing.[2] This project is a necessity since Riyadh's population is mainly dependent on using private cars rather than public transportation. Hence, people face road traffic regularly, and that has escalated greatly during the past few years. Therefore, launching Riyadh's Metro will be a major solution to congestion.

In the near future, Riyadh's metro will launch officially. Yet, people have no clear guidance on the lines and routes of Riyadh's buses and metro stations, nor their departure information. For that reason, they will spend lots of time figuring out where the nearest station to them and eventually just take a taxi or book a ride to their destination, which is considered a less affordable option.

With Riyadh's immense size and its rapidly expanding population, even waiting in lines to pay for tickets is frustrating and inefficient. Even so, time could be wasted by making wrong assumptions about the metro's timetable, creating a conflict by not providing passengers with an accurate reference that they can depend on. Not forgetting, the public transportation system may experience minor delays, yet passengers are not aware of that since there is no clear channel to let them know if any conflict arises.

People are becoming increasingly reliant on technology nowadays. This is mainly because mobile apps have greatly contributed to the simplification and efficiency of processes that were more difficult before they emerged. A technological solution is an utmost necessity, as it would provide the best solution to the struggle, we will all face by implementing a mobile-based application that provides with the services of Riyadh's Metro system.

Our application aims to optimize the use of public transportation by offering various objectives addressed specifically to passengers, who are the main users of our mobile application. These objectives are as follows.

- Visualize the full city transit map (6 lines) and every bus/metro station.
- Find the nearest bus/metro stations to your location.
- Easily plan a route by choosing the starting point/destination.
- Plan a route ahead of time by specifying the departing/arrival time along with the date.
- Search for all the possible routes to reach your destination.
- Display a selected route's details including its different stops, estimated duration for stops, and the total trip duration.
- Add a digital metro card by selecting a type of pass.
- Check the remaining pass duration of the digital metro card.
- Track the passenger's real-time location and show the remaining stations the passenger will go through.
- Purchase tickets.
- Send an alert if the passenger is heading towards the wrong route and recalculate the directions to reach the correct route.
- Send a notification when the passenger is approaching a stop.

"Sekkah" is a hybrid mobile application that provides access to all of the services offered by Riyadh's metro on a single platform for passengers of the city's bus and metro systems. The mobile application will be available in the English language and created using the Flutter programming language. Moreover, "Sekkah" features an admin dashboard to fully integrate certain services and provide accurate information regarding metro delays and station availability. The website is developed using HTML, CSS, JavaScript and React and will be available in the English language as well.

According to Sekkah's vision statement:

For passengers

Who want to ride Riyadh's Metro/bus

The "Sekkah" is a Mobile Application

That enables passengers to plan their route and access all the services provided by the metro/bus on one platform.

Unlike the old traditional ways Our product offers passengers an effective way to use public transportation that will save them time in their daily hustle across the city.

To successfully build "Sekkah", the agile scrum methodology was used, which takes an iterative approach to product development. In addition, the information gathered helps us create our database and properly implement the necessary functionalities. The locations of all metro lines, their intersections, and the metro stations that make up these lines were thoroughly researched. Six metro lines and their intersections, along with 85 metro stations, were gathered. Furthermore, more than 120 bus stops were gathered, and each stop's name, number, and location were manually stored into the database. We then had to use the Google Maps API to display the roads and routes in Riyadh. Finally, we developed our route optimization algorithm using our own logic algorithm, the essentials of the Dijkstra algorithm, and location services provided by the Google Maps API.

By understanding the challenges that Riyadh Metro might face upon its launch and seeing the huge shift to technology in every aspect of life, this sparked the development of a public transportation mobile application for Riyadh's Metro. Moreover, knowing that mobile apps have efficiently proved to be a flexible solution to extend the reach of a service to every individual, the development of this application will be a significant step forward that will help optimize the use of public transportation in Riyadh. In this application, passengers will be able to view metro lines on a map, find the nearest metro stations, plan their route, display the optimal route to their destination and its duration, add a digital metro card and by selecting a type of pass, purchase an online ticket, and track their real-time navigation, among other beneficial features. Additionally, to provide users using the application with reliable information about metro delays and station availability, an admin dashboard will be implemented. The sole purpose of this application is to offer passengers an effective means of

transport that saves as well as manages time in their daily hustle across the city of Riyadh. Hence, giving these passengers a ride with the utmost satisfaction.

"Sekkah" application is targeted at Riyadh's population and aims to provide them a transportation option that manages and conserves their time, dispenses with the need for private vehicles to get around the city, and helps to reduce traffic congestion. If we expanded Saudi Arabia's public transportation network to all its cities, we could reach a larger portion of the country's population. Additionally, the effects of the public transit system will also be amplified if it is extended to the Gulf regions.

Given that the Riyadh metro will shortly make its formal debut, the "Sekkah" application stands out. Nevertheless, as no application has yet been released, people lack specific information regarding the lines and itineraries of Riyadh's buses and metro stations. Moreover, the application will be built utilizing route optimization algorithms, which gives passengers the greatest possible public transportation experience and allow them to choose the best route to their destination, giving "Sekkah" another advantage.

To provide an overview of how this report is structured, the problem, objectives, scope, product vision statement, software methodology, and solution are all covered in this chapter as they pertain to the core of developing our application. As part of the second chapter, which is the "Background," we discuss our target domain of public transportation, along with understanding how mobile apps have evolved over time which ultimately led to develop a mobile application that meets the needs of public transportation. Also included in this report is a chapter entitled "Literature Review," which discusses relevant topics of interest and competing applications, analyzes their benefits and drawbacks, and contrasts them with our own. In the fourth part of the report, "System design and development," we describe our software engineering methodology, system requirements and design, which includes architectural, class, DFD diagrams, component-level designs along with our data and interface designs. Finally, we conclude this chapter by describing the implementation of "Sekkah" in depth. In the fifth chapter, user acceptance testing was conducted, demographic information about the testers was provided, non-functional testing was explained, and test results were finally discussed. As a conclusion, chapter six summarizes the project's goals, limitations and suggestions for future work. The report's references, appendices, and acknowledgments are organized in the final three chapters.

CHAPTER 2

- BACKGROUND -

2 Background

This chapter covers a major step in understanding what is behind our application, which is achieved by analyzing the background. To do so, we will study our targeted domain, which is public transportation, as well as understand the evolution of mobile applications and how this, in turn, led us to develop a mobile application that serves public transportation's services. Analyzing the background thoroughly will aid us in developing the application efficiently.

2.1 Public Transportation

Transportation all around the world is marked by significant congestion, accompanied by an increasing number of car accidents. Moreover, the high reliance on private cars led to rising levels of pollution emanating from the excessive consumption of energy. For this reason, there must be an alternative method of transportation that can address these issues effectively. For one thing, the use of public transportation in many countries has either not been introduced to its full capacity or has proven inefficient. Thus, people prefer using private cars since it is a faster and more convenient choice, seeing as the public transportation system is inadequate.

Public transportation, in its essence, is any transportation service that is shared among many passengers and is available for use by the public. There are various methods of public transportation, including buses, trolleybuses, trams, trains, rapid transit, and ferries.^[4] Shedding light on the public transportation system of a country is a crucial step, as it gives an insight into how well-developed a country is. ^[5] Therefore, many countries around the world have been putting their efforts into developing efficient public transportation systems.

Nonetheless, it is becoming extremely complex to ensure that passengers receive high-quality services when utilizing public transportation. This difficulty is mainly due to the continuous growth of the population, which makes transportation systems grow in size, thus making it more challenging to manage transportation system networks manually.

2.2 Intelligent Public Transportation Systems

As a result, in order to solve this problem, new intelligent systems must be implemented, both to optimize the performance of public transportation systems and to invest in new means that improve mobility. These intelligent systems, referred to as Intelligent Public Transportation Systems (IPTS), rely on many innovative, automated technologies that aim to enhance the public transportation systems' quality of service.[6]

Additionally, it seeks to promote the use of public transportation means in cities, thus contributing to a reduction in traffic congestion and pollution. Consequently, fostering the development of IPTS [7] has been sky-rocketing significantly. With this in mind, different components must exist in any IPTS, including location, mapping, and tracking.[8]

These components are established using various technologies, one of which is the Global Positioning System (GPS), which is used to visualize locations and has been widely utilized in navigation systems; Google Maps is an example. Additionally, mapping services refer to plotting any destination on a map, and that can be accomplished with the use of a digital map that optimizes your transportation experience by providing passengers with the nearest path to take. [8] Furthermore, tracking technologies have been established to help passengers get real-time navigation by integrating GPS technology as well. Using Google Maps API as an external software will be of major importance for location-based mobile applications, as it provides a digital map with the ability to display the nearest places, suggestions for a route, along with directions and important info about a place. With this API, passengers could utilize their public transportation experience.

2.3 Web Application Development

The building of application programs that reside on remote servers and are intended to be delivered to the user's device over the Internet is known as web application development. It is meant to be accessible through a network without the need to be downloaded; the end user can navigate many web applications (web apps) through web browsers such as Apple's Safari, Google Chrome, and Microsoft Internet Explorer. [9]

The development lifecycle for web applications is often brief and is overseen by a small development team. Client-side programming is used to construct the front end of web applications. A client is a computer program, such as a web browser. HTML, CSS, and JavaScript are often used in client-side programming. While CSS maintains the proper formatting of presented data, HTML programming tells a browser how to display the on-screen content of web pages. On a web page, JavaScript will execute JavaScript code, making some of the content interactive.

Web application scripts are made using server-side programming, which also powers client-side programming. Multiple scripting languages, including Ruby, Java, and Python, can be used to create scripts. Server-side scripting will produce a unique user interface and hide the source code used to build the interface. When creating online applications, data can be stored in databases like MySQL or MongoDB. [10]

2.4 Mobile Application Development

The process of creating software for smartphones and digital assistants, most frequently for Android and iOS, is known as mobile application development. The software can be pre-installed on the device, downloaded from the mobile app store, or accessed via a mobile web browser. Java, Swift, C#, and HTML5 are some of the programming and markup languages employed in this form of software development.

The development of mobile apps is expanding quickly. Organizations across industries must satisfy consumer expectations for real-time, practical ways to complete transactions and obtain information, from retail, telecommunications, and e-commerce to insurance, healthcare, and government. Today, the most common method for individuals and organizations to connect to the internet is through mobile devices and

the mobile applications that maximize their usefulness. Organizations must create the mobile applications that their customers, partners, and workers want if they want to remain relevant, responsive, and successful. [11]

2.5 Google Maps API

Google Maps' API enables developers to access Google Maps data and features for their own apps. It is possible to use this method to integrate customized Google Maps into the developer website or application.

To build Sekkah successfully, we had to use Google Maps API in multiple areas as to display the roads and routes of Riyadh in the homepage to find the nearest station to the passenger, as well as Planning a journey. [12]

2.6 Firebase

It is based on the infrastructure of Google. Firebase is a NoSQL database application that saves data in JSON-like documents.

There are several features, but the most important ones are as follows: authentication, which offers authentication by passwords, phone numbers, Google, Facebook, Twitter, and others. At Sekkah we used authentication feature to register the passengers and authenticates them to log in, also for resetting the passwords. [13]

Lastly, Cloud Firestore is a flexible as well as scalable NoSQL cloud database. It is used to store and sync all the data that Sekkah owns, it provides us real-time updates. [14]

2.7 PayPal

PayPal is a payment platform featuring a website and a phone app that allows for online money transactions between parties. It is a highly secure banking service that employs some of the most cutting-edge end-to-end encryption technology available. At Sekkah, PayPal has been our first choice for all payments in the app, whether for buying a ticket or a digital card pass.

2.8 Definitions

Dijkstra algorithm: an algorithm that is used for finding the shortest distance, or path, from starting node to target node in a weighted graph. [15]

Plan journey: The route and the places that you will visit.

Route optimization: The process of planning the fastest and most cost-effective way for your mobile field service workers to get from one appointment to another. [16]

Traffic congestion: a situation in which a long line of vehicles on a road have stopped moving or are moving very slowly.

Polyline: A continuous line that is composed of one or more connected straight-line segments, which, together, make up a shape.

Real-time tracking: The tracking method that makes use of GPS as well as logistics databases to determine the current location of a person, vehicle, or object at any moment in time. [17]

CHAPTER 3

- LITERATURE REVIEW -

3 Literature Review

This chapter covers the main publications that discuss common areas of interest with regard to our application's domain, which is the development of a public transportation mobile application. By conducting deep research on these studies, it would aid us in developing an improved application that satisfies all the users' needs. Furthermore, we will identify the competing applications and extract their strengths and weaknesses, along with the similarities and differences to our application.

At the beginning, there were a number of previously published studies about the transportation systems and the basic reasons for adopting Riyadh's Metro rather than only using the existing transportation methods. There is a paper discussing the "*Potential Impacts of Introducing Public Transport and Travel Strategies in Riyadh City, Saudi Arabia.*" [18] This paper aims to provide a comprehensive analysis of the various impacts of a new public transport system on the city's urban form and economy. It also explores the ways in which effective interventions can be made to improve the environment and social norms. The results of this study revealed that the city's urban form has the biggest impact on the uptake of public transport. It also noted that the provision of public transport services would improve the mobility and efficiency of the city, as well as the environment.

In addition, the advantages of utilizing a mobile application for visitors taking the metro in cities are examined in "*A Study of the Assistant Application for Tourists Taking Metros*" [19]. This study focuses on the development of an assistant application for tourists taking metros. The authors aim to help tourists shorten the time of purchasing tickets, provide clear metro information, and direct navigation. The study involved gathering information from 106 tourists in Wuhan metro stations by observation, survey, and testing. Moreover, the authors included mobile payment, indoor location technology, and other benefits of mobile devices. The study's findings suggest that using a mobile app can enhance tourists' metro-riding experiences.

Furthermore, another article discusses "*Optimizing Bus Lines Based on Metro-Bus Integration*" [20], metros are usually built and added on the basis of a completed bus network in Chinese cities. After the metro construction, it has faced with the problem of how to adjust and optimize the original bus lines based on the new metro system. So, this research primarily

suggests an integrated bus and metro line optimization strategy. The bus line optimization model is constructed based on the coopetition coefficient to verify the optimization model. The results show that the positive competition, efficient cooperation, and travel efficiency between metro and bus has been significantly enhanced after optimization.

In order to provide great optimization to passengers, Guo and Jin [21] propose a node label algorithm that finds the K shortest paths between two nodes (Origin-Destination), it is suitable for networks with parallel arcs in the same direction between two nodes. A conventional approach to the K-shortest algorithm is to compute enough shortest paths and discard paths that do not satisfy the constraints. Li, Cai and Luo [22] proposing a smart path finding method to recommend fast and comfortable routes to passengers, by including the structure of the metro network as a two-dimensional plan and time as the third dimension. The study uses forward search from station O (Origin) to calculate the reachability to the transit station, and then the reverse search is performed from station D (Destination) to identify the reachability to the departure transit station.

The integration of IoT into the field of transportation has led to the development of innovative solutions, including bus navigation systems. The “*IoT Bus Navigation System with Optimized Routing using Machine Learning*” [23] is a relatively new concept that has been proposed to offer significant advantages and benefits over traditional bus navigation systems. One of the main advantages of this system is its dynamic and streamlined routing characteristic. The use of machine learning algorithms and particle swarm optimization (PSO), allows the system to continuously learn and adapt to changes in traffic patterns and road conditions. This results in optimized routing and reduces the total operating costs by minimizing the public transportation distance, thus reducing the operations and maintenance costs. Studies have shown that PSO algorithms can converge more quickly and are less likely to get trapped in local minima compared to traditional optimization algorithms [24]. This makes PSO a suitable algorithm for use in the IoT bus navigation system, as it is able to find the optimal path for the bus to take in real-time. Furthermore, the use of machine learning algorithms allows the system to learn from past data and continuously improve its routing decisions. This leads to a more efficient and accurate bus navigation system, as the system is able to account for variables such as traffic patterns, road conditions, and passenger demand.

Depending on the numerous backends that were taken into consideration in these studies, a particular optimization algorithm or technique was used. The majority of these papers agreed

that route optimization for mobile applications would benefit passengers throughout their journey. Due to this, we'll work on a route optimization strategy that suits our problem.

3.1 Competitive Product Analysis

In this section, we will show the similar mobile transportation apps in the market and discuss the main similarities and differences with regards to our application.

Riyadh Bus

One of the crucial apps that makes it simpler for citizens and residents of the city of Riyadh to obtain accurate information about the bus routes, the bus network through maps and frequently asked questions is the Riyadh Bus application. The application makes it quick and easy for their customers to purchase tickets and directly use them on buses when travelling. [25]



Figure 1 - Riyadh Bus App

SAR

SAR is a Saudi mobile application that specializes in train and railway services. It finds available trips based on your desired route and travel dates. Even more, it gives you the opportunity to select your preferred seat and buy your tickets online.



Figure 2 - SAR App Logo

S'hail

S'hail is a mobile application developed by Dubai's RTA for the city's local transportation, providing a solution for all those who rely on public transport and ride-hailing services. The app gives you information in real time about all modes of transportation near you.



Figure 3 - S'hail App Logo

TfL Go

London TfL-Go is a mobile application that provides real-time train times as well as information for customers traveling by bus. Additionally, it offers tube and rail services and has a distinguishing feature that provides information about crowded stations, thus suggesting different routes as well as walking and cycling options. [26]



Figure 4 - TfL Go App

Transit

Transit is a mobile-based application that provides real-time transit data. It's supported in multiple countries and compatible with car-sharing and ride-hailing apps, along with multiple bike and scooter share systems in four American cities. Moreover, Transit allows users to look up bus and train schedules for their city, and users are able to find the nearest public transport stops, despite the fact that they're offline. [27]



Figure 5 - Transit App logo

In (Table 1) shown below, we will explain the distinction between our application and related functions in detail. We compared them according to their functionality, platform, and supported language content to facilitate the reader. Then we summarized the most important benefits of our application.

Table 1 - Competitive Product Analysis

Criteria	Riyadh Bus	SAR	S'hail	TfL Go	Transit	Sekkah
Functionality						
Access to previous trips.			😊			😊
Information about crowded stations.				😊	😊	
Departure information.		😊	😊	😊	😊	😊
Nearby stations.	😊		😊	😊	😊	😊
Online ticket payment.	😊	😊	😊			😊
Optimal routes.			😊	😊	😊	😊
view of the full lines' map.	😊		😊	😊	😊	😊
Personal live navigation.				😊	😊	😊
Metro station locations.		😊	😊	😊	😊	😊
Ride-hailing services.			😊	😊	😊	

Bus station locations.	😊		😊	😊	😊	😊
Select the departure/arrival time and date.		😊	😊	😊		😊
Track users' real time location and show the remaining stations the passenger will go through.						😊
sending a notification when the user reaches a stop.						😊
sending an alert if the user is headed in the wrong direction.						😊
Support language						
English	😊	😊	😊	😊	😊	😊
Arabic	😊	😊	😊			
Platforms						
iOS	😊	😊	😊	😊	😊	😊
Android	😊	😊	😊	😊	😊	😊
Web browser	😊	😊		😊		

The similarities between the domains are the public transportation's departure information, the ability to provide nearby stations, suggest optimal routes, view the city's transit full line map, metro station locations, bus station locations, and select the departure/arrival time and date. In our project, we will include the most common functionalities in all existing applications. What distinguishes "Sekkah" from the other applications is that it focuses solely on the metro/bus services, not ride-hailing services, while enhancing the user interface and improving three main functionalities. These functionalities include tracking passengers' locations in real-time and showing the remaining stations the passenger will go through, along with sending a notification when the passenger is approaching a stop and an alert if the passenger is heading towards the wrong route. In addition, to give users of the application reliable information on metro delays and station availability, "Sekkah" incorporates an admin dashboard.

CHAPTER 4

— SYSTEM DESIGN — & DEVELOPMENT

4 System Design and Development

4.1 Methodology

Specifying a development methodology to follow ensures that the process is guided by a predefined framework that plans and controls all development aspects. In this regard, the approach we followed to implement "Sekkah" mobile app is the Agile Framework, which is a step-by-step approach to product development that divides a large module into multiple small phases that iterate until a final product is developed.

Applying this framework to our application has numerous benefits, such as promoting a rapid software development process and managing changing requirements efficiently. To clarify, an agile approach prioritizes delivering a working product over process and documentation. Thus, each phase of the process focuses on implementing selected functionalities of the app, which helps release it in a timely manner. Moreover, an agile approach allows for changes to be made rapidly to the app since it is divided into iterative phases, thereby offering more convenience and flexibility to the development process. Taking these into account, the agile approach can be seen as a natural fit for mobile app development.[28]

However, agile development is not itself a methodology. It is an umbrella term that describes several agile methodologies. One particular example is the Scrum methodology, which is considered the most powerful of them all. The Scrum methodology implements flexible process control for software development through an iterative approach. Scrum creates progress by dividing the working process into a sequence of sprints that are time-framed equally. Before we begin a sprint, we must first define the sprint's requirements. When that sprint is completed, the results are evaluated against these requirements, and modifications are managed accordingly.[29]

The Scrum methodology is built on a 3x5x3 structure: 3 roles, 5 events, and 3 artifacts. To begin, a **role** refers to the scrum team responsible for delivering the product increments, and each scrum team consists of three major roles: a product owner, a development team, and a scrum master. The **Product Owner** is responsible for managing the product backlog, whereas the **Development Team** drives the plan of each sprint by delivering a potentially releasable "increment" at the end of the sprint, and the **Scrum Master** is in charge of ensuring that everyone understands Scrum by coaching both the product owner and the development team. This is then followed by the **events**, which are activities performed by scrum teams on a regular

basis, which are five events as follows: sprint, sprint planning, daily scrum, sprint review, and sprint retrospective. To begin, **Sprint** is the main event during a scrum where the team works together to deliver an increment in which the typical duration is four weeks per sprint. All the other events happen during the sprint. To illustrate, the **Sprint Planning** event is when the work to be done in the sprint is planned. Consequently, the **Daily Scrum** event takes place every day as a short meeting where members brief each other on their progress. By the end of each sprint, the **Sprint Review** event is undertaken, in which the team gets together to evaluate the increment by discussing what was "done" in the sprint. The final event is the **Sprint Retrospective**, where the team focuses on what went well and what needs to be improved in the future. To further complete the scrum structure, the last element is the **artifact**, which is the information used by the scrum team to define the product and the work needed to deliver it. There are three artifacts in a scrum framework, which are: the Product Backlog, the Sprint Backlog, and the Increment. The **Product Backlog** is the primary list of requirements that needs to get done and acts as the input for the sprint backlog. After that is the **Sprint Backlog**, which is a list of user stories selected from the product backlog for implementation in the current sprint. Finally, there is the **Increment**, which is the working product delivered by a sprint.[30]

During the app development process, we practiced agile principles by rapidly finishing the specified user stories and providing a working increment by the end of each sprint. Additionally, each sprint's deliverables were evaluated and then modified accordingly, thus following the agile principle that welcomes changing requirements. Even more, we were guided by the agile principles in the sprint's duration, where the time period is specified as four weeks for each sprint, thus aiming to deliver working software frequently. More importantly, we were motivated and worked as a team by assigning a task to each member and delivering the final app in the best possible condition; hence, we adopted the agile guidelines. [31]

To further increase our productivity during the project development, face-to-face meetings took place at the university to discuss the progress made, which corresponded with the agile manifesto. Moreover, our focus while developing the app was not only to develop working functions but also to write clean code for those functions along with an attractive design that draws the eye, which is parallel to the agile principles. Furthermore, we resorted to Jira software¹ for planning, tracking, and managing our agile software development project.

