WEB AND MOBILE APP DEVELOPMENT FOR SMART VEHICLE ENTRANCE & EXIT

ONG LIP WEI

UNIVERSITI TUNKU ABDUL RAHMAN

WEB AND MOBILE APP DEVELOPMENT FOR SMART VEHICLE ENTRANCE & EXIT

ONG LIP WEI

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Software Engineering

> Lee Kong Chian Faculty of Engineering and Science Universiti Tunku Abdul Rahman

> > May 2023

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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ABSTRACT

The year 2023 is marked by a growing interest in the field of artificial intelligence (AI), which offers new ways to address problems and enhance efficiency. One area in need of a more efficient solution is the monitoring of car access records and management of car owners, which currently involves the manual processes by paper and pen. To address this, YOLOV4 model has been deployed to detect car license plates, and real-time web and mobile applications have been implemented to monitor car access logs and manage car owners. The applications offer filter and search functions, making the query process more manageable. Additionally, it includes role and permission functions to restrict access to certain features for security purposes.

The web application is built using ExpressJS and Docker and deployed on two AWS cloud servers. HTTPS encryption and AWS Application Load Balancer are used to ensure security and reliability of web service. Furthermore, Github Actions is used to promote continuous integration and continuous deployment (CI/CD) flow. The React framework is utilized for the web application while React Native framework is used for mobile application development, both employing the Ant Design UI library to maintain consistency across screens. The Firebase cloud database is used for storing license plate pictures and providing real-time updates, while Algolia AI search service is employed for advance search functions.

Finally, the project went through three testing processes, including unit testing, system usability testing and onsite testing. The project used unit testing to ensure that every function works properly, also 5 participants were invited to conduct the usability test of the system. The SUS score of the web application was 89%, and the SUS score of the mobile application was 89.5%, both of which were higher than the average SUS score of 75%, demonstrating good usability. Finally, the project also conducted onsite testing in a residential area to ensure that the system can run stably in the working environment.

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LIST OF SYMBOLS / ABBREVIATIONS

ALPR	Automatic License Plate Recognition
CI/CD	Continuous Integration and Continuous Deployment
AI	Artificial Intelligence
RFID	Radio Frequency Identification
YOLO	You Only Look Once
OCR	Optical Character Recognition
OpenCV	Open Source Computer Vision Library
AWS	Amazon Web Services
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
DNS	Domain Name System
EC2	Elastic Compute Cloud
ALB	Application Load Balancer
HTML	HyperText Markup Language
CSS	Cascading Style Sheets
JS	JavaScript
JSX	JavaScript XML
CRUD	Create, Read, Update and Delete
URL	Uniform Resource Locator
SUS	System Usability Scale
WYSIWYG	What You See Is What You Get

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

The traditional approach to monitor car access to the apartment is to use the Radio-frequency identification (RFID) parking system, which involves RFID readers, RFID tags, and self-check stations. The RFID tag could be lost by the resident, causing security risk, and a damaged or lost tag could cause environmental pollution. Furthermore, one RFID tag costs around RM2 to RM4 (A Look at RFID Parking Systems and Alternative Options (Expert Guide), 2022). In addition, most security guards use paper and pen to manually register visitors and new residents. In addition, the price of automatic license plate recognition system (ALPR) solutions for consumers currently on the market remains high, raising the bar to use.

Smart Vehicle Entrance and Exit System can solve the problem of high cost, high security risk, and high pollution. The main physical facilities are a camera placed at the entrance and a Linux computer to detect the license plates and record the vehicle entry information. The virtual facilities include cloud databases to store car plates and car owners' information, two Amazon Web Services (AWS) servers to host the web application, and an Android mobile application for the manager to access the data easily.

Three main technologies are used to recognize license plates and extract license plate text: You only look once (YOLO), Optical character recognition (OCR), and Open-Source Computer Vision Library (OpenCV). ALPR consists of four main processing stages, as shown in Figure 1.1.



Figure 1.1: Four Stages of ALPR (Negassi, Goitom Araya, Awawdeh and Faisal, 2018).