¹ <https://2022-1st-gp20.atlassian.net/jira/software/projects/GP/boards/1>

Besides, to share our code simultaneously, GitHub for sekkah app² and for the admin³ was utilized as a programming resource used for code sharing.[32]

Finally, we, as a team, meet regularly after each sprint to see what could be enhanced in the following sprint to improve our work efficiency, similar to the agile manifesto.

4.2 System Requirements

4.2.1 System Users

The targeted audience for Sekkah is passengers. They are users who are interested in using the Riyadh Metro but lack clear directions on the metro lines and the city's bus and metro stations. There are three types of users that interact with Sekkah: Guest Passenger, Registered Passenger, and Administrator.

- **Guest Passenger:**

In Sekkah, guest passengers have several functions that can be used without registering. They can view the full map, which depicts metro lines and marks all bus/metro stations, then proceed to find the ones that are closest to them, along with the ability to plan their route and display its details.

- **Registered Passenger:**

Registered passengers have the same capabilities as guest passengers, but they can also track their real-time journey progress, add a digital metro card, and purchase tickets.

- **Administrator:**

An administrator's role is essential; since the admin has the ability to notify passengers of any expected bus or metro delays as well as provide an update on the availability of bus stations and metro lines periodically.

Regardless of the educational level, the administrator as well as passengers should be able to read English. To download the application, they must have an iOS or Android device, and some technical knowledge is required to use the app.

² <https://github.com/ReemaSaf/2022-GP1-20.git>

³ <https://github.com/ReemaSaf/AdminSite.git>

4.2.2 Requirements Elicitation and Analysis

To elicit the requirements for our application, we will collect information that helps us understand users' wants and needs for the system. This information will be collected by conducting a questionnaire that focuses on tackling the main issues the application is proposing to solve, along with the application's must-implement features according to the users' point of view. Our requirements elicitation approach involves using a questionnaire, as it could expand its reach to a greater number of our users, thereby providing us with more accurate results. The questionnaire, composed of 13 questions, was made online using Google Forms. From that, a total of 505 responses were collected, and the results were observed and analyzed in order to conclude our findings about the application's requirements.

As a result of carrying out a questionnaire, we found out that most of the respondents agreed with a specific answer. Thus, we will try to make our mobile app based on users' needs so that it fulfills all that they want.

Firstly, the results show that lots of people (74.5%) don't use public transportation as a means of transport, in addition to 20.7% who rarely use public transportation. 3% use them weekly, and only 1.8% use public transportation on a daily basis.

Secondly, 41.6% of the people's answers say that they encounter difficulties in using public transportation methods, while 31% say that they may have encountered some difficulties, and 27.4% say they have no problem using transportation methods.

Thirdly, 49.8% of the people who answered yes to the second question say that the type of difficulty they usually encounter is not being aware of how to access any public transportation method. 49.3% have difficulty finding adequate public transportation methods; 43.4% don't know the arrival times of any public transportation method; and 37.5% are not able to find/buy tickets for transportation. And finally, 23.3% haven't encountered any difficulties at all.

Fourthly, 55.2% of the results show that people rarely use mobile transportation apps, with 26.4% saying that they never use them. Although 14.9% of users use mobile transportation apps weekly and 3.4% use them daily.

In the fifth question, most people (82.5%) think that their public transportation experience could be enhanced using mobile apps. In addition, 16.6% think that mobile apps might enhance their experience. Finally, only 0.9% disagreed.

In the sixth question, the result indicated that 83% of our passengers found that being able to access the bus/metro schedule on the application is of extreme importance, along with an additional 12.4% seeing that it is important to some extent, as well as 0.7% showing that it might be of little importance and the remaining 3.9% not knowing whether it will be an important functionality.

In the seventh question, the result highlights that most people (91.3%) agreed that having the ability to plan your route on the app is extremely beneficial, and the rest (6.7%) thought that it may be useful, whereas (2.1%) of the people felt it might not be useful.

In the eighth question, we saw that 49% of people seemed to know where the nearest bus station to their house is located, while the remaining 42.8% are clueless as to where the bus station is located, leaving 8.3% of people not certain if they know the location.

In the ninth question, the result showed that almost everyone (95.2%) thinks that displaying the nearest bus/metro station as well as the duration it takes to get there is a major functionality, with an additional 3.9% showing that it might be beneficial, yet only 0.9% find it not worthwhile.

In the tenth question, 86% of people agreed on the need for tracking their location while on route to decide if the path is correct; with the other 11% seeing that they might need this feature, despite 3% of people who think it is irrelevant.

In the eleventh question, we found out that most people (86%) prefer to purchase their metro/bus tickets online, with 9.7% of these people perhaps preferring online tickets. However, 4.4% felt that buying tickets online was not their preferred choice.

In the twelfth question, the result highlights that the majority of people (89.5%) feel that owning a digital metro/bus card and being able to top it off with a balance will make the payment process more convenient, with 7.4% of them thinking it might ease their payment process, unlike the remaining 3.1% who thought it might not be that effective.

By analyzing the results from each question, we concluded our findings from the questionnaire. These findings will be beneficial in knowing our target users even more and understanding what they like and dislike regarding the mobile app. Furthermore, the results showed a motivation to improve the development of our application by specifying and exploring more features that will optimize the use of public transportation.

Questionnaire link: [Appendix A](#)

4.2.3 User Interactions

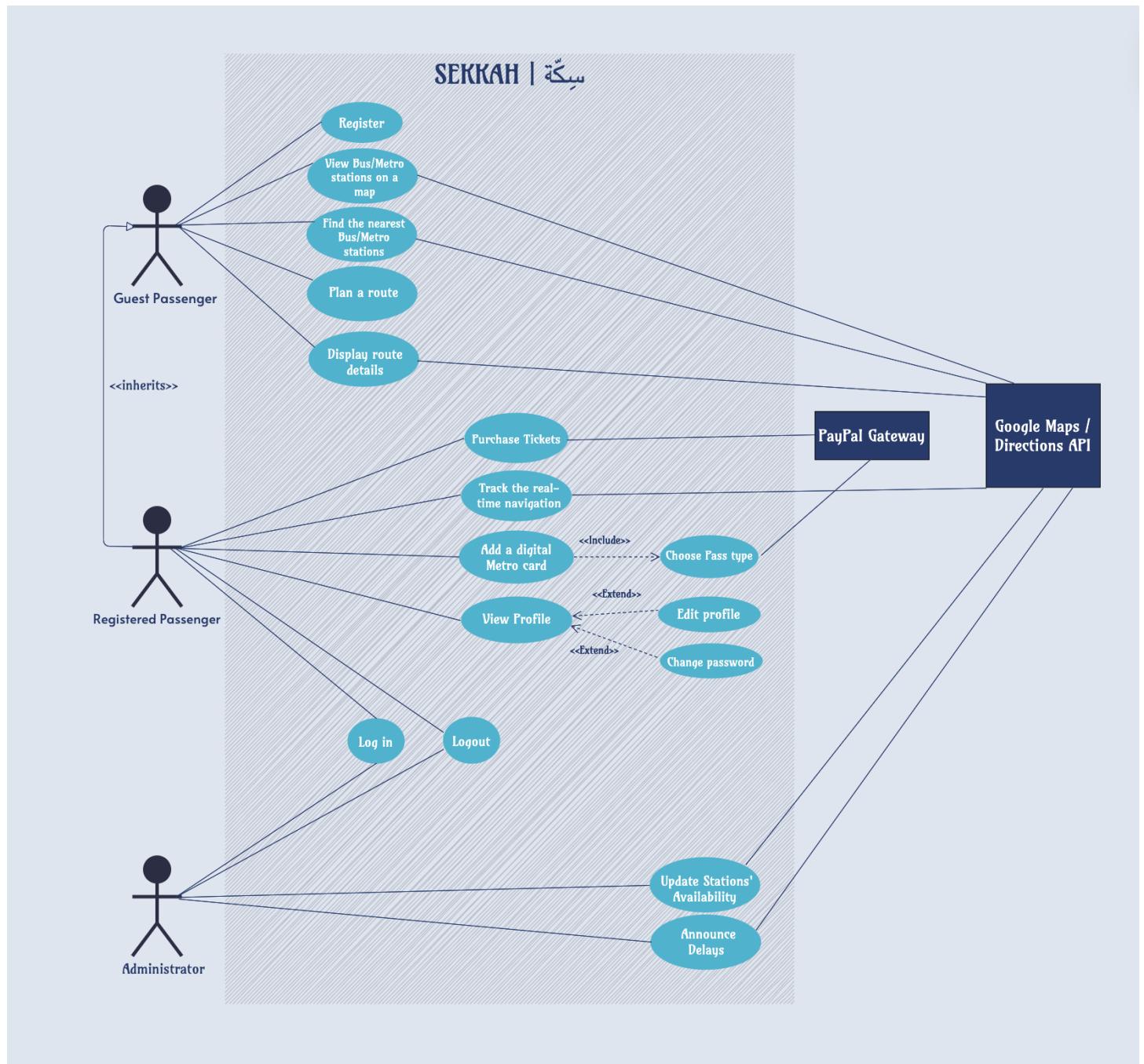


Figure 6 - User Interactions Diagram

4.2.4 Roadmap and Product Backlog

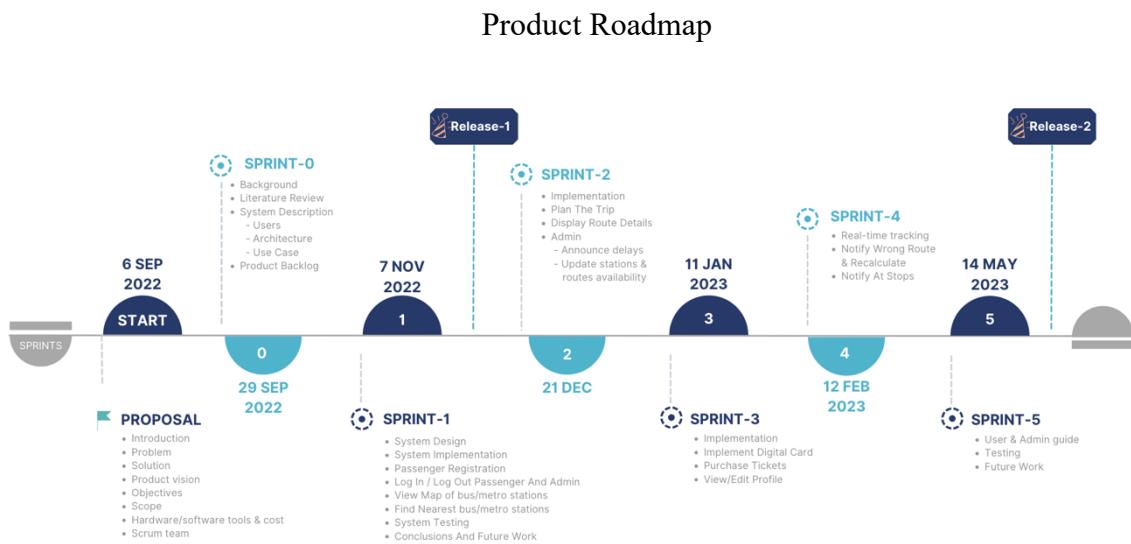


Figure 7 - Product Roadmap

Table 2 - Product Backlog

ID	PBIs	Size	Type	Status	Acceptance Criteria
1	As a passenger, I want to register for the application so that I can get access to all of its features.	2	Feature	Done	<p>As a new passenger, if I register using an empty field (first name, last name, email, and password), then an appropriate message will appear requiring me to fill it up.</p> <p>As a new passenger, if I register using an invalid email format, then an appropriate message will appear.</p>

				<p>As a new passenger, if I register using a password with a length less than 8 characters, then an appropriate message will appear requiring me to lengthen the password to 8 characters or more.</p>
				<p>As a new passenger, if I register using a password without a combination of capital and lower-case letters along with a number, then an appropriate message will appear requiring a minimum of one letter and one number for the password.</p>
				<p>As a new passenger, if I register using an email that already exists in the database, then an appropriate message will appear.</p>
				<p>As a new passenger, if I fill out all the registration fields correctly, then an appropriate message will show that the passenger has successfully registered.</p>

					As a new passenger, if my account has been successfully registered, then the system must transfer me to the application's main interface.
2	As a passenger, I want to log in using my email and password so that I can access my account.	2	Feature	Done	<p>As a passenger, if I log in with an empty field, then an appropriate message will appear requiring me to fill it up.</p> <p>As a passenger, if I log in using an invalid email format, then an appropriate message will appear.</p> <p>As a passenger, if I log in using a non-existing email in the database, then an appropriate message will appear.</p> <p>As a passenger, if I log in using the wrong password, then an appropriate message will appear.</p>

					<p>As a passenger, if I want to log in but I forgot my password, then an alternative way to retrieve the password via email will appear.</p> <p>As a passenger, if I fill out the login fields correctly, then the system must transfer me to the application's main interface.</p>
3	As an administrator, I want to log in using an email and password so that I can manage the application properly.	2	Feature	Done	<p>As an administrator, if I log in with an empty field, then an appropriate message will appear requiring me to fill it up.</p> <p>As an administrator, if I log in using an invalid admin email or password, then an appropriate message will appear.</p> <p>As an administrator, if I want to log in but I forgot my password, then an alternative way to retrieve the password via email will appear.</p>

					As an administrator, if I fill out the login fields correctly, then the system must transfer me to the admin's main interface.
4	As a passenger, I would like to be able to log out so that I have a more secure environment.	1	Feature	Done	As a passenger, if I click on the logout button, then it must bring me back to the welcome screen.
5	As an administrator, I would like to be able to log out so that I have a more secure environment.	1	Feature	Done	As an administrator, if I click on the logout button, then it must bring me back to the login screen.
6	As a passenger, I want to view all bus/metro stations on a map so that I am aware of where they are located.	4	Feature	Done	<p>As a passenger, if I want to view all bus/metro stations on a map, then the marker of each station must be shown clearly on the map.</p> <p>As a passenger, if I want to view all bus/metro stations on a map, then I must have the option to hide/show the markers of these stations.</p> <p>As a passenger, if I want to view all metro stations on a map, then their corresponding metro lines should be mapped along the map as well.</p>

					<p>As a passenger, if I want to view all bus/metro stations on a map, then clicking on a marked station will display a label indicating the type of station, its name, along with a navigation option from Google Maps to reach it.</p> <p>As a passenger, if I want to view my current location in the map, then I must grant the system location access.</p>
7	As a passenger, I want to find the nearest bus/metro stations so that I can plan my route accordingly.	4	Feature	Done	<p>As a passenger, if I want to find the nearest bus/metro station, then I must grant the system location access.</p> <p>As a passenger, if I want to find the nearest bus/metro stations, and the system doesn't have access to my current location, then a proper message will appear prompting the passenger to grant access.</p> <p>As a passenger, if I want to find the nearest bus/metro stations, then the scroll up panel beneath the map must show all the nearby stations.</p>

					<p>As a passenger, if I want to find the nearest bus station, then I must toggle to the Bus tab in the find nearby panel.</p> <p>As a passenger, if I want to find the nearest metro station, then I must toggle to the Metro tab in the find nearby panel.</p> <p>As a passenger, if I want to find the nearest bus/metro station, then the list of nearby stations must be sorted according to the nearest distance.</p>
8	As a passenger, I want to plan a route, so that I can know all the possible routes to reach my destination.	5	Feature	Done	<p>As a passenger, if I am planning my route, then I must enter the starting point and the destination to view all available routes.</p> <p>As a passenger, if I am planning my route, then I must select a place from the list of suggestions after typing in a field.</p>

				<p>As a passenger, if I am planning my route, then leaving the starting point empty should consider my current location by default.</p> <p>As a passenger, if I am planning my route, then clicking on the search button with an empty field will show a proper message.</p> <p>As a passenger, if I am planning my route, then clicking on the search button with the typed fields being not from the suggestions will show a proper message.</p> <p>As a passenger, if I am planning my route, then I can specify the starting point as my location by clicking on a current location button.</p> <p>As a passenger, if I am planning my route, then I can alternate the starting point and destination by clicking on a switch button.</p>
--	--	--	--	---

					<p>As a passenger, if I am planning my route, then I must press on the search button to view all the available routes.</p> <p>As a passenger, if I am planning my route, then viewing all possible routes should be sorted by shortest trip duration.</p> <p>As a passenger, if I am planning my route, then choosing a specific route should display its details.</p>
9	As a passenger, I want to see the total trip duration so that I can arrange my schedule accordingly.	2	Feature	Done	As a passenger, if I see the total trip duration of a route, then it must show the trip's distance in kilometers.
10	As a passenger, I want to display the details of a chosen route so that I can know the stops of that route.	3	Feature	Done	As a passenger, if I choose a specific route, then the route must be visualized on a digital map with marks on station stops.

					<p>As a passenger, if I choose a specific route, then the route's details must be provided, including all the stops' names, their types (metro/bus), and the total trip's duration.</p> <p>As a passenger, if I choose a specific route, then a ticket purchase option will be available.</p>
11	As an administrator, I want to announce delays arising from the buses so that passengers are aware.	3	Feature	Done	<p>As an administrator, if I want to announce a delay, then I must click on the Announce option in the main dashboard.</p> <p>As an administrator, if I want to announce a delay, then I must specify the affected bus station and its status (on time/delayed).</p> <p>As an administrator, if I announce a delay with an empty field (station/status) then an appropriate message will appear requiring me to fill it up.</p>

					<p>As an administrator, if I fill out (station/status) fields then click on “announce” button, then an appropriate message will appear to confirm the action.</p> <p>As an administrator, if I make a successful announcement, then it must be displayed on the affected route on the passenger’s screen.</p>
12	As an administrator, I want to update the availability of bus and metro stations so that passengers can get the available routes at the moment.	3	Feature	Done	<p>As an administrator, if I want to update the availability of any bus/metro station, then I must click on the Update option in the main dashboard.</p> <p>As an administrator, if I want to update the availability of any bus/metro station, then I must specify the station type, name, and status (available, unavailable).</p>

					<p>As an administrator, if I want to update the availability of any bus/metro station with an empty field then an appropriate message will appear requiring me to fill it up.</p> <p>As an administrator, if I fill out (station type / name / status) fields and click on “update” button, then an appropriate message will appear to confirm the action.</p> <p>As an administrator, if I update the availability of bus/metro station, then any route that has that station as a (starting/ ending) point will be changed accordingly.</p>
13	As a passenger, I want to add a digital card so that I can save money.	4	Feature	Done	As a passenger, if I want to add a digital card, then I must select the "+" button on the card.

					<p>As a passenger, if I am not logged in and I want to add a digital card, then clicking the “+” button will show a prompt to register/log in.</p> <p>As a passenger, if I want to add a digital card, then I must choose a pass type (daily/ weekly/ monthly).</p> <p>As a passenger, if I want to add a digital card, then I must pay with PayPal.</p>
14	As a passenger, I want to view my digital card so that I am aware of the left duration.	2	Feature	Done	<p>As a passenger, if I view my digital card when no pass has been added yet, then the text “activate your card” will show.</p> <p>As a passenger, if I view my digital card with an active pass, then I can check the left duration of the pass.</p> <p>As a passenger, if I view my digital card with a deactivated pass, then I can reactivate it with any pass type (daily/ weekly/ monthly).</p>

					As a passenger, if I want to view the digital card but my pass is not active, then the text “activate your card” will show in the card.
15	As a passenger, I want to purchase a ticket on the application, so that I can avoid standing in queues.	5	Feature	Done	<p>As a passenger, if I want to purchase a ticket, then I must be logged in.</p> <p>As a passenger, if I want to purchase a ticket, then I have the option to select the departure time and date.</p> <p>As a passenger, if I want to purchase a ticket, then I have the option to select the number of passengers.</p> <p>As a passenger, if I want to purchase a ticket, then I have the option to pay either via PayPal or by a pass.</p> <p>As a passenger, if I want to purchase a ticket and the number of passengers exceed one, then I must pay via PayPal.</p>

					As a passenger, if I purchase a ticket, then the ticket details will appear on screen.
16	As a passenger, I want to view the tickets' history so that I can display my purchased tickets	4	Feature	Done	<p>As a passenger, if I want to view the tickets' history, then I must click on the tickets tab.</p> <p>As a passenger, If I want to view the tickets' history and I haven't purchased any tickets, then a "no tickets" message will appear in the tickets tab.</p> <p>As a passenger, If I want to view the tickets' history and I already purchased ticket/s, then tickets will be sorted according to the trip's time.</p>
17	As a passenger, I want the application to track my route in real-time so that I know where I'm headed.	4	Feature	Done	<p>As a passenger, if I want the application to track my route in real-time, then I must provide access to my current location.</p> <p>As a passenger, if I want the application to track my route in real-time, then I can access the tracking feature</p>

				<p>in the printed ticket screen or the tickets tab.</p> <p>As a passenger, if the application tracks my route in real-time, then I must see my location progress visualized in a map.</p> <p>As a passenger, if the application tracks my route in real-time, then I must know the remaining number of stops as I progress.</p> <p>As a passenger, if the application tracks my route in real-time, then I must know the route details.</p> <p>As a passenger, if the application tracks my route in real-time, then I must get a notification once I approach a stop or reach my final destination.</p> <p>As a passenger, if the application tracks my route in real-time, then I must get a notification once I go to a wrong route.</p>
--	--	--	--	---

18	As a passenger, I want to view my profile so that I can access my personal information.	1	Feature	Done	<p>As a passenger, if I want to view my profile, then I must press the profile tab.</p> <p>As a passenger, if I want to view my profile, then my credentials (first name, last name, email) will be displayed.</p> <p>As a passenger, if I want to view my profile, then I must have these options (edit profile, change password, and help center).</p>
19	As an administrator, I want to view my profile so that I can access my personal information.	1	Feature	To Do	<p>As an admin, if I want to view my profile, then it must include my credentials (first name, last name, email, password).</p>
20	As a passenger, I want to edit my profile so that I can modify my personal information.	1	Feature	Done	<p>As a passenger, if I want to edit my profile, then I can only change my first/last name.</p> <p>As a passenger, if I edited my profile, then I must click on “update” to save my changes.</p>
21	As a passenger, I want to change my password, so	1	Feature	Done	<p>As a passenger, if I want to change my password, then I must fill in the current</p>

	<p>that I can have better security.</p>		<p>password along with the new password and the confirm password fields.</p> <p>As a passenger, if I want to change my password, then I have the option to hide/unhide the password.</p> <p>As a passenger, if I want to change my password and I enter a wrong current password, then the system will show a proper message indicating it is incorrect.</p> <p>As a passenger, if I want to change my password and I enter mismatching new passwords, then the system will show a proper message indicating that it must match.</p> <p>As a passenger, if I want to change my password, then I must click on the “update” button.</p> <p>As a passenger, if I changed my password, then I will get a message indicating it has been changed successfully.</p>
--	---	--	--

22	As an administrator, I want to edit my profile so that I can modify my personal information.	1	Feature	To Do	<p>As an administrator, if I click on the edit button, then I can change my password.</p> <p>As an administrator, if I click on the edit button, then I can change my first/last name.</p> <p>As an administrator, if I click on edit, then I can change my email account.</p>
23	As a passenger, I want to know when I am heading towards a wrong route so that I can navigate towards the correct one.	4	Feature	Done	As a passenger, if I am headed towards a wrong route while tracking my trip, then I must get a notification of a wrong route.
24	As a passenger, I want to be notified when I am approaching my stop/destination so that I can hop off.	3	Feature	Done	As a passenger, if I am approaching my stop/destination while tracking my trip, then I must get a notification of reaching the place ahead of time.

Deleted User story (19): As an administrator, I want to view my profile so that I can access my personal information.

Deleted User story (22): As an administrator, I want to edit my profile so that I can modify my personal information.

Justification: At Sekkah there is only One Administrator, and his personal information are fixed unlike the password.

4.3 System Design

4.3.1 Architectural Diagram

In this section, we will introduce the architecture of "Sekkah," a mobile application that serves a specific client type, namely passengers. This application is modeled in a 3-tiered client-server architectural style. This pattern consists of a thin client layer, an application server layer, and a database layer that stores the data for the application. [33] This pattern has numerous advantages over the basic client/server architecture, including the thin client layer's ease of deployment and maintenance and the middle and data layers' built-in scalability. This might give the system as a whole more adaptability and higher availability.

Our choice of a client-server architecture was based on many reasons, one being that the system is designed to be used on a mobile device application along with an admin website with a connection to a server using the Internet [34], so that clients could request services from the server, and then the server, in its turn, will access data from the database once needed. Moreover, using this pattern will be beneficial since our app requires high levels of performance. Furthermore, our application aims to serve multiple passengers at once. Hence, this pattern will be a great choice since it will allow the app to be accessed on any number of devices.

Our system focuses more on the interaction with the passengers than on data processing. Therefore, we didn't propose the pipe and filter architecture. Additionally, our application puts a strong emphasis on the performance level. Therefore, using a layered model with its multiple levels of interpretation would negatively impact the performance. Thus, we didn't propose this architecture. Taking everything into account, we found that the “3-tiered client-server architecture” is the most appropriate architectural pattern for our system.

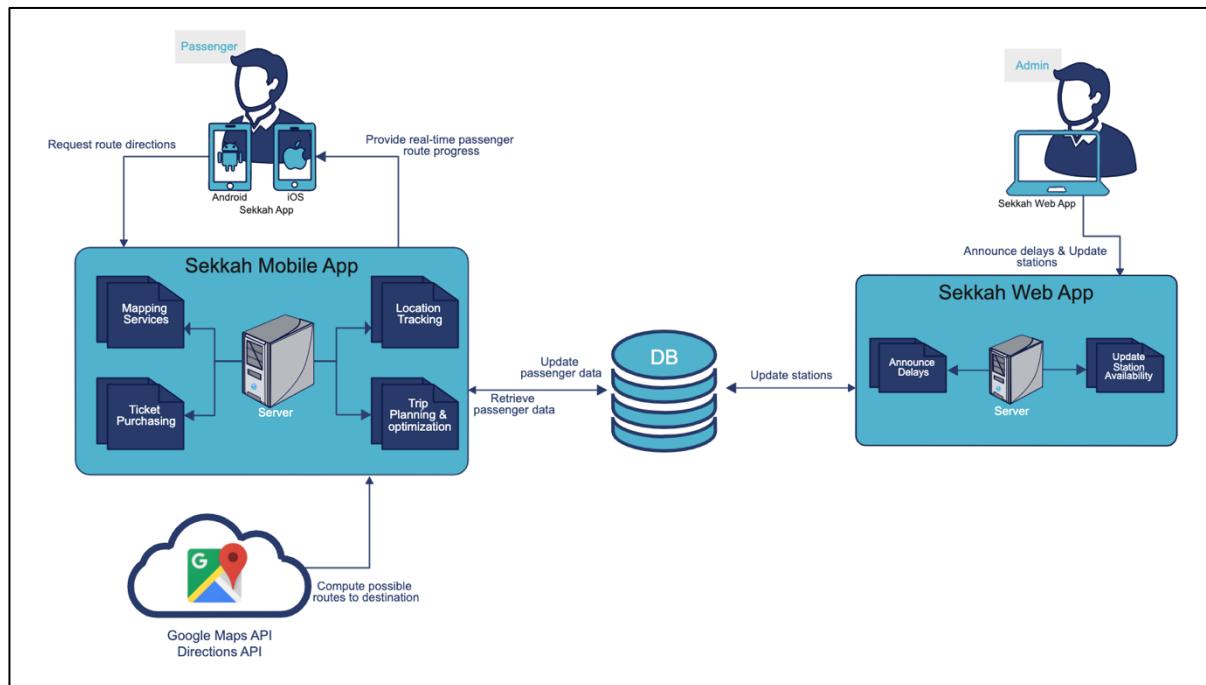


Figure 8 - Sekkah Architecture Diagram

4.3.2 Class Diagram /DFD

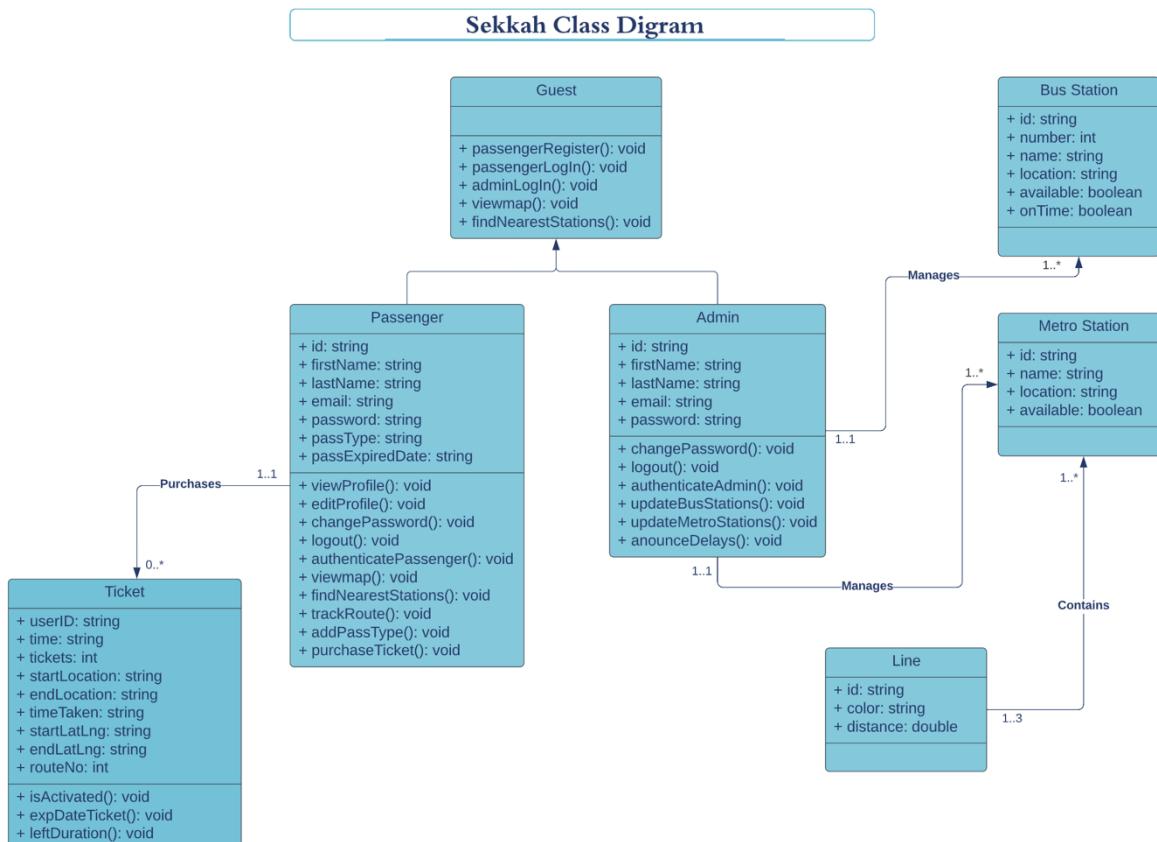


Figure 9 - Sekkah Class Diagram

4.3.3 Component Level Design

ID	PBI(user story)
6	As a passenger, I want to view all bus/metro stations on a map so that I am aware of where they are located.

View all bus/metro stations on a map functionality

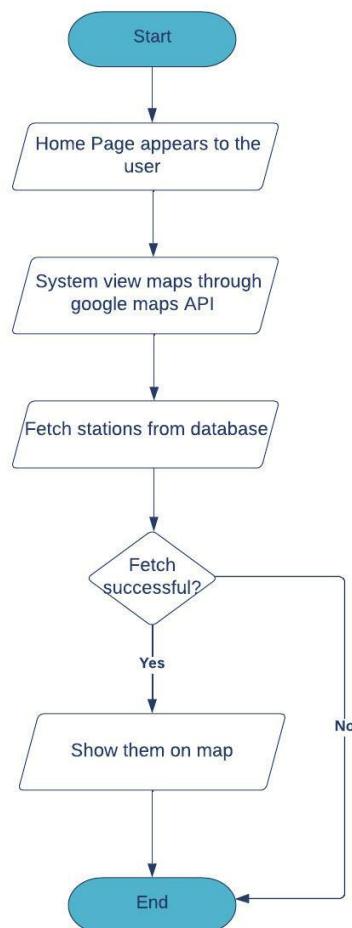


Figure 10 - View Stations FlowChart

ID	PBI (user story)
7	As a passenger, I want to find the nearest bus/metro stations so that I can plan my route accordingly.

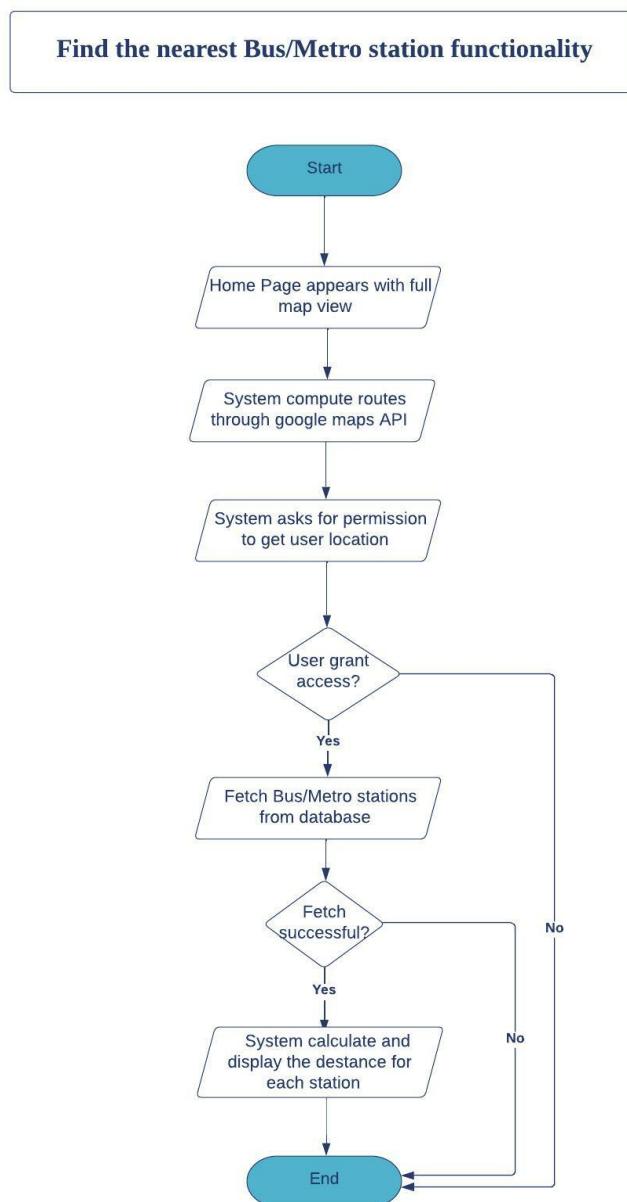


Figure 11 - Find Nearest Stations FlowChart

ID	PBI (user story)
12	As an administrator, I want to be able to update the availability of stations As a passenger, I want to plan a route, so that I can know all the possible routes to reach my destination.

Update the availability of stations functionality

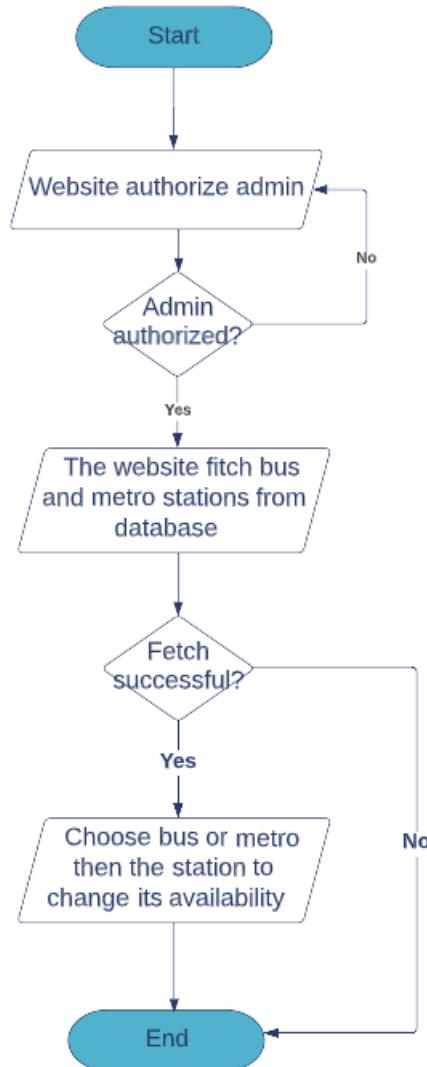


Figure 12 - Update Availability FlowChart

ID	PBI (user story)
13	As a passenger, I want to add a digital metro card so that I can ride the metro efficiently.

Activate digital metro card for registered passenger functionality

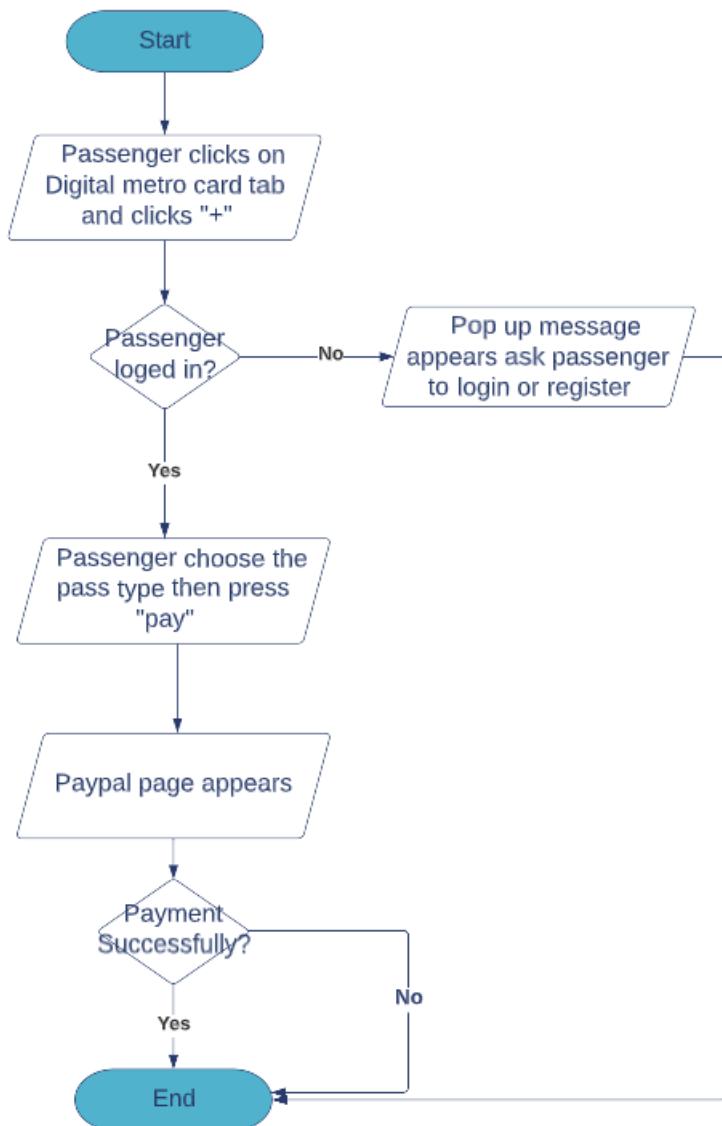


Figure 13 - Activate Digital Card FlowChart

ID	PBI (user story)
8	As a passenger, I want to plan a route, so that I can know all the possible routes to reach my destination.