In this project, there are 4 steps to detect and upload the license plate information to the cloud database, each step is listed below:

- (i) Monitor the entrance.
- (ii) Recognize the license plate.
- (iii) Use OpenCV to perform image processing
- (iv) Upload car access information to Firebase

The initial task is to send video frames of the entrance to the computer for image processing. The second step is to use the YOLO model to recognize and crop the license plate image from the original video frame. The process of the YOLO algorithm is shown in Figure 1.2. The third step is to use OpenCV to perform a series of image processing on the license plate image, the steps include image grayscale, image noise reduction, thresholding, dilation, and lastly license plate segmentation. After the image processing, the image is sent to OCR for character recognition. The process is shown in Figure 1.3.

After extracting the car plate number, the car plate image, the car plate number, and the car owner information will be uploaded to Firebase's Firestore and Firebase's Storage. The interface of Firebase's storage with car plate information is shown in Figure 1.4. Subsequently, user can view the car access log through the web and mobile applications.



Figure 1.2: YOLO's Object Detection Method (Agrawal, 2017).



Figure 1.3: Image Processing Step (Tham and Tan, 2021).

5 Firebase		FYP1 +	0				Go to docx 🛔 🧒
 Project Overview 	•	Stor	age				Ø
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11 Authentication Firestore Database			Protect you	r Storage resources	from abuse, such as	billing fraud or phishing	Configure App Check X
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Figure 1.4: Interface of Google Firebase with Car Plate Information (TAN, 2021).

1.2 Problem Statements

1.2.1 Security Risk

The transferable nature of RFID makes it easy to use, but it comes with a high security risk when RFID tags are robbed or stolen and can be used by criminals to gain access to apartments. Users may also abuse the system by sharing the RFID tags with family members.

1.2.2 High Cost

The price of the ALPR solution currently available on the market is too high. This section discusses the prices of the products of two companies that currently provide ALPR services. The first one is Zento company, Zento provides a one-stop ALPR solution for license plates in Malaysia and it is priced at 2,000 USD. The product includes a computer and camera to detect license plates and a backend management software to monitor vehicle entry and exit records (*Malaysia license plate recognition parking system with LPR camera ANPR camera* 2023). Figure 1.5 and Figure 1.6 show the ALPR product provided by Zento.

The second is Saskatchewan Government Insurance (SGI) which uses ALPR technology to detect stolen cars or unregistered license plates. SGI invested 5.1million in this technology and the price of each ALPR device is around 25,000 USD (Sgi, 2023).

It can be found that the price of products using ALPR technology available on the market is too high, which raises the bar to use.

Home \forall All Industries \forall Automotive accessories. Electomics & Tools	Vehicle Equipme	ent / Parking Equipme	nt			
	Malaysia License Plate Recognition Parking system with LPR Camera ANPR Camera					
<u>~</u>	📳 Test report av	vailable Chemical C	omposit	ion Analysis View	More	
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	Parking lot	10000				
	Lead time:(i)	Quantity (sets)	1 - 100	> 100		
		Lead time (days)	7	To be negotiated		
Q View larger image	Customization:	Customized logo (Min. order 5 sets) Customized packaging (Min. order 5 sets) More ~				

Figure 1.5: Zento's Pricing for ALPR Service (Malaysia license plate recognition parking system with LPR camera ANPR camera, 2023).


Figure 1.6: User Interface of Zento's Car Management Software (Malaysia license plate recognition parking system with LPR camera ANPR camera, 2023)

1.2.3 Unable To Monitor Vehicle Access

The current conventional apartment parking system in Malaysia is not able to record vehicle access information well. When a visitor wants to enter a compound, the traditional approach is to rely on the security guard to register the visitor via handwriting. Not only it is time taxing, and the entry permit document is hard to manage and store. Furthermore, RFID tags might be shared by family or friends, making it difficult to record accurate vehicle access information.

1.3 Aim and Objectives

The main aim of this project is to provide the manager with a system that automatically records vehicle access and allows him to view car access information easily. It can also facilitate the procedure of registering car owners. Specifically, the objectives of this project are:

- To develop real-time web and mobile ALPR applications to monitor car access log and manage car owners.
- (ii) To utilize AWS cloud services to deploy web application.

- (iii) To promote the continuous integration and continuous deployment (CI/CD) flow by using Github Actions to automatically deploy web application on AWS servers
- (iv) To deploy the ALPR system at the security guard station.
- (v) To use System Usability Scale to evaluate web and mobile applications.

1.4 Proposed Solution

The proposed solution aims to solve the encountered problems stated above, the camera will first capture the incoming video frame and send it to the Linux computer. It is responsible for car plate identification and character recognition. The processed result will then be uploaded to the Firebase cloud database and synced to the Algolia database. Firebase and Algolia act as the databases for the web and mobile applications. The web and mobile applications provide functions for the manager such as viewing the logbook of car access records and managing the car owners, and the manager can create a new account with limited access to the staff. This project uses AWS service to serve web application and uses Github Actions to promote CI/CD flow. The system overview is presented in Figure 1.7.



Figure 1.7: System Overview

The project uses a KAYETON camera and a Dell OpiPlex 3060 computer to complete the license plate recognition. The camera has a specification of 2.0 megapixels and supports 1080p video capturing and night detection. The computer's CPU, memory and storage configurations are i5-8500t, 16gb ram and 128gb m2.sata SSD. Figure 1.8 shows the price of the camera and Figure 1.9 shows the price of similar computer configurations. In this project, the cost of the computer and video is around RM1,500.



Figure 1.8: Price of Project's Camera.



Dell OptiPlex 3060 Micro - Intel Core i5 8th Gen - i5-8400T - Six Core 3.3Ghz - 256GB SSD - 8GB RAM -Windows 10 Pro

Figure 1.9: Price of Project's Computer

1.5 Proposed Approach

The project employs DevOps as the development approach, DevOps emphasizes the automation and integration of various processes and tools that support the delivery and deployment of software products. DevOps can benefit the project in many ways, such as:

(i) Faster and more frequent releases.

DevOps enables the project to adopt a continuous delivery approach, where software changes are delivered to customers in small and frequent batches. This reduces the risk of errors, bugs, and conflicts, and allows the project to respond to customer feedback and market demands more quickly and effectively.

(ii) Higher quality and reliability.

DevOps ensures that the software products are tested and verified at every stage of the development cycle, from coding to deployment. This reduces the chances of defects and failures and improves the performance and functionality of the software products. DevOps also enables the project to monitor and troubleshoot issues in real-time, and to implement corrective actions faster.

(iii) Reduced costs and waste.

DevOps helps the project optimize the use of resources and infrastructure and eliminate unnecessary or redundant tasks. DevOps also reduces the overhead and complexity of managing multiple environments, tools, and platforms. Lastly, DevOps enables the project to achieve more with less and to deliver more value to customers.

DevOps is a beneficial practice that can help the project to achieve its goals faster, better, and cheaper. DevOps can enhance the efficiency, quality, agility, and innovation of the software development and delivery process. The overview of software development methodology is displayed in Figure 1.10



Figure 1.10: DevOps Methodology (DevOps implementation roadmap and advantages, 2023).

1.6 Project Scope

The project's scope is to deploy the ALPR system at one residential area (here after referred to as "Site A") and to develop web and mobile applications of it for the manager. The former student of Universiti Tunku Abdul Rahman (UTAR) has developed the ALPR system. This project mainly focuses on integrating the existing ALPR system with the web and mobile applications created by React and React-native framework.

1.6.1 Targeted User

There is only one target user for this project, the manager of Site A. The manager is responsible for managing the car owners and monitoring the car access log. However, the system has role and permission functions, and the manager can make some pages of the web and mobile applications available to security guards or residence community members according to their needs.

1.6.2 Modules Covered

The list below states the modules covered in web and mobile applications:

(i) Car Access Log Module

After the user logs in to the application, the system will monitor the car access. If there is a vehicle passing by, it will present the new car access record to the user interface in real time. User can also search the car access logbook according to date, license plate number and car owner information.

(ii) Category Module

Users can create new categories to distinguish car owners. For example, user can label the car owner as visitor or resident.

(iii) Person Module

Users can register and manage car owners in the person module.

(iv) User Module

Manager can create an account in the user module for staff to use and assign a role for it, and when the information of the account is changed or the account is deleted, the staff that using this account will be forced to log out from the application automatically.