Plan a route functionality

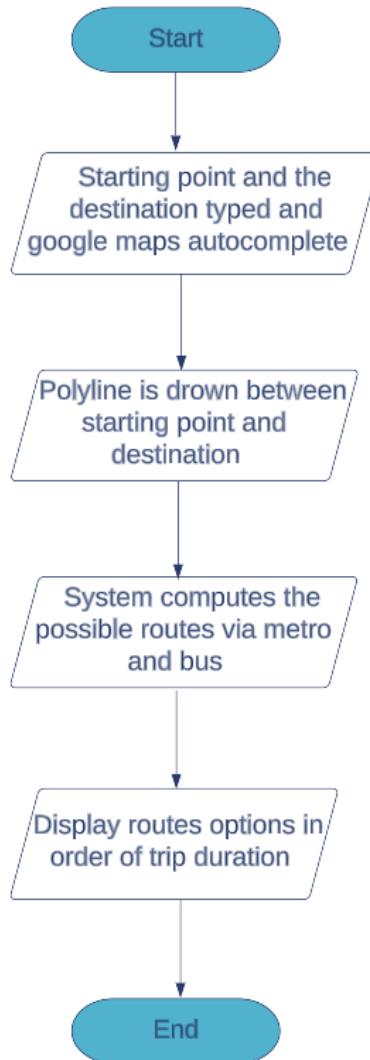


Figure 14 - Plan Route FlowChart

4.4 Data Design

4.4.1 Data Models

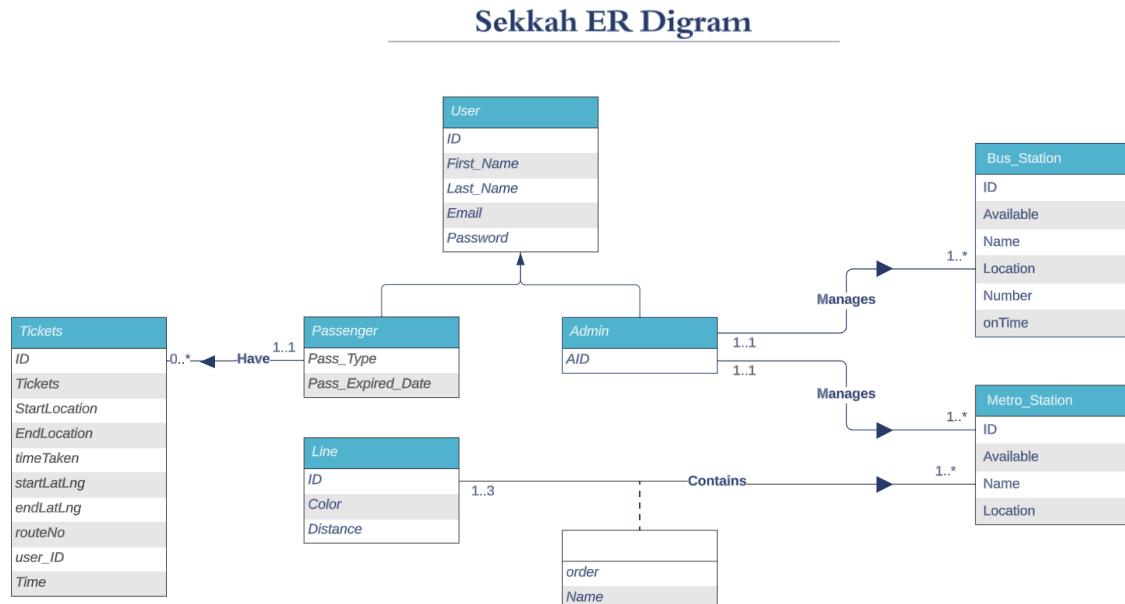


Figure 15 - ER Diagram

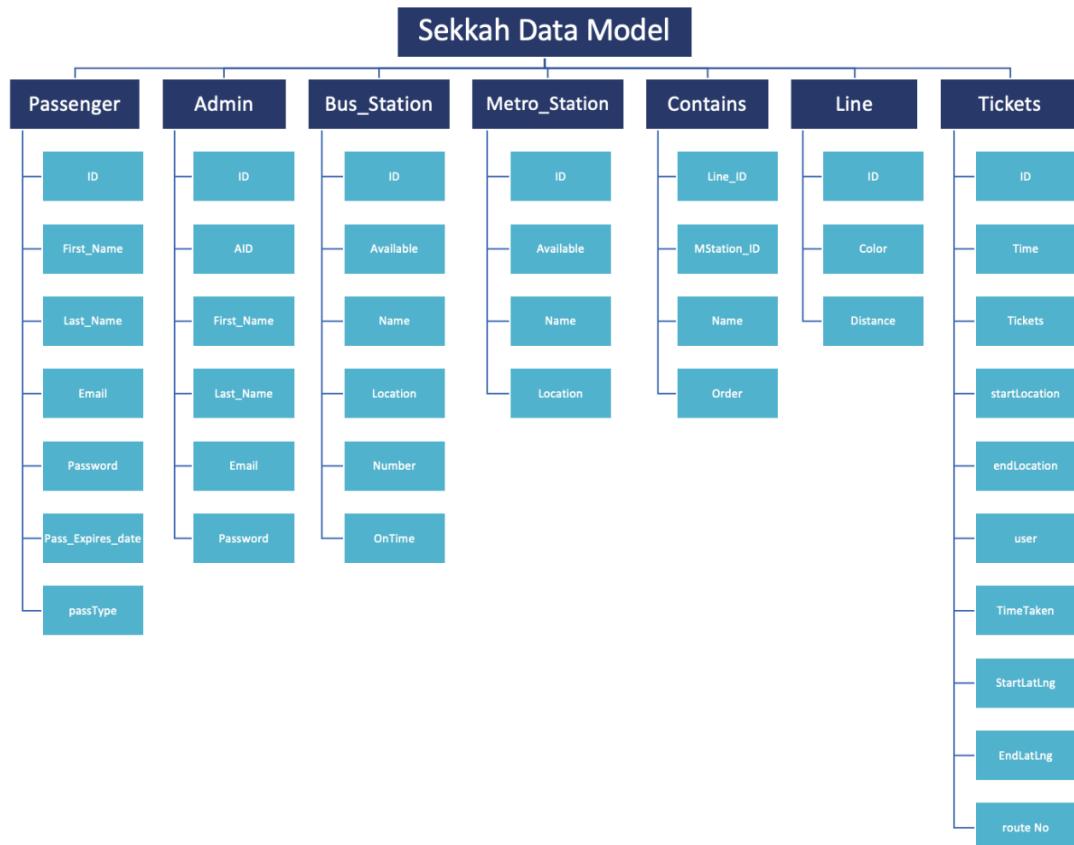


Figure 16 - Sekkah Data Model

4.4.2 Data Collection and Preparation

To properly develop "Sekkah" application, we needed to collect all the necessary data from the relevant entity, which is Riyadh Metro. The collected data aids us in building our database and implementing the required functionalities properly. In our case, the data collection process was not simple, as our application depends heavily on data. As a start, the collection of data included knowing the precise route of each metro line along with the different intersections among these lines. Furthermore, the exact coordinates (latitude and longitude) of metro stations and bus stations had to be accurately gathered. To collect the data, we first contacted Riyadh Metro Entity yet there was no clear response on their side. For that reason, we had to begin a thorough research process to find all the metro lines and the intersections between them in addition to the metro stations that make up these lines. By doing so, a total of 85 metro stations were collected which creates a combination of 6 metro lines along with their intersections, connecting the Riyadh metro network. Furthermore, as there was very limited information on the precise locations of bus stations, therefore, we had to go through Riyadh's various districts and roads to find the exact coordinates of each and every bus station we managed to see, then record it. As a result, more than 120 bus station was found, where each station along with its name, number, and location was stored manually in the database. Finally, to display the roads and routes within Riyadh, we had to utilize the Google Maps API which basically provides an optimization for location-based services. Moreover, the working schedule of the metro was recorded, hence, upon purchasing the tickets, the trips' arrival/departure times were set according to the metro' schedule. Furthermore, by collecting data, we discovered that the frequency of metro arrival time is 15 minutes, therefore, based on this, the range between each trip and the other in the journey planning process has been set to be 15 minutes.

4.5 Interface Design

Splash Screen & Welcome page

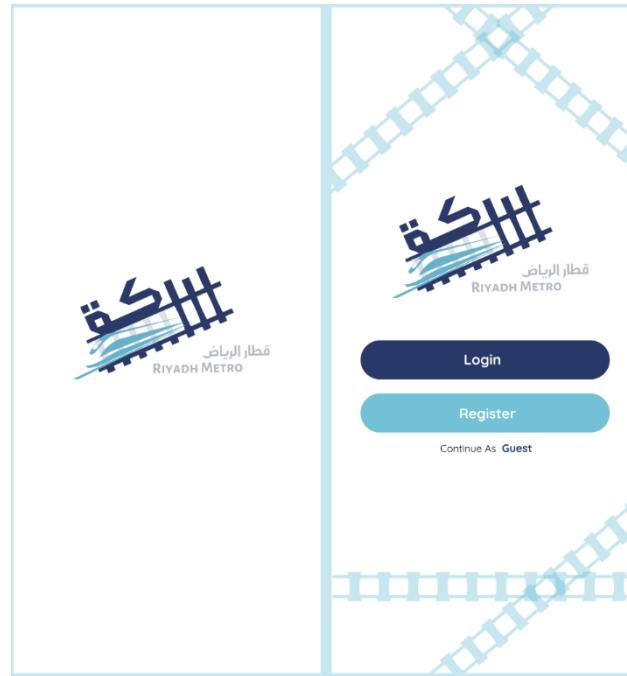


Figure 17 - Splash Screen & Welcome page Interface Design

Login & Register Page

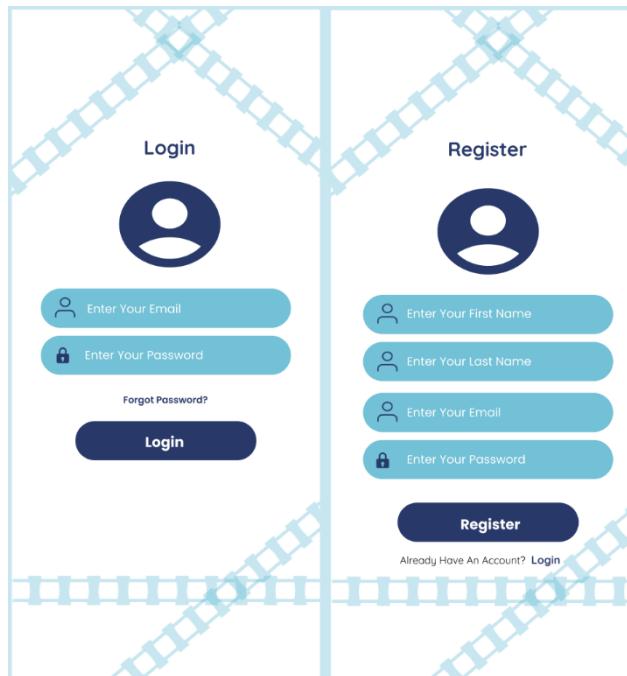


Figure 18 - Login & Register Interface Design

View Map Page



Figure 19 - View Map Interface Design

View Map Page (Find The Nearest Bus/Metro Stations)

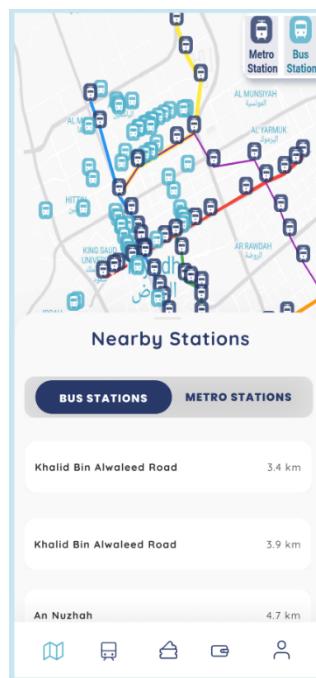


Figure 20 - View Map (Find Nearest Bus/Metro stations) Interface Design

Plan Route Page

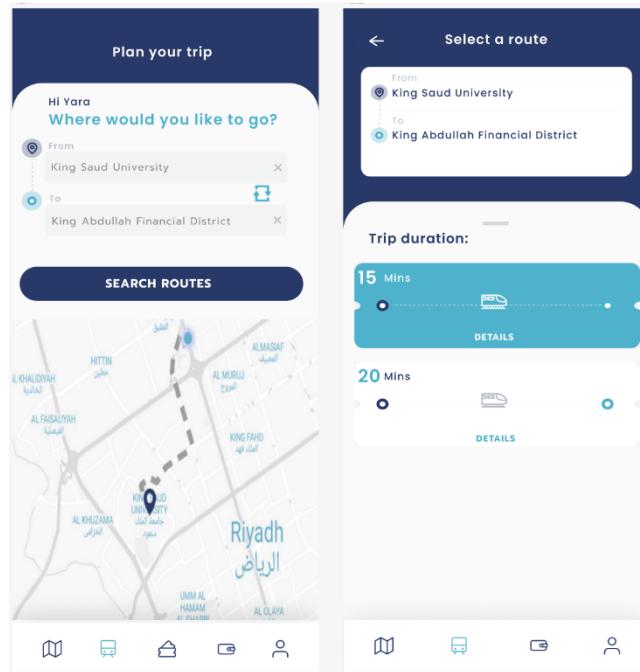


Figure 21 - Plan Route Page Interface Design

Plan Route Page (Detailed Route)

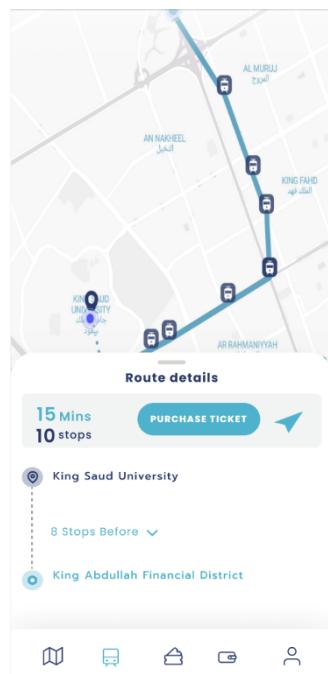


Figure 22 - Plan Route Page (Detailed Route) Interface Design

Plan Route Page (Purchase Ticket)

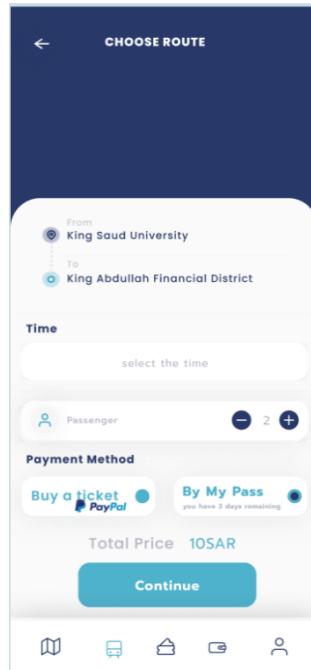


Figure 23 - Plan Route Page (Purchase ticket) Interface Design

Digital Card Page

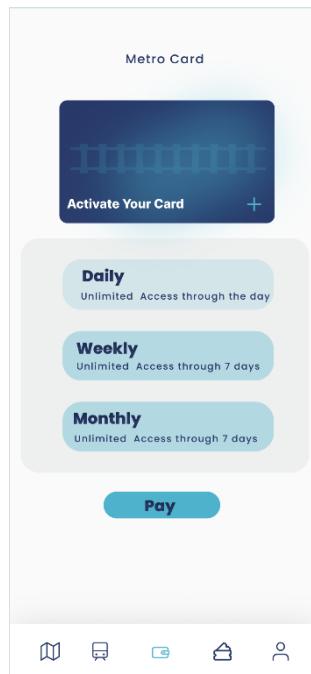


Figure 24 - Digital Card Page Interface Design

Tickets Page

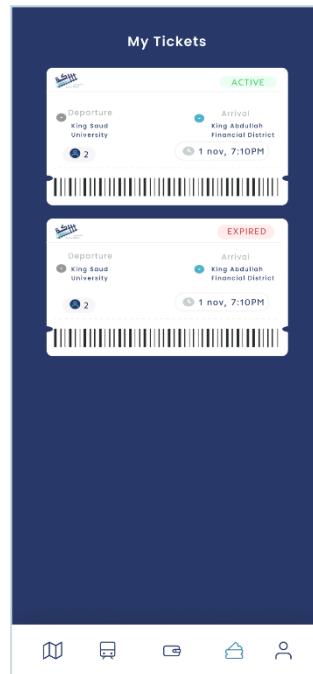


Figure 25 - Tickets Page Interface Design

Profile Page (Edit page)

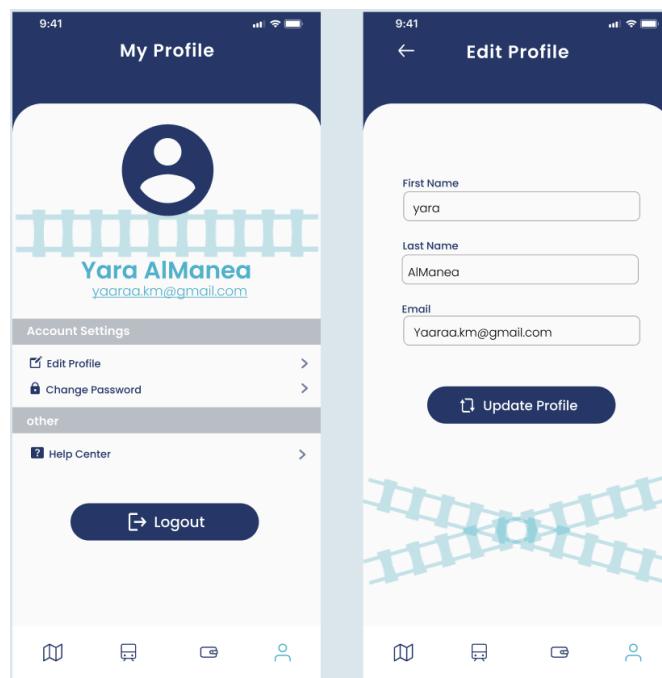


Figure 26 - Profile Page (Edit page) Interface Design

Profile Page (Change password)

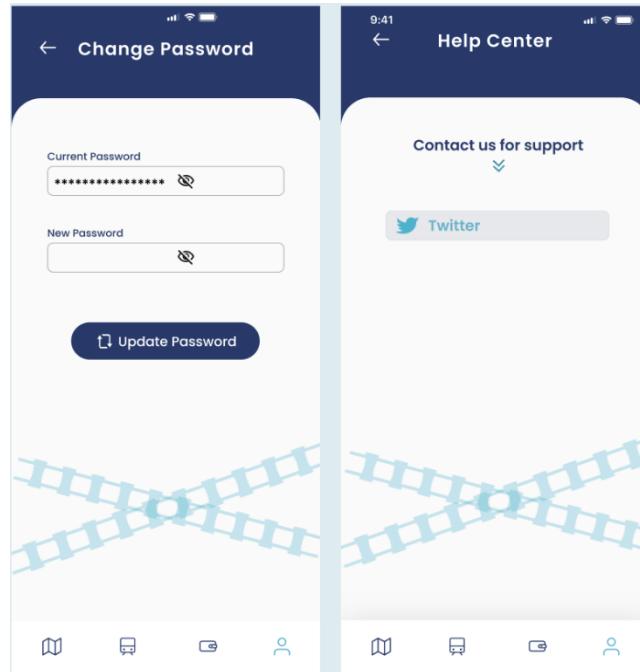


Figure 27 - Profile Page (Change password) Interface Design

Login (Admin)

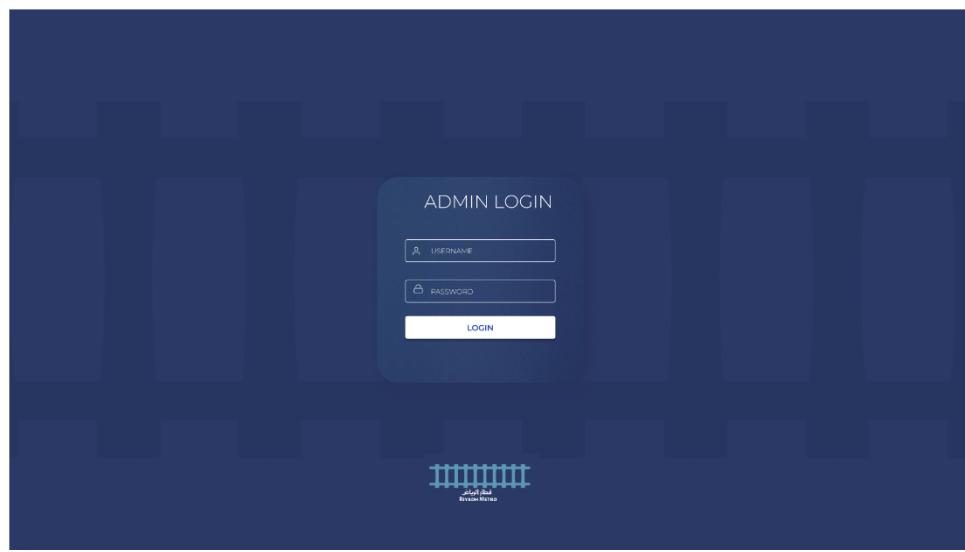


Figure 28 - Login (Admin) Interface Design

HomePage (Admin)



Figure 29 - HomePage (Admin) Interface Design

Site Map (Passenger)

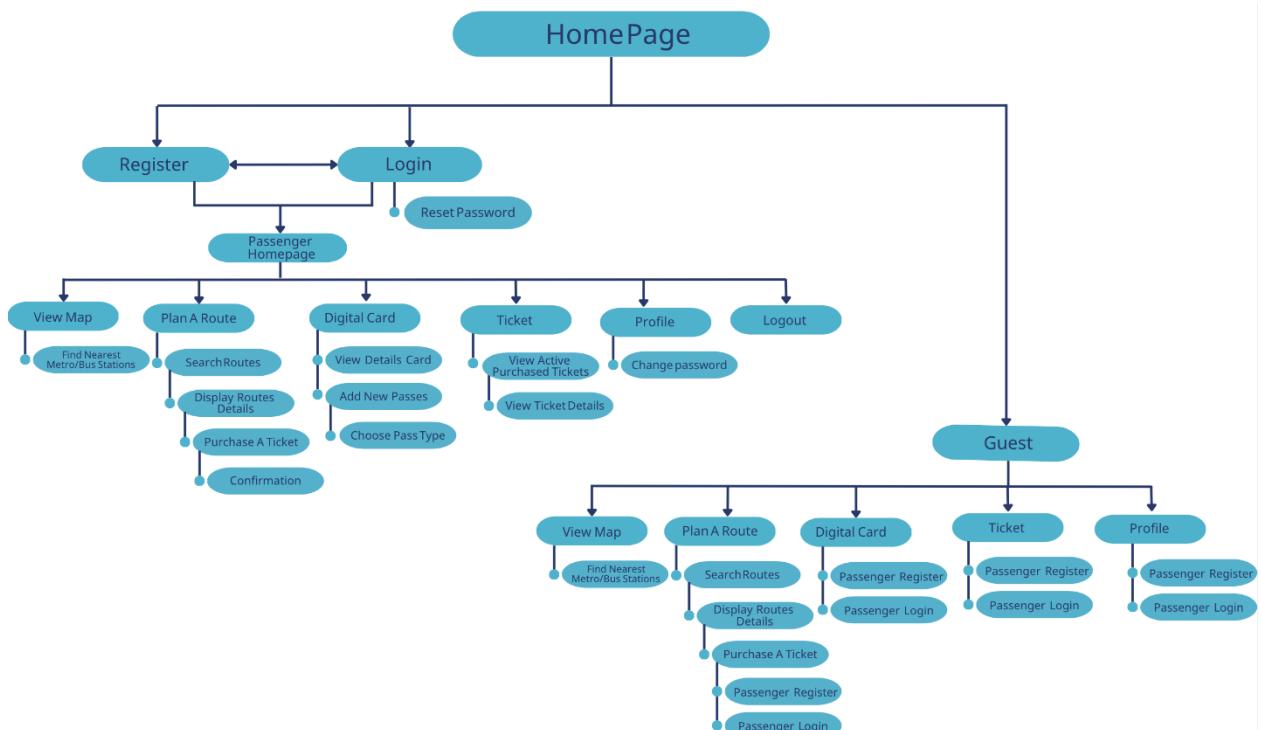


Figure 30 - Sekkah Site Map (Passenger)

Site Map (Admin)

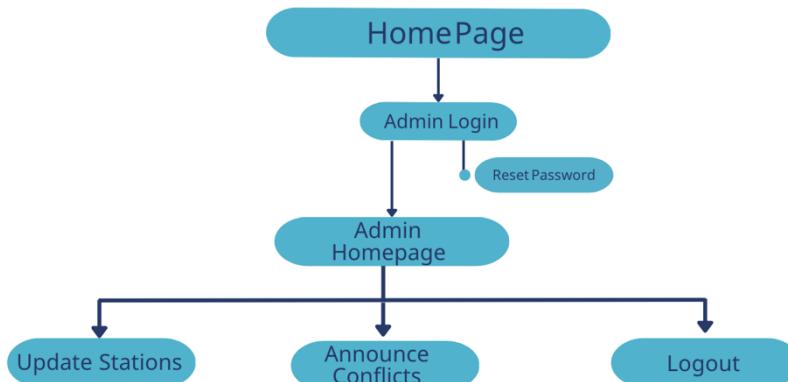


Figure 31 - Sekkah Site Map (Admin)

Incorporated UX guidelines in interface design:

- Enhancing the consistency of our app design:**

consistency in the icon colors and text fonts along with the navigation bar being in the bottom of the page.

- Error handling:**

simple error handling when the user fills the login/register fields in the wrong format the user will be informed immediately.

- Feedback interaction:**

When the user creates an account, the application will show a message "The account has been created successfully", giving the user feedback.

- Make navigation visible:**

Minimizing the user's memory load by making the navigation bar available at all times.

- Keep interactive elements familiar and predictable:**

The user will predict which page he's/she's in by showing a different visualization of the icon page color in the navigation bar. in addition to users can check interactivity by tapping on an element. Moreover the (view map) page icon is a map and the profile icon for the (profile) page represents a person which is familiar to the users.