(v) Role Module

Manager can create a new role in the role module, manager can also bind the application pages to the role, so the account with this role can view the targeted system's pages only.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, automation is becoming increasingly prevalent, prompting a shift from traditional parking systems to automated parking systems. In the traditional parking system, individuals are required to register and obtain RFID tags to verify their access to the compound or go through a handwriting procedure to register them. But these RFID tags are at risk of being reused by criminals, and as the number of vehicles increases, it becomes inconvenient to manage them. There is an urgent need for automated system applications that can automatically identify vehicles and generate tracking logs. These problems can be solved by deploying an ALPR system.

The ALPR system is an application that automatically detects license plates. First, it detects the area within the visual range through a camera, and when a vehicle enters the bounding box, it automatically performs license plate recognition and reads the license plate number. This information is then uploaded to the cloud for the ALPR system-based applications. All these procedures are automated, and no human intervention is required (Petiwala, Shukla, Mishra and Saini, 2021).

2.2 Car Plate Detection and Character Recognition Techniques

2.2.1 Edge Detection for Car Plate Position Detection

Firasanti, Ramadhani, Bakri, and Zaki Hamidi (2021) proposed a comparison between Canny Edge and Otsu Thresholding applied to license plate localization, the authors first preprocessed the image, which includes image graying, and blurring using bilateral filters. Figure 2.1 shows the result of the grayscale process and applying a filter bilateral.



Figure 2.1: Image Preprocessing (adopted from Firasanti, Ramadhani, Bakri and Zaki Hamidi, 2021).

The image graying reduces the complexity of the image and thus saves computational resources while the blurring of the image reduces the noise. After that, the authors used the Canny Edge and Otsu Thresholding algorithms to find the edges of license plates and then intercept the license plates in the edges. 30 samples were used for testing and the accuracy of Canny Edge was 100%, while Otsu thresholding was only 70%. Figure 2.2 shows the result of images after applying canny edge method and Otsu thresholding method. Figure 2.3 shows the comparison between canny edge and Otsu thresholding.



Figure 2.2: Result with Canny Edge and Otsu Thresholding (adopted from Firasanti, Ramadhani, Bakri and Zaki Hamidi, 2021).



Figure 2.3: Comparasion Between Canny Edge and Otsu Thresholding (adopted from Firasanti, Ramadhani, Bakri and Zaki Hamidi, 2021).

In another study where a similar approach was used for license plate segmentation, Samantaray and others (2021) Canny algorithm for segmenting license plates. The authors' image preprocessing only generates grayscale maps, and then the Canny Edge algorithm is used directly to recognize license plates. The authors used 15 samples for testing and the accuracy was 93.34%. Table 2.1 shows the accuracy result.

Name of the Operation	Total No. of Samples	No. of successful Samples	Failure Samples	Success Ratio
Localization of License Plate	15	14	1	93.34%
Separation of the Characters	14	12	3	85.71%
Character Recognition	12	11	1	91.67%

Table 2.1: Accuracy Analysis Table (adopted from Samantaray et al., 2021).

2.2.2 Neural network for car plate position detection

Currently, the mainstream feature extractors are MobileNet, GoogleNet, VGG16, ZFNet, ResNet, DenseNet, and so on and object detection frameworks are Faster R-CNN, YOLO, SSD.

Alborzi, Mehraban, Khoramdel and Ardekany (2019) used MobileNet as its feature extractor with SSD framework for license plate recognition, and the authors used 500 images for testing, and the accuracy was 82.60%. In addition, the authors also compared Mobilenet with GoogleNet and VGG16 and the result is shown in Table 2.2. The authors highlight that MobileNet achieves good accuracy with less computational resources than the abovementioned models. Also the authors show the comparison between MobileNet based SSD and R- CNN, Fast YOLO, YOLO and find that the accuracy and speed of the SSD exceeds Faster R-CNN and YOLOV1. It is very suitable to use in embedded computers. The Table 2.3 shows the results.

Model	ImageNet	Million	Million
	Accuracy	Mult_Adds	Parameters
1.0 MobileNet-224	70.6%	569	4.2
GoogleNet	69.8%	1550	6.8
VGG16	71.5%	15300	138
0.5 MobileNet-160	60.2%	76	1.32
Squeezenet	57.5%	1700	1.25
AlexNet	57.2%	720	60

Table 2.2: Comparison Between Popular Models (adopted from Alborzi,
Mehraban, Khoramdel and Ardekany, 2019).

Table 2.3: Results on Pascal VOC2007 Test for Popular Networks and SSD (adopted from Alborzi, Mehraban, Khoramdel and Ardekany, 2019).

Method	mAP	FPS	batch size	# Boxes	Input resolution
Faster R-CNN(VGG16)	73.2	7	1	~6000	$\sim 1000 \times 600$
Fast YOLO	52.7	155	1	98	448×448
YOLO(VGG16)	66.4	21	1	98	448×448
SSD300	74.3	46	1	8732	300×300
SSD512	76.8	19	1	24564	512×512
SSD300	74.3	59	8	8732	300×300
SSD512	76.8	22	8	24564	512×512

In addition to using SSD for license plate detection, Lee and the others (2018) used YOLO9000 as the framework, which is based on YOLOV2 improvement, and its biggest feature is its ability to detect 9000 categories in real time. The training model uses 2500 images, and the accuracy of YOLO9000 is 93.20% while that of Faster RCNN is 93.90%. besides the accuracy of YOLO9000 is similar to Faster RCNN, the detection speed is several times faster. The Table 2.4 shows the comparison between faster R-CNN and Yolo9000.

Table 2.4:License Plate and Vehicle Detection Recall Performance (adopted
from Lee et al., 2018).

Method	Total Recall	Small	Small + Inclined	Medium	Medium + Inclined	Large	FPS
Faster R-CNN[13]	93.90%	90.76%	88.95%	99.31%	94.85%	99.56%	11
YOLO9000	93.20%	90.35%	87.67%	98.61%	93.68%	99.50%	57

2.2.3 Use of Texture and Color Features for Car Plate Position Detection

Nooruddin, Sharna, and Ahsan (2020) used the texture and color features of license plates for license plate segmentation as further processing of the edge detection algorithm to further filter the image based on the license plate color or texture. Sun, Li, Xu, and Wang (2018) found that after detecting the edges using the sobel operator alone, dilation of the image to fill the license plate cavity would cause sticking between the words of the license plate. By restricting the red of the image RGB values to 0-50, 155-255 in to remove the unnecessary pixels other than license plates. The image before and after applying the red channel filter is shown in Figures 2.4 and 2.5. The authors also compared the accuracy of the traditional method and the new method for license plate location and proved that this new method is helpful for license plate location. The table of results is shown in Table 2.5.



Figure 2.4: Result of Dilation (adopted from Sun, Li, Xu and Wang, 2008).

Figure 2.5: The Output of Red Channel Filter (adopted from Sun, Li, Xu and Wang, 2008).

Table 2.5: Comparative Result of Locating License Plate (adopted from Sun,Li, Xu and Wang, 2008)

	Successful cases				
Different images	Apply color	Without apply			
	filter	color filter			
100 blue LPs	98 (98%)	92 (92%)			
40 yellow LPs	40 (100%)	13 (32.5%)			
20 white LPs	18 (90%)	3 (15%)			
20 black LPs	20 (100%)	19 (95%)			
20 disturbed LPs	11 (55%)	8 (40%)			
Total 200 LPs	187 (93.5%)	135 (67.5%)			

Nooruddin, Sharna and Ahsan (2020) take a different approach by extracting histogram features for each dimension of RGB for the image. Pooling is used to reduce the dimensionality of the data, with minPool highlighting the darker areas of the window and maxPool highlighting the brighter areas of the window. The process is shown in Figure 2.6. After the features are extracted, each feature is merged, and random forest machine learning is used for training and application. The machine learning model can frame the possible locations of license plates, and finally the composite result is merged to form the final image output. Figure 2.7 shows the process of detection and localization.



Figure 2.6: The Input Image and Extracted Features (adopted from Nooruddin, Sharna and Ahsan, 2020).



Figure 2.7: The Detection and Localization Process (adopted from Nooruddin, Sharna and Ahsan, 2020).

Performance is measured in different color spaces including RGB, LAB and YCbCr. The performance measure of detection and localization is shown in Table 2.6. In RGB color space, it achieves the highest precision.