4.6 Implementation

This part covers the system implementation steps in detail. Implementation is the step at which the system's functionalities described earlier are translated into a tangible, working application. To implement "Sekkah," we need to tackle some major steps, starting with the specification of the hardware and software tools needed to develop "Sekkah" as an application along with the admin's dashboard website. Then, we will dig deeper into the implementation process by explaining how our system connects to external systems. After that, we will explain how we implemented "Sekkah" by showing code samples for various system components, such as major functions, along with our own logic. Finally, we will elaborate on the challenges and difficulties encountered during the development of "Sekkah."

As a start, the "Sekkah" application and admin website required no major hardware tools other than computers and mobile devices, which were used to develop and test both the application and website. As for the software tools, we utilized Visual Studio Code as a standalone source code editor with Flutter/Dart as a programming language for the hybrid mobile application, whereas HTML, CSS, and Javascript were utilized to develop the admin website. Additionally, Android Studio and XCode were used as IDEs for Android and iOS applications, respectively. Furthermore, we resorted to Jira software for planning, tracking, and managing our agile software development project. Besides, to share our code simultaneously, GitHub was utilized as a programming resource for code sharing. Also, to create appealing interfaces for "Sekkah", we utilized Figma as a collaborative interface design tool. In addition, for data storage, we made use of the services provided by Firebase Cloud Firestore, given that it is a scalable database used for mobile, web, and server development. To properly host and deploy the admin's website [37], a Netlify server [38] was used as a reliable cloud-based hosting service. Not to mention, the admin's website took advantage of the ReactJS library to enable reading or updating any data stored on the Firebase database instantly with automatic synchronization on the "Sekkah" application.

To implement "Sekkah", we connected it to existing APIs equipped with ready-to-use packages employed directly in our application. One such API would be the Google Maps API, which offers location-based services. To connect to this API, we began by creating a Google

Developer account, which is connected to the Google Maps platform. Following that, we generated the Google Maps' API key, which is extremely crucial to having a successful connection between "Sekkah" and the Google Maps API. After that, we added the key to the "AndroidManifest.xml" and "AppDelegate.swift" files, allowing Google Maps to run on Android and iOS devices accordingly. By implementing these primary steps, which are then followed by simpler steps, our application was successfully connected to the API. By connecting to this API, maps are instantly integrated into the app and may even be customizable according to our preferences. These maps are then enhanced by adding further features to them, such as providing a plotted map of the stations, an option to navigate to any pinned station via Google Maps, a place suggestion list provided by auto-completing any typed place[36], and even real-time GPS tracking. Not to mention, the Google Maps API is beneficial in the routing process as well, since it automatically offers geocoding, or the process of converting a location's geographic coordinates into a street address, making it easily recognizable by humans.

Furthermore, "Sekkah" stores all its data in an external, cloud-hosted NoSQL database known as the Cloud Firestore Database. In addition to the data storage service this database provides, it also provides authentication and authorization services for logged-in passengers using "Sekkah". Similarly, the admin account is authenticated and authorized upon login via the same database. To connect to the database, we started by creating a project in Firebase and adding the required collections, which represent tables. Within each collection, we will have documents that represent instances, and inside each document, we will have attributes that basically represent fields of that particular instance. After that, we must get the Android package name of the created project and place it in the "build.gradle" file located in the android/app directory, along with adding the Firebase configuration file "google-services.json" to that same directory. By doing this major step, followed by other minor steps, our application was successfully connected to the database.

Moreover, a third-party application, PayPal, was used in the implementation process. Essentially, the PayPal Gateway is a payment platform that allows for online money transactions between parties. Hence, PayPal was integrated with the "Sekkah" application using WebView to enable passengers to purchase tickets with a click of a button. To

successfully integrate PayPal with Flutter, we had to make a PayPal app by navigating to the PayPal developer account dashboard. By making an app, we obtained two IDs: a secret ID and a client ID. Following that, we added the necessary dependencies to the "pubspec.yaml" file. After that, we created a PayPal service file in our code where we utilized the PayPal API for testing mode as well as adding to it the two previously obtained ids. Finally, to test the payment integration, PayPal Sandbox[41], a virtual testing environment segregated from the actual PayPal production environment, was used.

Equally important, a key component to using Cloud Firestore in our application is defining adequate models[40]. To use "Sekkah", we must be able to work with data efficiently. However, Dart objects are used within the app, whereas Firestore exchanges data in JSON format. Hence, to simplify the exchange of data between "Sekkah" and the Firestore, we needed to outline models for the collections defined in the Firestore, where each model not only outlines its attributes and a constructor but also provides a way to convert from and to a Dart object. In each defined model, we created a function called `toMap()`, which is responsible for returning a map to the database when presented with a Dart object. Additionally, we created another function called `fromMap()`, which is responsible for initializing all the variables with the values that are retrieved from the database. Defining models on their own doesn't do anything. Instead, a "reference" must be created by using the "Collection" annotation, which acts as a pointer to a collection within the Firestore database. Examples of models defined in "Sekkah" are numerous, including: bus station model, contains model, distance model, line model, metro station model, route model, and user model. Therefore, the combination of these components, along with others, helped us bring out the "Sekkah" application.

Table 3 - Code snippet (I)

locationProvider.dart	
Description	This file is used to call and fetch the user's current location which has been requested by the function placed in the locationServices class . Additionally, after retrieving the user's location, the distanceBetween function utilizes the geolocator class[35] in order to calculate the distance between the user's current location and the destination which represents any metro/bus station. The distance is calculated by using the Haversine formula [39] , where the resulting distance is provided in meters.
Code snippet	
	<pre>Future<double> distanceBetween(GeoPoint endLocation, LatLng? currentPosition) async { final double distance = Geolocator.distanceBetween(endLocation.latitude, endLocation.longitude, currentPosition!.latitude, currentPosition.longitude) / 1000; print(distance); return distance; }</pre>

Table 4 - Code snippet (2)

locationServices.dart	
Description	<p>This file is essentially created for the sole purpose of retrieving the Location Permission Request Status, and depending on the provided status, it will either return True or False accompanied with a dialog box. Essentially, the request() function will ask the user to grant access to location, if access hasn't already been granted before, then it returns the status.</p> <p>There are a set of different status, including: Granted, Denied, Limited (Allow once or Only While Using) , and Permanently Denied (Never Ask Again, the user in this case may change the status via the device's settings, which will be shown after making a new request permission call).</p>
Code snippet	
	<pre>class LocationServices { Future<bool> checkForPermission(context) async { String errorMessage = ErrorHandelling.getMessageFromErrorCode(errorCode: 'location'); var status = await Permission.location.request(); if (status.isGranted) { return true; } else if (status.isDenied) { showAlertDialog(errorMessage); return false; } else if (status.isLimited) { return true; } else if (status.isPermanentlyDenied) { showAlertDialog(errorMessage); return false; } else { return false; } } }</pre>

Table 5 - Code snippet (3)

Station_controller.dart	
Description	<p>This file is used to retrieve collections of both Bus Stations and Metro Stations by calling the function <code>get_bus_stations()</code> and <code>get_Metro_stations()</code> respectively, then fetches the user's current location from the <code>Provider class</code>.</p> <p>After fetching the necessary collections, we will convert the retrieved data from the database and map it into the required format by using the <code>fromMap()</code> function. To do so, we start by iterating through the documents included in the snapshot then calling the <code>map()</code> function which creates a <code>new array</code>, via the <code>toList()</code> function, that is populated with the results of calling the <code>fromMap()</code> function on every element.</p> <p>Following that, we created a <code>temporary list</code> then initiated a for loop which iterates through each item in the new array created by the <code>toList()</code> function and fetches the location of that item(station). After that, it calculates the distance between the item and the user's current location then stores the resulting distance in the temporary list along with the item itself. After iterating through all items, it will store the results of the temporary list into the corresponding <code>station array</code> (metro, bus). Finally, it will sort the items in each array by comparing the distance of each item to the other, such that the least distance will be placed first and the highest distance will be placed last.</p>
Code snippet	
	<pre>class StationsController extends GetxController { final provider = Get.put(LocationProvider()); RxList<DistanceModel> BusStations = <DistanceModel>[].obs; RxList<DistanceModel> MetroStations = <DistanceModel>[].obs; var stations_loading = false.obs; var mstations_loading = false.obs; get_bus_stations() async { stations_loading(true); final position = provider.currentLatLang; var result = await FirebaseFirestore.instance.collection("Bus_Station").get(); final data =</pre>

```

        result.docs.map((e) =>
BusStationModel.fromMap(e.data())).toList();
    final tempList = <DistanceModel>[];
    for (var item in data) {
        final location = item.Location;
        await provider.distanceBetween(location, position).then((distance) {
            tempList.add(DistanceModel.mapToBusModel(item, distance));
        });
    }
    BusStations.addAll(tempList);
    BusStations.sort(
        (a, b) {
            return a.Distance.compareTo(b.Distance);
        },
    );
    print("here is result data ${BusStations.length}");
    stations_loading(false);
    update();
}

```

Table 6 - Code snippet (4)

auth_controller.dart	
Description	<p>In this file, we introduced some of the functions which require user authentication, including: logging in, signing up, continuing as guest, updating the user's profile, resetting or changing the password, and logging out.</p> <p>Additionally, to know whether the logged in user has a valid pass, we created a method that checks for all possible conditions. To begin, we retrieved the <i>user instance</i> from firebase then compared the <i>current date</i>(today) to the <i>user's date</i> (date upon creating the pass) to check if it is expired or not.</p> <p>To compare the two values, we started by checking if the <i>expiry date</i> of the user's pass <i>equals zero</i>, in this case, it is <i>expired</i>. Otherwise, if the <i>current date is ahead of the user's date</i> that indicates that the pass is still <i>valid</i> and has not yet expired.</p> <p>Along with that, we decided to check the difference between the two dates. therefore, if the <i>difference is zero</i>, then we will calculate the <i>remaining time in hours</i> until expiry. Else, we will add a <i>string "day/s"</i> depending on the remaining number of days. Finally, if the</p>

current date is after the user's date, then that means the pass is no longer valid and is *expired*.

Code snippet

```
static Future<String?> checkIfUserHasPass() async {
    try {
        final user =
            FirebaseAuth.instance.currentUser; //Getting firebase auth instance

        final db = FirebaseFirestore.instance;
        DocumentSnapshot userObj =
            await db.collection('Passenger').doc(user!.uid).get();

        final mUser = UserModel.fromMap(userObj.data() as Map<String, dynamic>);

        final currentDate = DateTime.now();
        final userDate = DateTime.fromMillisecondsSinceEpoch(
            int.parse(mUser.Pass_Expired_date));

        if (mUser.Pass_Expired_date == "0") {
            await db.collection('Passenger').doc(user!.uid).update(
                {
                    'Pass_Expired_date': "0",
                },
            );
            LeftDuration = "Expired";
            return LeftDuration;
        } else if (currentDate.isBefore(userDate)) {
            var diff = userDate.difference(currentDate).inDays;
            if (diff == 0) {
                LeftDuration =
                    userDate.difference(currentDate).inHours.toString() + " Hours";
            } else {
                if (diff == 1) {
                    LeftDuration = diff.toString() + " Day";
                } else {
                    LeftDuration = diff.toString() + " Days";
                }
            }
            return LeftDuration;
        } else if (currentDate.isAfter(userDate)) {
            await db.collection('Passenger').doc(user!.uid).update(
                {
                    'Pass_Expired_date': "0",
                },
            );
        }
    }
}
```

```
);

LeftDuration = "Expired";
return LeftDuration;
} else {
await db.collection('Passenger').doc(user!.uid).update(
{
'Pass_Expired_date': "0",
},
);
LeftDuration = "Expiring";
return LeftDuration;
}
} on Exception catch (err) {
Get.snackbar("error", err.toString());
}
return null;
}
```

Table 7 - Code snippet (5)

Map_controller.dart	
Description	Code snippet
<p>In this file, we introduced a set of functions that will help us in building the map view, which primarily plots all the stations(metro, bus) as markers and also shows the different lines of the metro as polylines.</p> <p>In this part, the function <code>getAllLines()</code> retrieves the Line collection from the database as a snapshot then iterates throughout all the docs in that collection. After that, it will add each doc to the <code>_allLines.value array</code> after converting it into the necessary format using <code>fromMap()</code>, then it will return an <code>array list</code> of all the lines by the end of the function. The same structure is followed by the remaining functions, including: <code>getAllContains()</code> , <code>getAllStations()</code>, <code>getAllBuses()</code>.</p>	<pre>Future<List<LineModel>> getAllLines() async { return await FirebaseFirestore.instance .collection('Line') .get() .then((QuerySnapshot querySnapshot) { for (var doc in querySnapshot.docs) { _allLines.value .add(LineModel.fromMap(doc.data() as Map<String, dynamic>)); } return _allLines.value; }); }</pre>

Table 8 - Code snippet (6)

Map_controller.dart	
Description	<p>In this part, we will indicate how each station has been plotted as a marker based on the line it lies at, the code snippet has been applied for only one of the lines for the sake of simplification since the same concept has been applied to the remaining lines.</p> <p>To begin, we created six array lists (for each line we have) all with a ContainsModels type that have been named according to their line number, initially all arrays are empty. Consequently, all the lines' references have been retrieved from Firestore. After that, we started filtering each element in the allContains array according to the line number it belongs to, such that if the element's Line_ID equals the reference for line1, as an example, then in that case it will check the order number of that station and depending on that, it will be added to the line1 array in the adjacent order.</p> <p>Following that, we will sort each line array according to the order number, in order to make sure that there are no duplicates. In addition, we will clear all the stations within each route array, so that upon relaunching the app, stations are not plotted on top of the old ones.</p> <p>Furthermore, to create a polyline in the map, we started assigning values to each route. By creating a for loop that iterates through every element in each line array separately, all stations within each line are compared with the stations in the allStations array and if the IDs match, then that station is added to the corresponding route.</p> <p>Then, we will clear the polyline value for the sole purpose of not duplicating it in the case of relaunching the app. Finally, we added polylines to the map by creating each and every line separately then converted from geoPoint to LatLng so that we are able to use it in the map.</p>

Code snippet

```

void setPolyLineData() {
    List<ContainsModel> line1 = [],
    DocumentReference line1Ref =
        FirebaseFirestore.instance.collection('Line').doc('Line_1');

    for (var element in allContains) {
        if (element.Line_ID == line1Ref) {
            if (!line1.any((e) => e.Order == element.Order)) {
                line1.add(element);
            }
        }
    }
    line1.sort((a, b) => a.Order.compareTo(b.Order));
    route1Stations.clear();

    for (var element in line1) {
        if (allStations.firstWhere((e) => e.id.toString() == element.MStation_ID.id)
            .id.toString() == element.MStation_ID.id) {
            route1Stations.add(
                allStations.firstWhere((e) => e.id.toString() == element.MStation_ID.id));
        }
    }
    _polyline.value.clear();
    _polyline.value.add(
        Polyline(
            polylineId: const PolylineId('1'),
            width: 4,
            points: geoPointToLatLng(route1Stations.map((e) => e.Location).toList()),
            color: Colors.blue),
    );
}

```

Table 9 - Code snippet (7)

viewMap.dart	
Description	In the <code>setMarkersToShow()</code> function of the viewMap file, we created several conditions such that we could control hiding/unhiding the bus and metro stations' markers in the map of the homepage.
Firstly, in the case that both buttons were clicked (the top right bus/metro icons), therefore, all station markers will be visible . Secondly, if the metro button is clicked and the bus button isn't, then we will only show the metro stations while bus stations are hidden. Thirdly, if the bus button is clicked and the metro button isn't, then we will only show the bus stations while metro stations are hidden. Finally, if both buttons were unclicked , then we will make all the stations invisible on the map.	
Code snippet	
<pre>void setMarkersToShow() { if (showMetro.value && showBus.value) { markersType.value = MarkersToShow.both; } else if (showMetro.value && !showBus.value) { markersType.value = MarkersToShow.metro; } else if (!showMetro.value && showBus.value) { markersType.value = MarkersToShow.bus; } else if (!showMetro.value && !showBus.value) { markersType.value = MarkersToShow.none; } }</pre>	

Table 10 - Code snippet (8)

addPoints.dart	
Description	
	<p>In this file, we explore how the planning algorithm works and precisely how we add points (stops) to a specific route. The way the algorithm works is that if the starting and destination lie on the same metro line, then we will get the full line on which they lie. After that, we want to get all the stations that lie between the starting station (which was selected based on the nearest distance from the starting location) and the ending station (which was selected based on the nearest distance from the starting location).</p> <p>Not to mention, we must check whether the starting station comes before the ending station by utilizing the order attribute. Depending on the order of stations, we will either retrieve the list of all stations in the collection in ascending or descending order. After getting this list, we will validate whether each element in that list lies at our desired line; if so, we will add this station to an initially created empty array called nameList.</p> <p>After retrieving all the station names in that line, we will need to get their coordinates in order to precisely draw the route. To do so, we created a for loop for the namelist array, and then we will call the getMetroStation function, which basically takes in the station's name and retrieves its details. Following this step, we will start checking each retrieved element to see if it is precisely either the starting station or the ending station. If the condition is true, then only in that case will we add it to the exproute array, which primarily stores the route details. By the end, we reach the element that happens to be our ending station, and in that case, that stops the process of adding elements to the exproute array; otherwise, each element is added one by one to that array.</p>

Code snippet

```

Future<List<RouteModel>?> addPoints(
    {ContainsModel? startingLine, ContainsModel? endLine}) async {
  List<String> nameList = [];
  bool? isAdd = false;
  List<RouteModel> exproute = [];
  if (int.parse(startingLine!.Order) > int.parse(endLine!.Order)) {
    await metroService.containsDescending().then((value) {
      value.forEach((e) async {
        if (e.Line_ID.id == startingLine.Line_ID.id) {
          print("===== ${e.Name} ===== ${e.Line_ID.id} &&
${e.Order}");
          nameList.add(e.Name);
        }
      });
    });
  } else {
    await metroService.containsAssending().then((value) {
      value.forEach((e) async {
        if (e.Line_ID.id == startingLine.Line_ID.id) {
          print("===== ${e.Name} ===== ${e.Line_ID.id} &&
${e.Order}");
          nameList.add(e.Name);
        }
      });
    });
  }
  for (var element in nameList) {
    await metroService.getMetroStation(Name: element).then((v) {
      v.forEach((element) {
        if (element.Available == true) {
          print(
            "+++++++++++++++++++++ ${element.Name} &&
${element.Location.latitude} && ${element.Location.longitude}");
          if (element.Name == startingLine.Name ||
              element.Name == endLine.Name) {
            isAdd = true;
          }
          if (isAdd == true) {
            exproute.add(RouteModel(
              type: 'metro',
              isShow: true,
              name: element.Name,
              lat: element.Location.latitude,
              lng: element.Location.longitude));
            if (element.Name == endLine.Name) {
              isAdd = false;
            }
          }
        }
      });
    });
  }
  return exproute;
}

```

During our implementation of "Sekkah," we faced multiple setbacks and obstacles, yet we managed to solve them, no matter the effort it took or how complex it was. To begin, a difficult challenge to solve was the retrieval of data from Firebase, specifically the station markers, which, when combined, create each corresponding metro line they lie on. Furthermore, we encountered different algorithms to compute the nearest station from the user's current location, some of which were based on the point-to-point distance rather than the accurate distance that can be navigated using a vehicle; thus, we needed to implement an algorithm that corresponded with our requirements. Another difficulty was that any major change implemented in the database, such as the change of any document field, had a corresponding effect on the application; this goes back to the fact that we have created models for these collections; hence, any change to the database must, in turn, be changed in the model classes as well. A major setback that we faced during our implementation was the fact that our metro lines and stations, bus or metro, were neither publicly published nor accessible via Google Maps. As a result, we followed many approaches to create an optimized journey planning process but reached a dead end due to the graph nodes not being available at all; therefore, we did our own logic for our planning algorithm, which was definitely a time-consuming task, but after conducting various tests on each and every condition, we modified our app to be at its best performance. Additionally, since our application is developed in Flutter, it should properly work on both iOS and Android. Yet, we faced some minor issues in iOS that required us to make some changes to our code; however, we managed to make both devices work, thankfully.

To properly develop “Sekkah”, we resorted to the help disk as well as experts in order to receive feedback on some concerns, which mainly involved the database relationships as well as the retrieval of data from Firebase and the different algorithms used to calculate the shortest path. Additionally, we also searched for similar systems and what approach they used to implement common functionalities, which gave us an insight into how we can implement our functions as well.

To get a deeper look into the implementation details, you can view the [GitHub Repository Link](#).

CHAPTER 5

- SYSTEM EVALUATION -

5 System Evaluation

5.1 Experimental Results

No experiments were undertaken to implement our application.

5.2 User Acceptance Testing

User Acceptance Testing (UAT) is a type of system evaluation that determines whether the system meets business requirements and can be used by end users. It assesses user interface acceptance, technical elements, significant strengths, and major weaknesses. As a result, we distributed a survey on our application to users from the target demographics.

5.2.1 Demographics of Participants

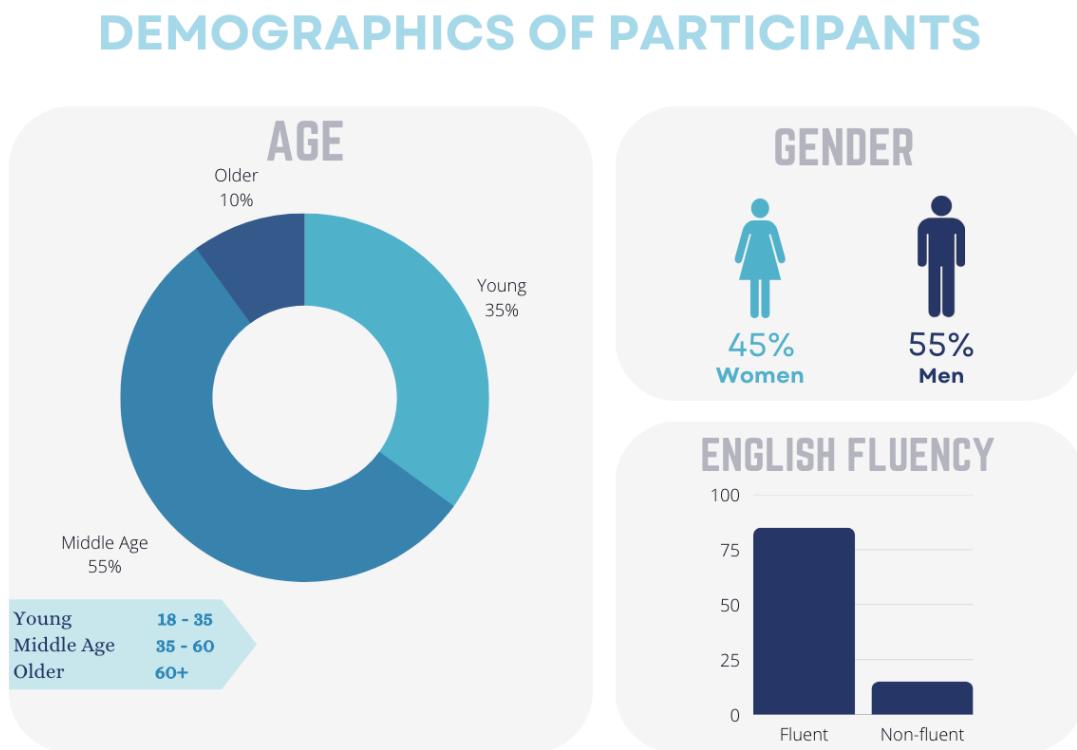


Figure 32 – Participants' Demographics

5.2.2 Questionnaire/Interview Results

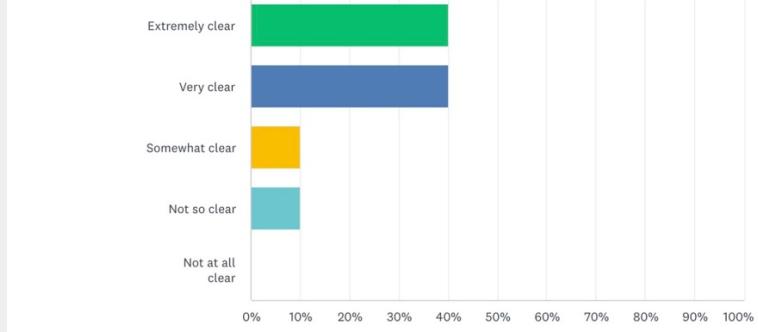
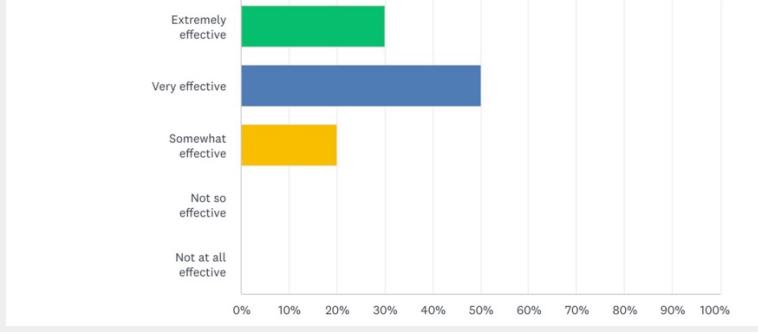
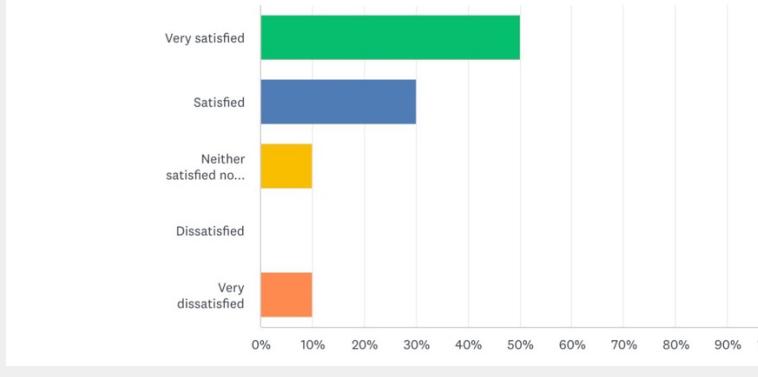
The results were based on five multiple-choice questions, where each question had its own customized choices. Since we both developed an application for users and a website for admins to manage the app, we undertook two surveys, one for each.

In Sekkah's app survey, 40% of our users thought that the metro lines and stations plotted on Sekkah's map were extremely clear. Furthermore, 50% of them described the process of locating the nearby stations as very effective. Additionally, 50% were satisfied with the accuracy of the trip planning feature, with the remaining 10% dissatisfied. Yet, 60% of users thought that the long loading time of the trip planning process should be improved, whereas 30% said that providing place suggestions could be enhanced, and finally, 10% thought that generating route options could be improved. Moreover, 60% agreed that the process of purchasing a ticket was very easy. Not to mention, 50% of them said that adding a digital card was not difficult at all, while 10% felt that it was in fact difficult. Equally important, 70% agreed that the app is extremely visually appealing. In addition, 30% of our users reported that the system might have crashed, while the remaining 70% didn't encounter any problems during their experience with Sekkah.

In Sekkah's admin survey, 70% of users felt that navigating through Sekkah's admin dashboard was very smooth. Even more, 60% of them thought that the different functions provided by Sekkah's admin dashboard were extremely effective. Also, 40% of users agreed that making an announcement or updating the admin dashboard was extremely easy, whereas 20% might have faced difficulty. Finally, 40% of users rated the overall quality of Sekkah as a very high-quality app, with 50% rating it as a high-quality app and the remaining 10% rating it as low-quality, which we will for sure investigate and work on enhancing.

Questionnaire link: [Appendix B](#)

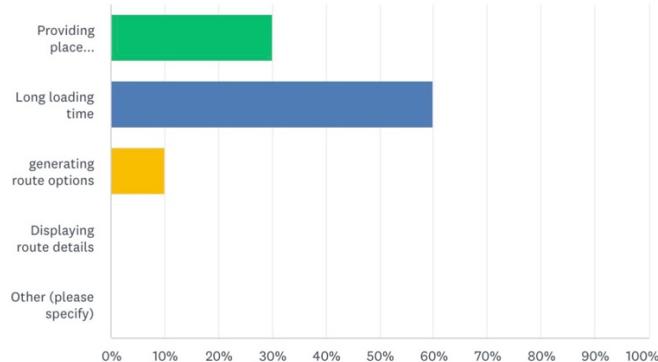
Table 10 - User Questionnaire Results

Questions	Answers												
1. I thought that the metro lines and stations plotted on Sekkah's map were	<p>I thought that the metro lines and stations plotted on Sekkah's map were</p> <p>Answered: 20 Skipped: 0</p>  <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Extremely clear</td> <td>45%</td> </tr> <tr> <td>Very clear</td> <td>40%</td> </tr> <tr> <td>Somewhat clear</td> <td>10%</td> </tr> <tr> <td>Not so clear</td> <td>10%</td> </tr> <tr> <td>Not at all clear</td> <td>0%</td> </tr> </tbody> </table>	Response	Percentage	Extremely clear	45%	Very clear	40%	Somewhat clear	10%	Not so clear	10%	Not at all clear	0%
Response	Percentage												
Extremely clear	45%												
Very clear	40%												
Somewhat clear	10%												
Not so clear	10%												
Not at all clear	0%												
2. How would you describe the process of locating the nearby stations to you?	<p>How would you describe the process of locating the nearby stations to you?</p> <p>Answered: 20 Skipped: 0</p>  <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Extremely effective</td> <td>30%</td> </tr> <tr> <td>Very effective</td> <td>50%</td> </tr> <tr> <td>Somewhat effective</td> <td>20%</td> </tr> <tr> <td>Not so effective</td> <td>0%</td> </tr> <tr> <td>Not at all effective</td> <td>0%</td> </tr> </tbody> </table>	Response	Percentage	Extremely effective	30%	Very effective	50%	Somewhat effective	20%	Not so effective	0%	Not at all effective	0%
Response	Percentage												
Extremely effective	30%												
Very effective	50%												
Somewhat effective	20%												
Not so effective	0%												
Not at all effective	0%												
3. How satisfied were you with the accuracy of the trip planning feature?	<p>How satisfied were you with the accuracy of the trip planning feature?</p> <p>Answered: 20 Skipped: 0</p>  <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Very satisfied</td> <td>50%</td> </tr> <tr> <td>Satisfied</td> <td>30%</td> </tr> <tr> <td>Neither satisfied nor dissatisfied</td> <td>10%</td> </tr> <tr> <td>Dissatisfied</td> <td>0%</td> </tr> <tr> <td>Very dissatisfied</td> <td>10%</td> </tr> </tbody> </table>	Response	Percentage	Very satisfied	50%	Satisfied	30%	Neither satisfied nor dissatisfied	10%	Dissatisfied	0%	Very dissatisfied	10%
Response	Percentage												
Very satisfied	50%												
Satisfied	30%												
Neither satisfied nor dissatisfied	10%												
Dissatisfied	0%												
Very dissatisfied	10%												

4. What aspects of the trip planning process should be improved?

What aspects of the trip planning process should be improved?

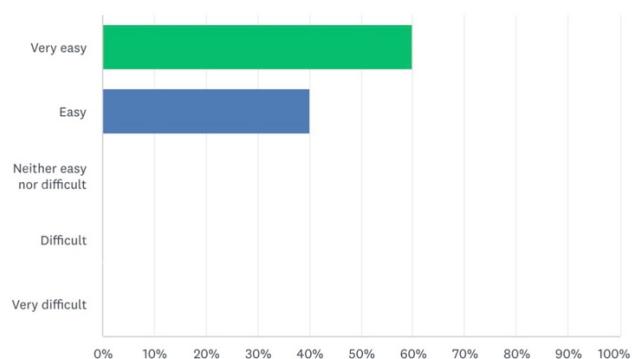
Answered: 20 Skipped: 0



5. What are your thoughts regarding the process of purchasing a ticket?

What are your thoughts regarding the process of purchasing a ticket?

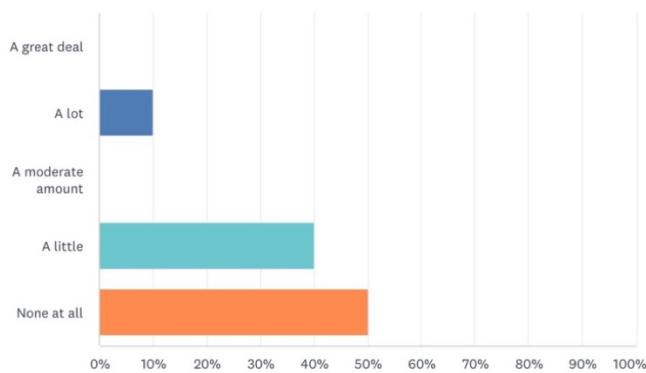
Answered: 20 Skipped: 0



6. To what extent was adding a digital card difficult?

To what extent was adding a digital card difficult?

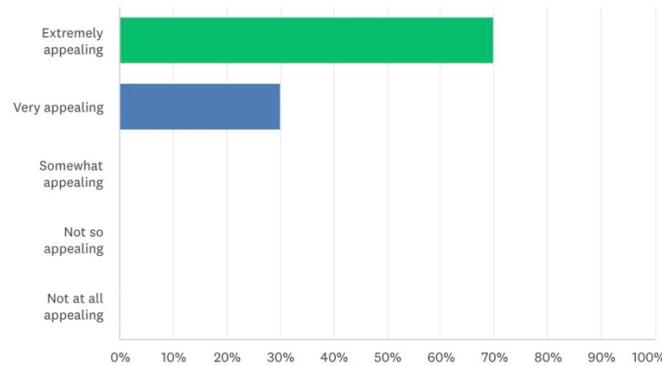
Answered: 20 Skipped: 0



7. How visually appealing is the app?

How visually appealing is the app?

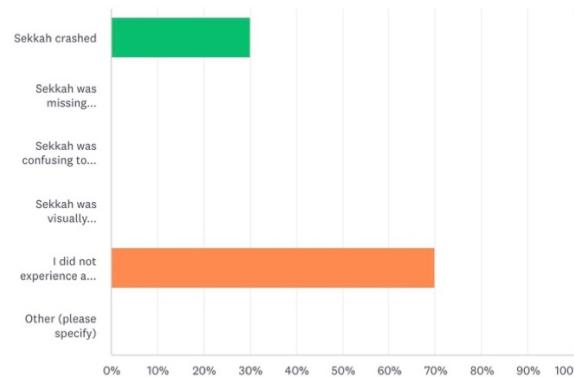
Answered: 20 Skipped: 0



8. Which, if any, of the issues below have you encountered during your experience with Sekkah? (Select all that apply.)

Which, if any, of the issues below have you encountered during your experience with Sekkah? (Select all that apply.)

Answered: 20 Skipped: 0



ANSWER CHOICES

RESPONSES

▼ Sekkah crashed	30.00%
▼ Sekkah was missing features I needed	0.00%
▼ Sekkah was confusing to use	0.00%
▼ Sekkah was visually unappealing	0.00%
▼ I did not experience any problems	70.00%
▼ Other (please specify)	Responses 0.00%

9. In your own words, is there anything that you hope Sekkah will offer in the future?

In your own words, is there anything that you hope Sekkah will offer in the future?

Answered: 9 Skipped: 11

Providing the app in arabic language

5/9/2023 08:14 PM

[View respondent's answers](#) [Add tags▼](#)

Adding more route options when planning

5/9/2023 12:04 PM

[View respondent's answers](#) [Add tags▼](#)

An emergency option that locates nearby hospitals

5/8/2023 02:45 AM

[View respondent's answers](#) [Add tags▼](#)

No

5/7/2023 08:14 PM

[View respondent's answers](#) [Add tags▼](#)

I do not want to add anything Sekkah is very clear and effective

5/6/2023 10:04 PM

[View respondent's answers](#) [Add tags▼](#)

The color of the line appears in the route details

5/6/2023 06:45 AM

[View respondent's answers](#) [Add tags▼](#)

there is none ❤

5/5/2023 06:13 PM

[View respondent's answers](#) [Add tags▼](#)

A favourite place option so I could quickly search for it

4/29/2023 12:24 AM

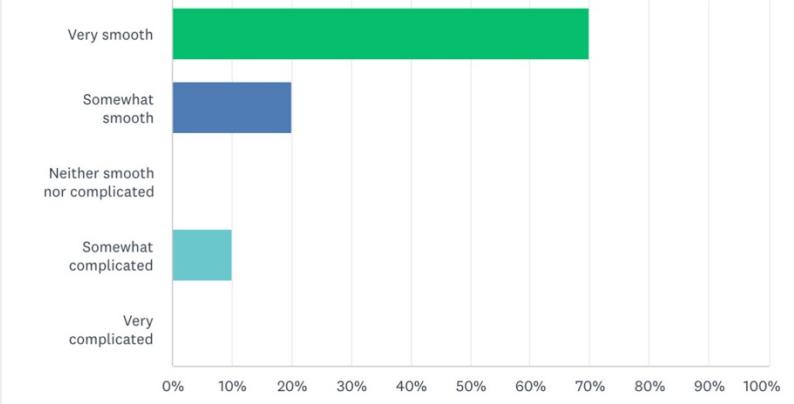
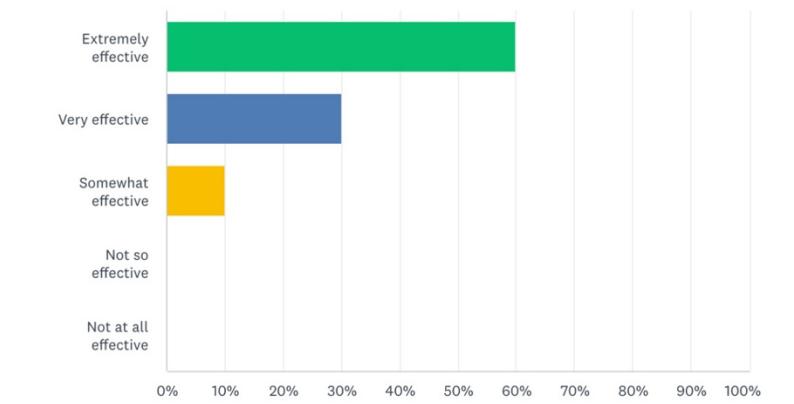
[View respondent's answers](#) [Add tags▼](#)

Route planning using only bus stations

4/29/2023 12:08 AM

[View respondent's answers](#) [Add tags▼](#)

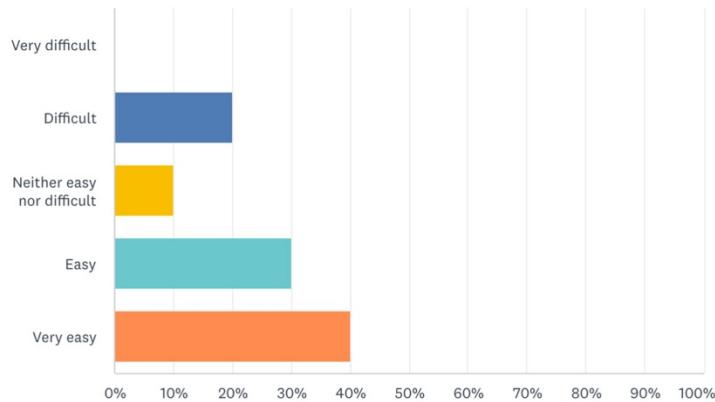
Table 11 - Admin Questionnaire Results

Questions	Answers												
<p>1. I feel that navigating through Sekkah's admin dashboard was</p>	<p>I feel that navigating through Sekkah's admin dashboard was</p> <p>Answered: 20 Skipped: 0</p>  <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Very smooth</td> <td>~70%</td> </tr> <tr> <td>Somewhat smooth</td> <td>~20%</td> </tr> <tr> <td>Neither smooth nor complicated</td> <td>~10%</td> </tr> <tr> <td>Somewhat complicated</td> <td>~5%</td> </tr> <tr> <td>Very complicated</td> <td>~0%</td> </tr> </tbody> </table>	Response	Percentage	Very smooth	~70%	Somewhat smooth	~20%	Neither smooth nor complicated	~10%	Somewhat complicated	~5%	Very complicated	~0%
Response	Percentage												
Very smooth	~70%												
Somewhat smooth	~20%												
Neither smooth nor complicated	~10%												
Somewhat complicated	~5%												
Very complicated	~0%												
<p>2. I thought that the different functions provided by Sekkah's admin dashboard were</p>	<p>I thought that the different functions provided by Sekkah's admin dashboard were</p> <p>Answered: 20 Skipped: 0</p>  <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Extremely effective</td> <td>~60%</td> </tr> <tr> <td>Very effective</td> <td>~30%</td> </tr> <tr> <td>Somewhat effective</td> <td>~10%</td> </tr> <tr> <td>Not so effective</td> <td>~5%</td> </tr> <tr> <td>Not at all effective</td> <td>~0%</td> </tr> </tbody> </table>	Response	Percentage	Extremely effective	~60%	Very effective	~30%	Somewhat effective	~10%	Not so effective	~5%	Not at all effective	~0%
Response	Percentage												
Extremely effective	~60%												
Very effective	~30%												
Somewhat effective	~10%												
Not so effective	~5%												
Not at all effective	~0%												

3. How easy or difficult was it to make an announcement or update in the admin dashboard?

How easy or difficult was it to make an announcement or update in the admin dashboard?

Answered: 20 Skipped: 0



4. What is a missing feature that you think should be provided in Sekkah's admin dashboard?

What is a missing feature that you think should be provided in Sekkah's admin dashboard?

Answered: 8 Skipped: 12

Showing a report for Sekkah app usage

5/9/2023 05:09 PM

[View respondent's answers](#)

Add tags▼

Having a feature that receives user complaints about app bugs for maintenance

5/9/2023 08:07 AM

[View respondent's answers](#)

Add tags▼

Providing a screen showing current stations status and details

5/8/2023 02:13 PM

[View respondent's answers](#)

Add tags▼

I found it very good and smooth.

5/7/2023 08:09 PM

[View respondent's answers](#)

Add tags▼

None

5/6/2023 06:07 AM

[View respondent's answers](#)

Add tags▼

clarity of the delaying time

5/5/2023 06:13 PM

[View respondent's answers](#)

Add tags▼

when announcing a delay, providing a slot the admin can choose from

5/5/2023 04:36 PM

[View respondent's answers](#)

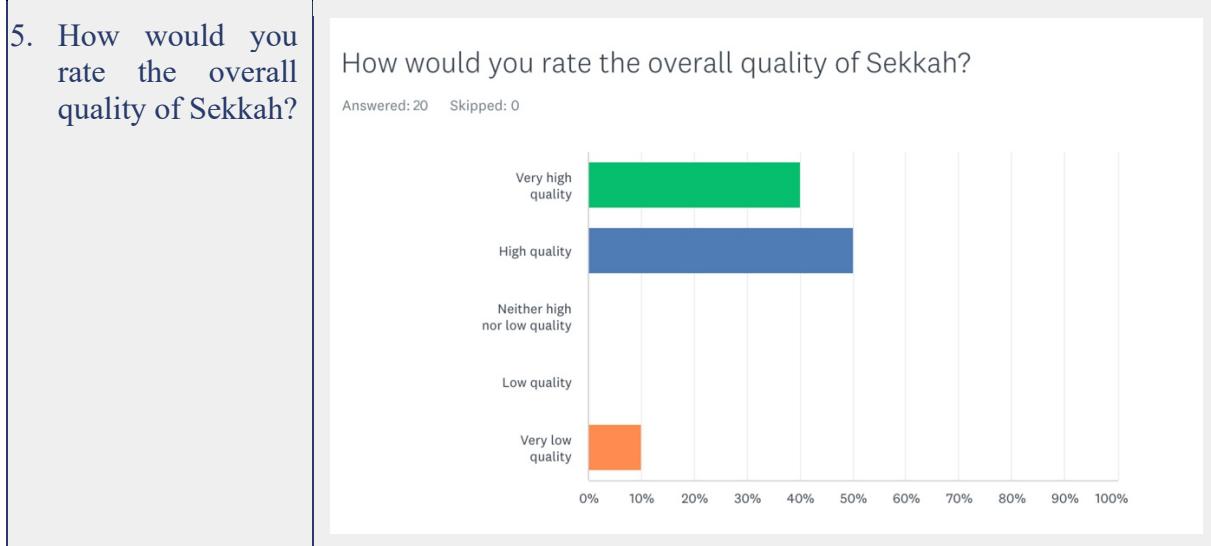
Add tags▼

The option to change the name or number for any station

4/29/2023 12:30 AM

[View respondent's answers](#)

Add tags▼



5.3 Quality Attributes (NFR testing)

Non-Functional Testing is a sort of software testing that examines a software application's non-functional features. It is intended to assess a system's readiness based on nonfunctional criteria that are never addressed by functional testing. As a result, after the UAT, we asked our users to evaluate (learnability, performance, and portability) non-functional features.