Color Space	Performance Metrics	IoU = 30%	IoU = 50%
	Accuracy	89.9	80.1
RGB	Precision	98.0	97.9
	Recall	91.5	81.6
	F1 Score	94.6	88.6
	Accuracy	87.8	76.2
1.10	Precision	96.5	95.6
LAD	Recall	90.3	78.2
	F1 Score	93.2	85.7
	Accuracy	89.3	76.5
VOLO-	Precision	95.7	94.9
TCDCF	Recall	92.7	79.3
	F1 Score	94.2	86.3

Table 2.6: Performance Measures (%) of Detection and Localization (adopted from Nooruddin, Sharna and Ahsan, 2020).

2.2.4 Character Recognition

Suraj, Sridhar, Jijesh and Shivashankar (2018) used OCR template matching method for character recognition. First, the character dataset is prepared by cropping each character from the license plate and resizing it to a uniform size. The dataset is shown in Figure 2.8.

After that they performed character recognition on the license plate, first detecting each character by contour, and then make each character framed by a rectangle with the help of the contour. Each character image is sent into the character dataset for template matching to obtain the maximum relevant value and output the corresponding text. The flow of character extraction is shown in Figure 2.9.



Figure 2.8: Dataset of Alphabets and Numbers (adopted from Suraj, Sridhar, Jijesh and Shivashankar, 2018).



Figure 2.9: Extraction, Cropping and Resizing of First Character (adopted from Suraj, Sridhar, Jijesh and Shivashankar, 2018).

In addition to manually writing the OCR template matching method, OCR also provides a tesseract library. Tesseract is an open-source toolkit, the recognition process is listed as below:

(i) Uploading images.

Convert the image into binary data and send it to the tesseract program.

(ii) Page analysis

Determine whether the text is in horizontal or vertical orientation.

(iii) Character block analysis

Search for small character blocks first and detect the area around the block, if there is a connected area, it will redefine the contour of the connected domain, if there is no other character field nearby, it will be ignored as noise.

(iv) Character recognition

Each character in the character block is recognized and its character data is given to the classifier for training to improve the accuracy.

(v) Correction and output

The ambiguous spaces are corrected, and the text is exported.

Firasanti, Ramadhani, Bakri and Zaki Hamidi (2021) used OCR tesseract for character recognition. Figure 2.10 shows the cropped input image and Figure 2.11 shows the recognition result. From the 30 samples, the average license plate character recognition rate is 72%. Figure 2.12 shows the license plate samples and their recognition results.



Figure 2.10: Cropped License Plate Image (adopted from Firasanti, Ramadhani, Bakri and Zaki Hamidi, 2021).

top left (94, 152) button right (479, 265) Detected Number is: D -1669 VCJ

Figure 2.11: License Plate Character Identification (adopted from Firasanti, Ramadhani, Bakri and Zaki Hamidi, 2021).

No.	License Plate Image	Real License Number	Extraction Result	Lumin ance (Lux)	Accuration
1	R PARE SAL	B 3016 TSU	B 3016 TSU	9668	100%
2		AD4 18U	AD4 18U	10915	100%
3	9 2270 FRI 66.537	B 3270 FNL	3270 FAL	9175	85%
4	B 3763 KYH 05-20	B 3763 KVH	t 3763 KVH	12998	90%

Figure 2.12: Samples of License Plates With High Accuracy (adopted from Firasanti, Ramadhani, Bakri and Zaki Hamidi, 2021)

The first two methods used OCR for character recognition, next Rusakov (2020) used ResNet neural network for character position recognition. Firstly, different license plate datasets were used for training and to eliminate the bounding rectangle distortion and symbol detection errors, so on the dataset, negative samples were eliminated. The flow of character position detection is shown in the following Figure 2.13.



Figure 2.13: The Scheme of the Symbol Detection Module (adopted from Rusakov, 2020).

Character recognition consists of three ResNet neural networks, the first module trains characters, the second module trains numbers, and the third module trains regions, and the three modules are computed and merged into one line of license plate numbers. The following Figure 2.14 shows the symbol recognition module and Table 2.7 shows the accuracy of the car plate detection module, symbol detection module, and symbol recognition module. They achieved high accuracy with each of them at over 80%.



Figure 2.14: The Scheme of the Symbol Recognition Module (adopted from Rusakov, 2020).

	Module quality parameters				
Modules	Accuracy	Detection (recognition) time			
Plate detection	81,2 % [0.5:0.95] mAP	$50 \text{ ms} \pm 10 \text{ ms}$			
Symbol detection	95,2 % [0.5:0.95] mAP	$20 \text{ ms} \pm 5 \text{ ms}$			
Symbol recognition	Mean accuracy 99,32 %	$10 \text{ ms} \pm 3 \text{ ms}$			

Table 2.7: Validation of Modules of the Automatic License Plate RecognitionSystem (adopted from Rusakov, 2020).

2.2.5 Summary

In summary, with several license plate location algorithms: Edge detection, neural network, and method based on color and texture. Here we compare the advantages and disadvantages of them. Table 2.8 compare the different license plate location algorithms. As for character recognition, we have OCR template matching, an OCR Tesseract toolkit, and neural network methods. The advantages and disadvantages are shown in Table 2.9.

License plate location detection algorithms	Advantages	Disadvantages
Edge detection method	Perform well in high contrast with clear edge of license plate	Easily get influenced by the environment.
Neural network	Goodlearningabilityandadaptability,modelperformancebasedon training images.	Complex networks can slow down recognition

Table 2.8: Comparison of License Plate Location Detection Algorithms

				The	computat	tional
	Perform	well	in	overhead	l is larger	than
Color and texture feature	high-	con	trast	Edge d	letection	and
	environme	ent		sensitive	to license	plate
				color.		

Character recognition Disadvantages Advantages algorithms The Recognition speed is characters skew OCR template matching fast and quite will affect the accurate recognition accuracy. Recognitio speed is The computation is fast and quite OCR tesseract toolkit slower than the OCR accurate, easy to template matching deploy. Good learning ability and Complex networks can Neural Network adaptability, high slow down recognition fault tolerance

 Table 2.9:
 Comparison of Character Recognition Algorithms

2.3 Applications of ALPR System

Shkurti, Aliu, and Kabashi (2021) propose a parking management system with automatic license plate recognition. The associated hardware is a camera for capturing vehicle photos and a Raspberry Pi as the computer for processing and recognizing the images. The related software is OpenCV for image processing, and OpenALPR library for license plate and character recognition, developed using Flask. When a vehicle enters a designated area, the camera will automatically scan the license plate and record its license plate number and the time it entered the system. After that, the system will automatically calculate the driver's parking fee and register it in the database. The detailed flow chart is shown in Figure 2.15.



Figure 2.15: System stages for plate recognition (adopted from Shkurti, Aliu and Kabashi, 2021)

The web application was developed using the Flask web framework and provides the main functions of logging in, displaying vehicles entering the parking lot, displaying vehicles exiting the parking lot, registering users, providing payment services, and displaying access reports to the parking lot. Figures 2.16-2.21 shows the information of the web page.



Figure 2.16: The Login Page (Shkurti, Aliu and Kabashi, 2021).



Figure 2.17: Main Page Showing Entering Car (Shkurti, Aliu and Kabashi, 2021).



Figure 2.18: Main Page Showing Exiting Car (Shkurti, Aliu and Kabashi, 2021).

			Customers		
+ Add	new rec	ord			
Drag a col	umn hea	der and drop it here to group by that o	olumn		
_		Name T	Surname T	Brand T	Plate
1	0	Filan	Fisteku	Golf	04-487-GB
×	1	Lamir	Shkurti	Audi	04-456-FI
×	1	Test	User	Bmw	04-444-BA
	1	20 * items per page			1 - 3 of 3 items

Figure 2.19: Main Page Showing Exiting Car (Shkurti, Aliu and Kabashi, 2021).

	-			Payment			
ag a c	column)	header and drop it here to group	by that column				
		Customer T	Membership T	Value T	Start date 🛛 🔻	End date 🛛 🔻	Date
×××	1	Test User Lamir Shkurti Filan Fisteku	Weekly Yearly Monthly	10.00 300.00 40.00	08/02/2021 08/02/2021 08/02/2021	15/02/2021 08/02/2022 09/03/2021	08/02/2021 20:20:28 08/02/2021 20:13:34 08/02/2021 19:55:55
				Total: 350.00			
	î	(+)(+) 20 + items p	er page				1 - 3 of 3 items

Figure 2.20: Customer Page (Shkurti, Aliu and Kabashi, 2021).