Table 12 - NFR

User story	Quality Attribute	Measure	Results
As a passenger I want the app to be portable by accessing it on both iOS and android devices so that I can use the app on whatever device I own.	Portability: How can the system or its components be used with both iOS and android devices.	Passengers should be able to run the application on both iOS and android devices.	Test scenario: We provided the application to the users and asked them to access and use their preferred platform and after completing the task, provide a feedback about the app's performance

			<p>and the platform they used.</p> <p>Number of users who completed the task:</p> <p>20</p> <p>Results: Passengers have been able to use the application on both iOS and android devices.</p>
As a passenger I want the app to be user-friendly and easy to learn without prior training so that I don't get frustrated.	<p>Learnability:</p> <p>How fast is it for passengers to complete the main functionalities once they see the interface.</p>	Passengers need less than 20 minutes to complete the main functionalities.	<p>Test scenario:</p> <p>We provided the application to the users and asked them to access and use it, but before using it, start the timer to see how long it takes to learn and know how to use the app, and after completing the main functionalities, with how long it took to complete the main functionalities.</p>

			<p>Number of users completed the task: 20</p> <p>Results:</p> <p>Minimum: 15 minutes</p> <p>Average: 17 minutes.</p> <p>Maximum: 20 minutes</p>
As a passenger, I want the system to display my route trip on the map within a minute of my search so that I don't waste my time.	<p>Performance:</p> <p>How responsive is the system and its components?</p>	Passengers need a minute to display their route trip on the map.	<p>Test scenario:</p> <p>We have provided the application to the users and asked them to access and use it, but before you start planning your route use the timer to see how long it takes, and then provide us with how long it took to display your route trip on the map.</p> <p>Number of users completed the task: 20</p> <p>Results:</p> <p>All the passengers were able to display their route trip on the map within a minute.</p>

5.4 Discussion

Based on the questionnaire results, it is evident that users find Sekkah to have an overall high rating for quality, indicating a well-developed and functional system. The design and development of the system seem to have addressed several user requirements successfully.

Based on user feedback, it is evident that passengers find the metro lines and stations displayed on the map to be clear, indicating a good visual representation. The majority of passengers also consider the process of locating nearby stations to be effective, suggesting that this feature has been successfully implemented.

While the trip planning accuracy is satisfactory for a significant number of passengers, there are areas that need improvement, particularly the long loading time and overall visualization of the place suggestions list. These issues should be addressed to enhance the overall user experience. On the positive side, passengers find the process of purchasing a ticket and adding a digital card to be easy, indicating good usability in these areas.

Visually, the app is deemed appealing by all users, which demonstrates the success of the design and visual elements of the application. However, some passengers reported app crashes, which need to be addressed to ensure stability and reliability.

In terms of future expectations, passengers expressed a desire for Sekkah to offer Arabic language support, a quick access feature for favorite places, and route planning options that exclude the metro and focus on buses only. These insights provide valuable input for future development and enhancement of the system.

Moving to the admin questionnaire results, navigating through Sekkah's admin dashboard is generally smooth, indicating a user-friendly design. However, a small number of users found it complicated, suggesting the need for further improvements in terms of ease of use.

The functions provided by Sekkah's admin dashboard were considered very effective by the majority of users, indicating successful implementation of the required features. While most users found making announcements or updating stations availability to be easy, a few encountered difficulties. This feedback highlights the need for streamlining these processes to ensure a consistent and straightforward experience for the administrator.

In terms of non-functional requirements, the system demonstrates good performance, with all passengers able to display their route trip on the map within a minute. The learnability aspect of the system is also satisfactory, as passengers need less than 20 minutes to complete the main functionalities. Moreover, the system's portability is confirmed, as passengers were able to use the application on both iOS and Android devices.

The UAT results indicate that the system generally meets user expectations and fulfills the desired requirements. However, the presence of app crashes reported by some users suggests the need for further testing and bug fixes to ensure a stable and reliable experience for all users. Additionally, the NFR results show good performance in terms of responsiveness and portability, as well as satisfactory learnability.

CHAPTER 6

- CONCLUSIONS & FUTURE WORK -

6 Conclusions and Future Work

In this chapter, we will present the document's conclusion as a fulfillment of the project's objective. Furthermore, it reinforces the fundamental outcomes obtained from the previous chapters. Following that, the global and local impacts will be discussed before diving into the project's limitations and improvements for future work by the end of this chapter.

In our daily hustle, we tend to face road traffic regularly, thus making transportation extremely frustrating and time-consuming. This issue has been a constant struggle in Riyadh, the capital of Saudi Arabia. Transportation in Riyadh is unendurable due to the significant traffic congestion, seeing that the city is rapidly growing and the number of vehicles has been strikingly rising. Not to mention, the use of public transportation hasn't been addressed yet; therefore, this has led to the reliance on private cars solely as a method of transportation. For this reason, an alternative method of transportation must be introduced to help reduce congestion to a great extent. The Riyadh Metro is a proposed rapid transit system that would serve as Riyadh's public transportation backbone and, in turn, provide a major solution to congestion.

Nevertheless, people nowadays are relying on technology to a great extent, as it helps simplify daily tasks that were more complex before mobile apps came to light. With this in mind, the development of a public transportation mobile application for Riyadh's Metro will be a crucial step forward that will enable passengers to make use of the metro's services with a click of a button, rather than manually locating nearby stations, asking strangers about the metro schedule, or even standing in queues to purchase tickets.

Hence, we propose "Sekkah", a hybrid mobile application that serves the users of Riyadh's Metro by offering numerous features, including a digital map marked with both bus and metro stations as well as the metro line routes. Additionally, users are able to find the nearest bus or metro station from their current location. Moreover, users can plan their route and purchase a ticket, then proceed to track their real-time location along the route. Furthermore, a digital metro card can be added for passengers, and they can choose their preferred type of pass,

whether daily, weekly, or monthly. The development methodology we followed to implement "Sekkah" is the Scrum methodology.

To summarize our development process, we began the "Introduction" chapter by identifying the problem and constructing a corresponding solution, along with outlining the project's scope, objectives, product vision statement, and software methodology utilized to develop the application. This was followed by the "Background" chapter, where thorough research was conducted on our targeted domain, thus gaining a wide perspective on the fundamentals that our project is built on. After that, the "Literature Review" chapter began by analyzing related publications and exploring similar applications to discover features that we could potentially offer and identify what makes us stand out. Once we got an insight into the features of similar systems, we began the "System Design and Development" chapter by describing our software development methodology in detail. Consequently, we defined the system's requirements by identifying the users of "Sekkah", then undertook various requirement elicitation approaches to understand their needs. This led us to depict how users interact with the system using an illustrative model, the use case diagram. Then a reflection of the system's features was shown as a list of functional and non-functional requirements in the product backlog. Moreover, we designed the system by utilizing a variety of models, such as architectural diagrams, class diagrams, DFD diagrams, flowcharts, and ER diagrams, along with our interface designs. After that, the UX standards that our application complies with were briefly described. This chapter is concluded by describing the implementation of "Sekkah" in depth, including a description of the different configurations made, an explanation of how the system connects to external systems, and a discussion of the challenges encountered during implementation. Altogether, we worked on developing a carefully modeled system that produces a concrete, functional application. "Sekkah" was tested by a variety of users as soon as it became a functional application, marking the start of the "System Evaluation" chapter. The purpose of testing is to ensure that the system as a whole is fault-free. We undertook user acceptance testing to assess our application and included the demographics of our testers, followed by an analysis of the test results. Additionally, measurements were undertaken to test out our non-functional requirements, and results were recorded. Finally, we deduced from the findings whether our system satisfied the requirements and collected suggestions for future application enhancements. This chapter, "Conclusions and Future Work", presents the document's

conclusion as a fulfillment of the project's objective. Furthermore, it reinforces the fundamental outcomes obtained from the previous chapters. Following that, the global and local impacts will be discussed before diving into the project's limitations and improvements for future work by the end of this chapter. Finally, the report's references, appendices, and acknowledgments are organized in the final three chapters.

The proposed development of the "Sekkah" application would have a significant impact on Riyadh's local population in general and public transportation passengers in particular.

- **Local Impact:**

The "Sekkah" application is targeted at Riyadh's population and aims to provide them with an effective transportation experience that manages and saves their time, maximizes their use of public transportation, and eliminates the need for private cars to get around the city, thus contributing to the reduction of traffic congestion.

- **Global Impact:**

Expanding Riyadh's public transportation network to all the neighboring cities would increase our reach to include the entire population of Saudi Arabia. Furthermore, the system's impact will be multiplied if the public transportation network is stretched throughout the Gulf regions as well. Another key point to consider is expanding the scope of our system to include additional modes of transportation such as taxis and railways. By doing so, we hope to serve a broader range of people through various modes of transportation.

- **Challenges encountered during the software development:**

Since the Riyadh Metro project is still under development, we faced some difficulties in the adequate collection of data, such as collecting the precise metro lines and their intersections, along with the accurate locations of metro and bus stations. Equally important, we had to utilize a shortest path algorithm in order to plan the journey efficiently, yet due to the fact that the Riyadh metro is not yet accessible via Google Maps, this was an obstacle that required huge efforts and significant time to work on since we started creating our own logic in addition to any utilized packages and APIs,

which was certainly difficult, yet we managed to improve it at our best effort. Additionally, to develop the "Sekkah" application, we used the Flutter/Dart programming language, which is a completely new language that we, as a group, weren't familiar with earlier, so we were on a self-learning journey initially. Another key point is the fact that our system is composed of various interrelationships among bus stations, metro stations, lines, and others, thus making the implementation of some functions a bit complex as it has many dependencies. Furthermore, since "Sekkah" is developed as a hybrid mobile app, we had to check that all packages and functionalities were working as expected on both iOS and Android, which was a cumbersome task.

- **Limitations:**

"Sekkah" application is effective right now and offers passengers a number of beneficial functions. It does, however, have limitations that could be addressed, such as:

- Only the English language is supported by the application.
- Few route options are generated in planning.
- Planning feature is not available for bus transit only.
- Long loading time needed to generate route options.
- Purchasing a ticket is only limited to PayPal.

- **Future Work:**

In the future, we intend to broaden our user reach by first making the application available in Arabic. Additionally, a crucial element to keep in mind is that we'll adapt our application to account for any future growth plans seeking to broaden the Riyadh public transportation network in order to further extend our reach to people.

In our development efforts, we primarily concentrated on implementing Sekkah's most essential features for users. Therefore, as a future development possibility, we plan to add more functionalities to Sekkah, including:

- Getting updated information about crowded stations.
- Providing the ability to add any purchased ticket directly to the wallet.
- Having a favorite routes option for passengers to save their most frequently used trips.
- Generating more route options to the planning feature.
- Providing the ability to plan by utilizing buses for transit only.
- Integrating other payment methods including Apple Pay and Google Pay.
- Optimizing the planning algorithm performance and enhancing its user experience.
- Adding an emergency option which locates the nearby hospitals and how to reach them.
- Showing the tracking progress from outside the app in the notification banner.

Furthermore, we will work on enhancing the admin dashboard such that it reflects positively on the app, some of the major improvements we are opting for includes:

- ❖ Providing a full KPI and usage report of Sekkah app in the admin dashboard.
- ❖ Integrating a system for reviewing user complaints and issues about the app.
- ❖ Displaying a screen that provides a summary of current stations' status and latest activities done by admin.
- ❖ Having a slots option in the announce delay where the admin can specify the exact delay time.
- ❖ Having the ability to make modifications on stations' details (name, number, status).

Taking everything into consideration, Sekkah aspires to evolve in every aspect that contributes to better performance for both passengers and administration, with the ultimate goal of offering the best public transportation experience possible.

CHAPTER 7

- ACKNOWLEDGEMENTS -

7 Acknowledgements

We would like to express our gratitude to our project supervisor, Dr. Meriam Kefi , for providing us with invaluable guidance and feedback throughout the project. We are also thankful to our mentors, Abeer AlDrees and Hend AlBassam, for their expert advice and support.

We would like to extend our appreciation to our team leader Yara AlManea and the members, Reema AlSaif, Najd AlNasrallah, and Razan AlDhafian, for their hard work and dedication in completing this project. Their contributions have been instrumental in achieving our goals

We are grateful to our Committee Dr.Arwa Al-Sultan, Dr.Hailah Al-Balla,

Dr.Abeer Al-Dayel, Dr.Sara Al-Khudair, and Dr.Hessah Al-Saaran for their valuable insights and feedback

Lastly, we would also like to extend our thanks to King Saud University for all the support and resources, which have been instrumental in the successful completion of this project.

CHAPTER 8

- REFERENCES -

8 References

- [1] "Riyadh Metro Transport," Riyadh Metro Transport. <http://riyadhmetro.com/> <https://www.slideshare.net/ihudhaif/dr-alwalid-alekrish-arriyadh-development-authority> (Accessed Sep. 06, 2022).
- [2] K. Frank, "Research the riyadh metro - knight frank," *THE RIYADH METRO*, 2018. <https://content.knightfrank.com/research/1546/documents/en/riyadh-metro-2018-5615.pdf>. (Accessed Sep. 21, 2022).
- [3] "How to Develop a Real-Time Public Transport App? - Matellio Inc." Software Development Company UK. <https://www.matellio.co.uk/blog/how-to-develop-a-real-time-public-transport-app/> (Accessed Sep. 06, 2022)
- [4] "What is Public Transportation: Modes and Benefits." Conserve Energy Future. https://www.conserve-energy-future.com/benefits_of_public_transportation.php (Accessed Sep. 06, 2022)
- [5] "Public transport system in the Gulf region, a case study of the city of Riyadh", Wit press elibrary, WIT Press. <https://www.witpress.com/elibrary>. (Accessed: Sep. 21, 2022).
- [6] S. Sangkhanan, "Smart Bus Management System Architecture Using Mesh App and Service Architecture," *130 Volume 15, Number 5, September 2020 Journal of Software*, 2020. <http://www.jsoftware.us/vol15/424-L153.pdf> (Accessed Sep. 21, 2022).
- [7] Elkosantini, Sabeur and Darmoul, Saber, *Intelligent Public Transportation Systems: A Review of Architectures and Enabling Technologies*, 2013.
- [8] H. MAKINO, "Intelligent Transport Systems (ITS) - japan Society of Civil Engineers," *JSCE*, Aug-2016. https://www.jsce-int.org/system/files/ITS_Introduction_Guide_2.pdf (Accessed Sep. 21, 2022).
- [9] A. Bates, "5 most popular browsers - Market share trends," *Insightportal*, May-2015. <https://www.insightportal.io/news/all-news/5-most-popular-browsers-market-share-trends> (Accessed Sep. 26, 2022).

- [10] “What is web application development? - Definition from WhatIs.com.” SearchCloudComputing. <https://www.techtarget.com/searchcloudcomputing/definition/web-application-development> (Accessed Sep. 19, 2022)
- [11] “Introduction to Mobile Application Development.” IBM. <https://www.ibm.com/cloud/learn/mobile-application-development-explained> (Accessed Sep. 20, 2022).
- [12] Juviler, J. (2022) *Google maps API: How to get started*, HubSpot Blog. <https://blog.hubspot.com/website/google-maps-api> (Accessed: April. 3, 2023).
- [13] *What is Firebase?*. Educative. (n.d.). <https://www.educative.io/answers/what-is-firebase> (Accessed Jan. 2, 2023).
- [14] Firebase: Firestore - javatpoint <https://www.javatpoint.com/firebase-firestore> (Accessed Sep. 20, 2022).
- [15] Neelam tyagi, *What is Dijkstra's algorithm? examples and applications of Dijkstra's algorithm* <https://www.analyticssteps.com/blogs/dijkstras-algorithm-shortest-path-algorithm> (Accessed Sep. 20, 2022).
- [16] Boost efficiency and support sustainability with route optimization. <https://www.salesforce.com/resources/guides/what-is-route-optimization/> (Accessed Sep. 20, 2022).
- [17] What is real-time tracking in logistics? Definition & Overview <https://locus.sh/resources/glossary/real-time-tracking/> (Accessed Sep. 20, 2022).
- [18] Alotaibi, Omar & Potoglou, Dimitris, *Potential Impacts of Introducing Public Transport and Travel Strategies in Riyadh City, Saudi Arabia*, 2016.
- [19] Anqi Wang, Linye Zhang, *A Study of the Assistant Application for Tourists Taking Metros*. International Scholarly and Scientific Research & Innovation, 2019.
- [20] Wei, Junjun & Long, Kejun & Gu, Jian & Ju, Qingling & Zhu, Piao, *Optimizing Bus Line Based on Metro-Bus Integration*, 2020.

- [21] J. Guo and L. Jia, “A new algorithm for finding the K shortest paths in a time-schedule network with constraints on arcs,” *Journal of Algorithms & Computational Technology*, vol. 11, no. 2, pp. 170–177, 2016. doi:10.1177/1748301816680470
- [22] *A new algorithm for finding the K shortest paths in a ... - sage journals*
https://www.researchgate.net/publication/338779886_A_Smart_Path_Recommendation_Method_for_Metro_Systems_With_Passenger_Preferences (Accessed Sep. 20, 2022).
- [23] Samer I. Mohamed, *IoT Bus Navigation System with Optimized Routing using Machine Learning. I.J. Information Technology and Computer Science*, 2021.
- [24] W. Fan and R. Machemehl, *using a Simulated Annealing Algorithm to Solve the Transit Route Network Design Problem, Journal of Transportation Engineering*, 2006
- [25] Riyadh bus. riyadh bus - riyadibus.sa (Accessed Sep. 20, 2022).
- [26] “TfL providing real-time crowdedness information through app.” Intelligent Transport. <https://www.intelligenttransport.com/transport-news/126299/tfl-go-update/> (Accessed Nov. 15, 2022).
- [27] “Transit (app).” Wikipedia. [https://en.wikipedia.org/wiki/Transit_\(app\)](https://en.wikipedia.org/wiki/Transit_(app)) (Accessed Nov. 15, 2022).
- [28] 5 key benefits of using Scrum for mobile app development, (2020)
<https://justcoded.com/blog/5-key-benefits-of-using-scrum-for-mobile-app-development/#:~:text=Scrum%20an%20effective%20Agile%20methodology,the%20startup%20and%20the%20team.> (Accessed Mar. 5, 2023).
- [29] Scrum - what is it, how it works, & how to start <https://www.atlassian.com/agile/scrum> (Accessed Dec. 18, 2022).
- [30] Insights on agile scrum methodology, (Jun 2022) <https://www.tridhya.com/insights-on-agile-scrum-methodology/> (Accessed Sep. 20, 2022).
- [31] 12 principles behind the Agile Manifesto: Agile Alliance
<https://www.agilealliance.org/agile101/12-principles-behind-the-agile-manifesto/> (Accessed Feb. 3, 2023).
- [32] Use of agile methodology for mobile applications - researchgate
https://www.researchgate.net/publication/310503566_Use_of_Agile_Methodology_for_Mobile_Applications (Accessed . 3, 2022).

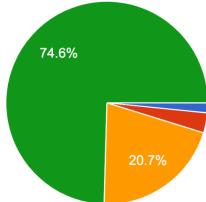
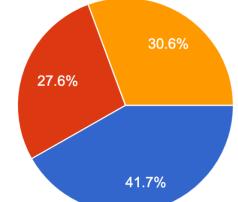
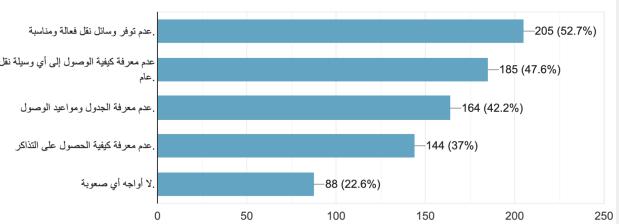
- [33] A. M. HAZIQ LIM, “Architecture of mobile web application for generating dynamic ... - core,” *core.ac.uk*, 2008. <https://files.core.ac.uk/pdf/13518/235631229.pdf> (Accessed May. 12, 2023).
- [34] N. N. Jamal, “Real-time Campus University Bus Tracking Mobile Application - Researchgate,” *researchgate*, Jul-2018.
https://www.researchgate.net/publication/328834009_Real-Time_Campus_University_Bus_Tracking_Mobile_Application
- [35] his G. plugin for F. is developed by Baseflow, “Geolocator: Flutter Package,” Dart packages, <https://pub.dev/packages/g>
- [36] “Place Autocomplete,” Google,
<https://developers.google.com/maps/documentation/places/web-service/autocomplete> (accessed May 14, 2023).
- [37] “Admin page,” Admin Page, <https://sekkah.netlify.app/>
- [38] “Develop and deploy websites and apps in record time,” Netlify,
<https://www.netlify.com/>.
- [39] Haversine formula https://en.wikipedia.org/wiki/Haversine_formula (Accessed Jan. 14, 2023).
- [40] Defining models: Flutterfire <https://firebase.flutter.dev/docs/firestore-odm/defining-models/> (Accessed Jan. 14, 2023).
- [41] Keval audiya, PayPal payment integration in flutter <https://protocoderspoint.com/paypal-payment-integration-in-flutter-app/> (Accessed Jan. 14, 2023).

CHAPTER 9

- APPENDIX A -

9 Appendix A

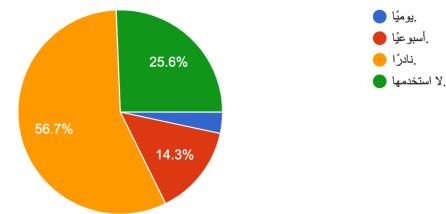
Questionnaire:

Question	Chart												
<p>How often do you use public transportation as a means for transport? (SAR trains, SAPTCO buses, and Taxis)</p> <ul style="list-style-type: none"> ● Daily. ● Weekly. ● Rarely. ● I don't Use it. 	<p>(ما معدل استخدامك لوسائل النقل العام الحالية؟ (قطار سار ، حافلات ساينتكو</p> <p>503 responses</p>  <table border="1"> <thead> <tr> <th>Category</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td> يومياً</td> <td>74.6%</td> </tr> <tr> <td> أسبوعياً</td> <td>20.7%</td> </tr> <tr> <td> نادراً</td> <td>2.3%</td> </tr> <tr> <td> لا استخدمها</td> <td>2.4%</td> </tr> </tbody> </table>	Category	Percentage	يومياً	74.6%	أسبوعياً	20.7%	نادراً	2.3%	لا استخدمها	2.4%		
Category	Percentage												
يومياً	74.6%												
أسبوعياً	20.7%												
نادراً	2.3%												
لا استخدمها	2.4%												
<p>Do you encounter any difficulties in using public transportation methods?</p> <ul style="list-style-type: none"> ● Yes. ● No. ● Maybe. 	<p>هل تواجه حالياً أي صعوبة في استخدام وسائل النقل العام؟</p> <p>503 responses</p>  <table border="1"> <thead> <tr> <th>Category</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>نعم</td> <td>41.7%</td> </tr> <tr> <td>لا</td> <td>30.6%</td> </tr> <tr> <td>ربما</td> <td>27.6%</td> </tr> </tbody> </table>	Category	Percentage	نعم	41.7%	لا	30.6%	ربما	27.6%				
Category	Percentage												
نعم	41.7%												
لا	30.6%												
ربما	27.6%												
<p>If yes, what type of difficulty do you usually encounter?</p> <ul style="list-style-type: none"> ● Not finding adequate public transportation methods. ● Not being aware of how to access any public transportation method. ● Not knowing the arrival times of any public transportation method. ● Not being able to find/buy tickets for transportation. ● I do not encounter any difficulty. 	<p>(إذا كانت الإجابة بـنعم ، فما هي الصعوبة التي تواجهها عادةً؟ (اختر كل ما هو صحيح)</p> <p>389 responses</p>  <table border="1"> <thead> <tr> <th>Difficulty Type</th> <th>Count (%)</th> </tr> </thead> <tbody> <tr> <td>عدم توفر وسائل نقل فعالة ومتاسبة</td> <td>205 (52.7%)</td> </tr> <tr> <td>عدم معرفة كيفية الوصول إلى أي وسيلة نقل</td> <td>185 (47.6%)</td> </tr> <tr> <td>عدم معرفة الجدول ومواقع الوصول</td> <td>164 (42.2%)</td> </tr> <tr> <td>عدم معرفة كيفية الحصول على التذاكر</td> <td>144 (37%)</td> </tr> <tr> <td>لا اواجه اي صعوبة</td> <td>88 (22.6%)</td> </tr> </tbody> </table>	Difficulty Type	Count (%)	عدم توفر وسائل نقل فعالة ومتاسبة	205 (52.7%)	عدم معرفة كيفية الوصول إلى أي وسيلة نقل	185 (47.6%)	عدم معرفة الجدول ومواقع الوصول	164 (42.2%)	عدم معرفة كيفية الحصول على التذاكر	144 (37%)	لا اواجه اي صعوبة	88 (22.6%)
Difficulty Type	Count (%)												
عدم توفر وسائل نقل فعالة ومتاسبة	205 (52.7%)												
عدم معرفة كيفية الوصول إلى أي وسيلة نقل	185 (47.6%)												
عدم معرفة الجدول ومواقع الوصول	164 (42.2%)												
عدم معرفة كيفية الحصول على التذاكر	144 (37%)												
لا اواجه اي صعوبة	88 (22.6%)												

How often do you use mobile transportation apps (Uber, Careem, jeeny, Bolt)?

- Daily.
- Weekly.
- Rarely.
- I don't Use it.

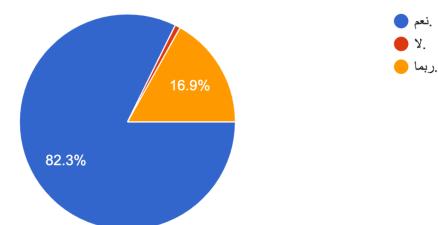
(ما معدل استخدامك لتطبيقات وسائل النقل المختلفة؟ (أوبر، كريم، جيني، بولت)
503 responses



Do you think your public transportation experience could be enhanced using mobile apps?

- Yes.
- No.
- Maybe.

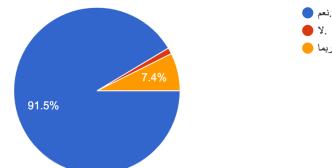
هل تعتقد أنه يمكن تحسين تجربتك لوسائل النقل العام باستخدام تطبيقات الجوال؟
503 responses



With the launching of Riyadh Metro, do you think having a mobile app used to visualize bus stations/ metro lines as helpful to you?

- Yes.
- No.
- Maybe.

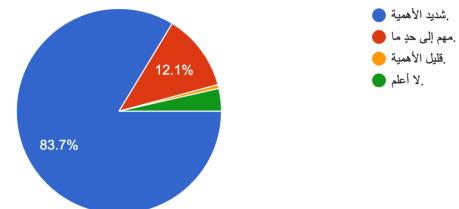
مع قرب إطلاق مشروع مترو الرياض ، هل وجود تطبيق يوفر خريطة مرنية محدثة بمحطات المترو/الحافلات سيكون ذات فعالية؟
503 responses



How convenient is it for you to access the bus and metro schedule directly on a mobile app?

- Very convenient.
- Convenient to an extent.
- Not that convenient.
- I don't know.

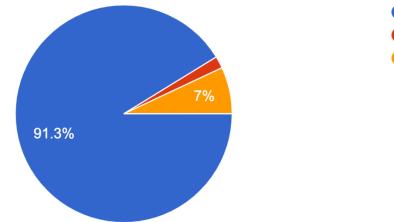
ما مدى أهمية الوصول إلى جدول المترو/الحافلات مباشرة على تطبيق الجوال؟
503 responses



Do you see that planning your journey ahead of time on mobile apps is useful?

- Yes.
- No.
- Maybe.

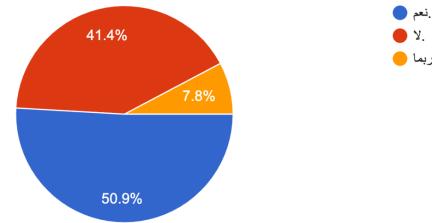
هل ترى أن تحديد وجهتك مسبقاً على تطبيقات الجوال مفيد؟
503 responses



Do you know where the nearest bus station to your home is located ?

- Yes.
- No.
- Maybe.

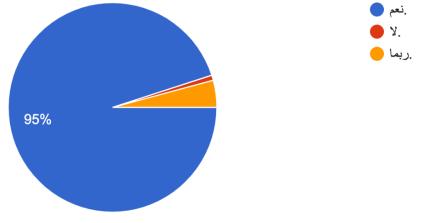
هل تعرف أين تقع أقرب محطة مترو/حافلات من منزلك؟
503 responses



Do you find the ability to know the nearest bus station and metro line to you along with the estimated duration it takes as beneficial?

- Yes.
- No.
- Maybe.

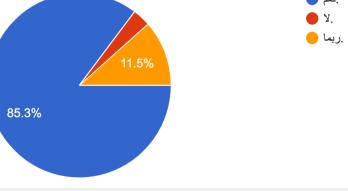
هل تعتقد أن إظهار أقرب محطة مترو/حافلات لك مع المدة الزمنية المتوقعة للوصول إليها أمر مفيد؟
503 responses



Do you need to track your real-time location during any transportation to know if you are on the correct path?

- Yes.
- No.
- Maybe.

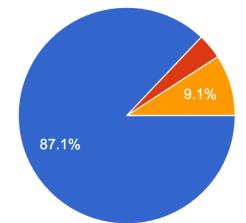
عند استخدامك لوسائل النقل العام هل تحتاج إلى خاصية تتبع الموقع الحالي لمعرفة ما إذا كنت على المسار الصحيح؟
503 responses



Do you prefer buying your metro/bus tickets online?

- Yes.
- No.
- Maybe.

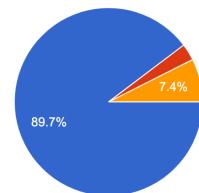
هل تفضل شراء تذاكر المترو/الحافلات عبر الانترنت؟
503 responses



If yes, do you think having a digital metro card and being able to charge it with balance will ease your payment process?

- Yes.
- No.
- Maybe.

إذا كانت الإجابة بنعم ، فهل تعتقد أن امتلاك بطاقة مترو رقمية والقدرة على شحنها سيسهل عملية الدفع الخاصة بك؟
485 responses



\

CHAPTER 10

- APPENDIX B -

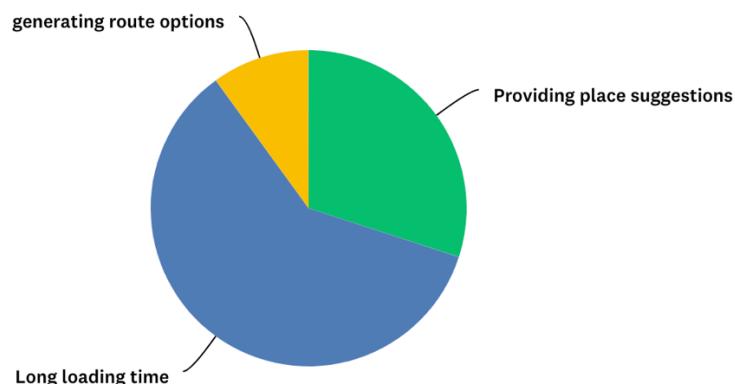
10 Appendix B

Passenger Questionnaire:

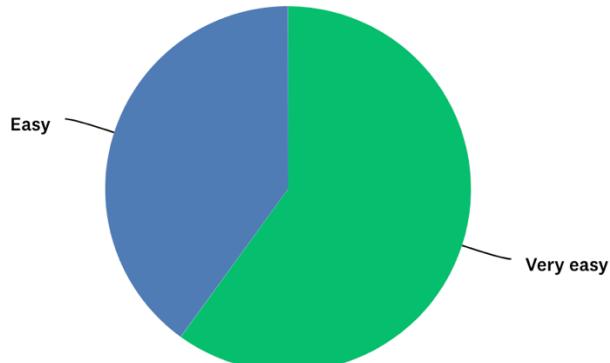
Table 13 - User Questionnaire Results



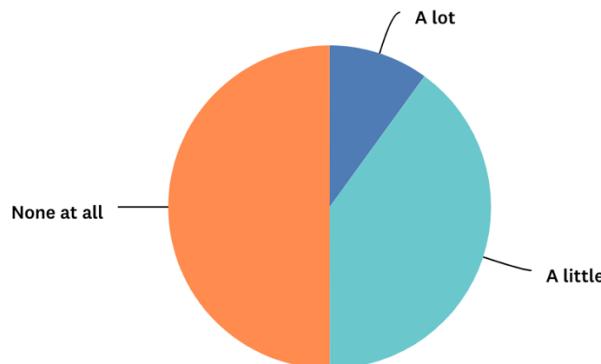
What aspects of the trip planning process should be improved?

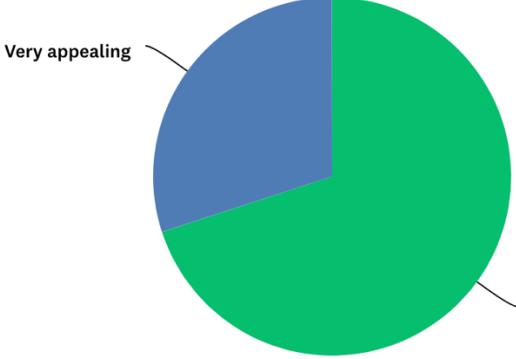
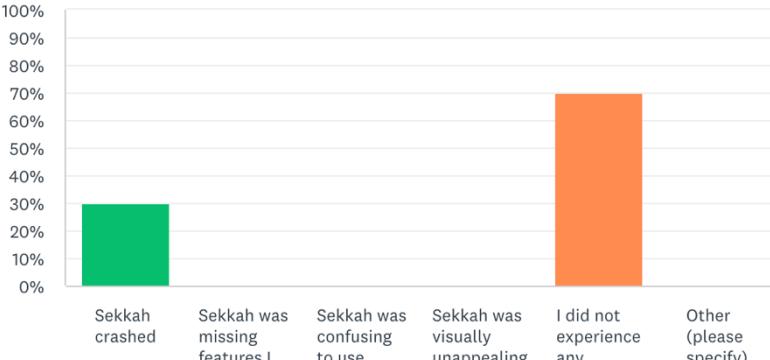


What are your thoughts regarding the process of purchasing a ticket?



To what extent was adding a digital card difficult?

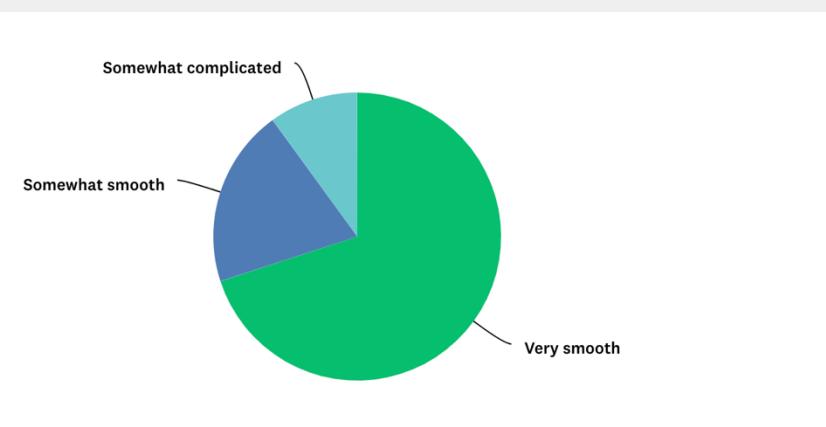
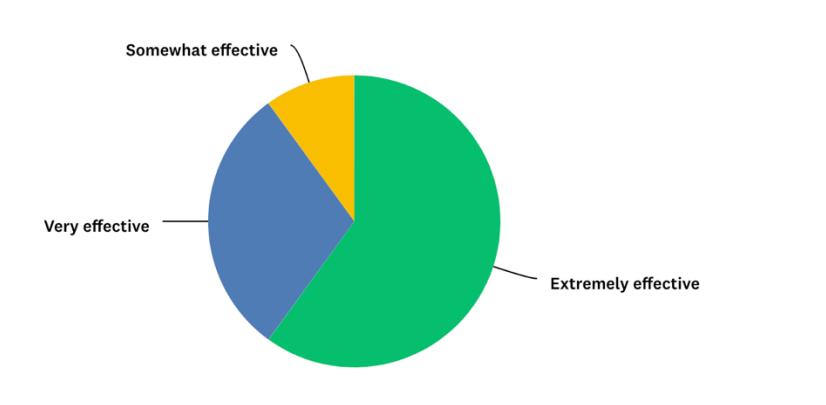
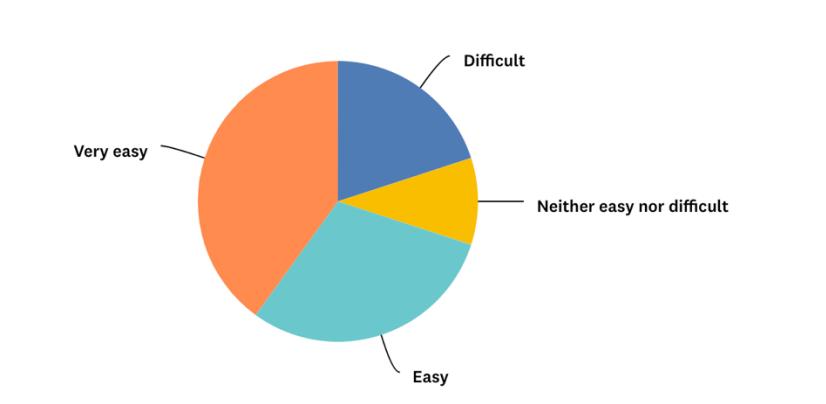


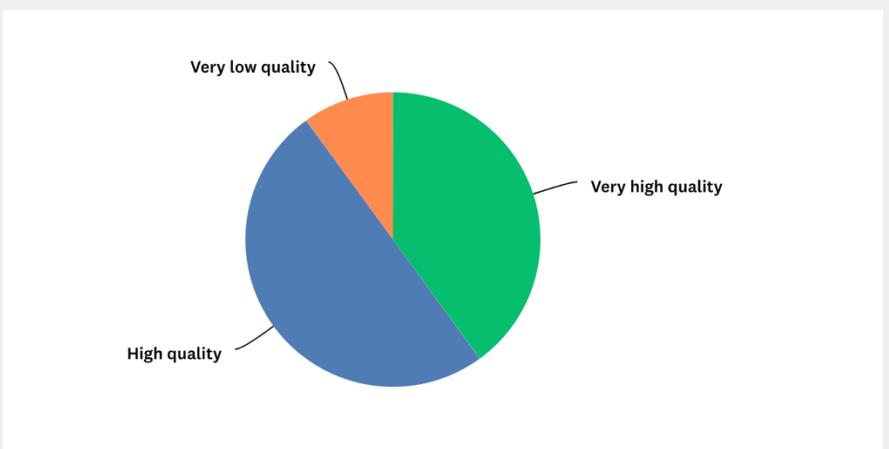
<p>How visually appealing is the app?</p>	 <table border="1"> <thead> <tr> <th>Appeal Level</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Extremely appealing</td> <td>~75%</td> </tr> <tr> <td>Very appealing</td> <td>~25%</td> </tr> </tbody> </table>	Appeal Level	Percentage	Extremely appealing	~75%	Very appealing	~25%
Appeal Level	Percentage						
Extremely appealing	~75%						
Very appealing	~25%						
<p>Which, if any, of the issues below have you encountered during your experience with Sekkah? (Select all that apply.)</p>	 <table border="1"> <thead> <tr> <th>Issue</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Sekkah crashed</td> <td>~30%</td> </tr> <tr> <td>I did not experience any problems</td> <td>~70%</td> </tr> </tbody> </table>	Issue	Percentage	Sekkah crashed	~30%	I did not experience any problems	~70%
Issue	Percentage						
Sekkah crashed	~30%						
I did not experience any problems	~70%						
<p>In your own words, is there anything that you hope Sekkah will offer in the future?</p>	<p>In your own words, is there anything that you hope Sekkah will offer in the future?</p> <p>Answered: 9 Skipped: 11</p> <p><input type="checkbox"/> Providing the app in arabic language 5/9/2023 08:14 PM View respondent's answers Add tags</p> <p><input type="checkbox"/> Adding more route options when planning 5/9/2023 12:04 PM View respondent's answers Add tags</p> <p><input type="checkbox"/> An emergency option that locates nearby hospitals 5/8/2023 02:45 AM View respondent's answers Add tags</p>						

	<input type="checkbox"/> No 5/7/2023 08:14 PM	View respondent's answers Add tags
	<input type="checkbox"/> I do not want to add anything Sekkah is very clear and effective 5/6/2023 10:04 PM	View respondent's answers Add tags
	<input type="checkbox"/> The color of the line appears in the route details 5/6/2023 06:45 AM	View respondent's answers Add tags
	<input type="checkbox"/> there is none ❤ 5/5/2023 06:13 PM	View respondent's answers Add tags
	<input type="checkbox"/> A favourite place option so I could quickly search for it 4/29/2023 12:24 AM	View respondent's answers Add tags
	<input type="checkbox"/> Route planning using only bus stations 4/29/2023 12:08 AM	View respondent's answers Add tags

Admin Questionnaire:

Table 14 - Admin Questionnaire Results

Questions	Answers										
I feel that navigating through Sekkah's admin dashboard was	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Very smooth</td> <td>~75%</td> </tr> <tr> <td>Somewhat smooth</td> <td>~15%</td> </tr> <tr> <td>Somewhat complicated</td> <td>~10%</td> </tr> </tbody> </table>	Response	Percentage	Very smooth	~75%	Somewhat smooth	~15%	Somewhat complicated	~10%		
Response	Percentage										
Very smooth	~75%										
Somewhat smooth	~15%										
Somewhat complicated	~10%										
I thought that the different functions provided by Sekkah's admin dashboard were	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Extremely effective</td> <td>~70%</td> </tr> <tr> <td>Very effective</td> <td>~25%</td> </tr> <tr> <td>Somewhat effective</td> <td>~5%</td> </tr> </tbody> </table>	Response	Percentage	Extremely effective	~70%	Very effective	~25%	Somewhat effective	~5%		
Response	Percentage										
Extremely effective	~70%										
Very effective	~25%										
Somewhat effective	~5%										
How easy or difficult was it to make an announcement or update in the admin dashboard?	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Very easy</td> <td>~45%</td> </tr> <tr> <td>Easy</td> <td>~30%</td> </tr> <tr> <td>Difficult</td> <td>~15%</td> </tr> <tr> <td>Neither easy nor difficult</td> <td>~10%</td> </tr> </tbody> </table>	Response	Percentage	Very easy	~45%	Easy	~30%	Difficult	~15%	Neither easy nor difficult	~10%
Response	Percentage										
Very easy	~45%										
Easy	~30%										
Difficult	~15%										
Neither easy nor difficult	~10%										
What is a missing feature that you think should be provided in Sekkah's admin dashboard?	<p>What is a missing feature that you think should be provided in Sekkah's admin dashboard?</p> <p>Answered:8 Skipped:12</p>										

<p>How would you rate the overall quality of Sekkah?</p>	<p><input type="checkbox"/> Showing a report for Sekkah app usage 5/9/2023 05:09 PM View respondent's answers Add tags▼</p> <p><input type="checkbox"/> Having a feature that receives user complaints about app bugs for maintenance 5/9/2023 08:07 AM View respondent's answers Add tags▼</p> <p><input type="checkbox"/> Providing a screen showing current stations status and details 5/8/2023 02:13 PM View respondent's answers Add tags▼</p> <p><input type="checkbox"/> I found it very good and smooth. 5/7/2023 08:09 PM View respondent's answers Add tags▼</p> <p><input type="checkbox"/> None 5/6/2023 06:07 AM View respondent's answers Add tags▼</p> <p><input type="checkbox"/> clarity of the delaying time 5/5/2023 06:13 PM View respondent's answers Add tags▼</p> <p><input type="checkbox"/> when announcing a delay, providing a slots the admin can choose from 5/5/2023 04:36 PM View respondent's answers Add tags▼</p> <p><input type="checkbox"/> The option to change the name or number for any station 4/29/2023 12:30 AM View respondent's answers Add tags▼</p>								
	 <table border="1"> <thead> <tr> <th>Quality Rating</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Very low quality</td> <td>~10%</td> </tr> <tr> <td>High quality</td> <td>~45%</td> </tr> <tr> <td>Very high quality</td> <td>~45%</td> </tr> </tbody> </table>	Quality Rating	Percentage	Very low quality	~10%	High quality	~45%	Very high quality	~45%
Quality Rating	Percentage								
Very low quality	~10%								
High quality	~45%								
Very high quality	~45%								