				Parking				
arag a column l	neader and drop it he	re to g	roup by that column					
image	Customer	٣	Plate T	Entry time T	Exit time T	Elapsed time	Value T	StatT
04 ° 688 · FR	Anonymous		04-688-FR		08/02/2021 19:42:09	1h 37m	2.40	Exit
04 = 460 EB	Anonymous		04-460-EB		08/02/2021 19:15:44	1h 17m	2.30	Exit
04 - 487 · GB	Lamir Shkurti		04-456-FI	08/02/2021 19:05:33				Entry
04 * 602 · GN	Anonymous		04-612-GN		08/02/2021 19:01:32	Oh 55m	1.50	Exit
04 · 487 · GB	Filan Fisteku		04-487-GS		08/02/2021 18:44:44	1h 31m	Monthly	Exit
04 ° 460 EB	Anonymous		04-460-EB	08/02/2021 18:07:37				Entry
04 299 HO	Anonymous		04-299-H0	08/02/2021 18:07:21				Entry
04 299 HO	Anonymous		04299H0	08/02/2021 18:07:06				Entry
04 · 602 · GN	Anonymous		04-602-GN	08/02/2021 18:06:25				Entry
04*602-0	Anonymous		04602GN	08/02/2021 18:05:49				Entry
04 ° 688 · FR	Anonymous		04-688-FR	08/02/2021 18:05:04				Entry
04 - 487 · GB	Filan Fisteku		04-487-GB	08/02/2021 17:13:50				Entry
04 - 487 · GB	Filan Fisteku		04-487-GB		08/02/2021 16:47:44	0h 7m	Monthly	Exit
04 · 487 · GB	Filan Fisteku		04-487-68	08/02/2021 16:40:12				Entry
04:456-FI	Lamir Shkurti		04-456-FI		08/02/2021 16:35:19	4h 9m	Yearly	Exit

Figure 2.21: Logbook of Car Access Records (Shkurti, Aliu and Kabashi, 2021).

This system recognizes the license plate with an accuracy rate of 85%, but the system also has defects, that is, the camera can only be placed in a fixed position and is sensitive to light. In the case of insufficient light, it cannot identify the license plate. Tian and others (2014) proposed another framework for smart parking, which includes a vehicle detection module, an access control module, and a system management software module. Figure 2.22 shows a sketch of the system hardware design.



Figure 2.22: System Hardware Sketch (Tian et al., 2014).

The camera will automatically capture a photo of the car, which will then be sent over to the computer for license plate recognition and verification. Once the verification is passed, the barrier will be opened to allow the vehicle to enter the parking lot. In addition, the barrier can also be operated by the controller or software application. At the same time when that vehicle leaves, the camera will take a picture of that vehicle and compare it with the picture at the entrance. The overview of the system management software is shown in Figure 2.23.



Figure 2.23: Flowchart of Data Processing (Tian et al., 2014).

The vehicle images are first collected by the video capture card, then go through image pre-processing and license plate detection module, and finally the recognized license plates are stored in the system database. The author used QT framework developed in C++ to build the GUI application on a Dell Vostro Desktops computer with Intel(R) Core(TM) E7200, 4GB memory. Figures 2.24 and 2.25 are the screenshots of application.



The system can be more than 95% accurate but can be affected by light and environment, causing license plate recognition errors. The system processes a car in an average time between 30ms and 100ms, which is very fast. Table 2.10 shows the system accuracy test results.

Number of records	System	False	Missing
each day	Accuracy	positive rate	recognition rate
394	91.88%	7.11%	1.01%
301	93.69%	5.65%	0.66%
421	93.82%	5.94%	0.24%
337	95.85%	3.72%	0.43%
363	95.04%	4.41%	0.55%
368	95.92%	3.81%	0.27%
256	96.09%	3.52%	0.39%
253	96.44%	3.16%	0.40%
283	96.47%	2.83%	0.7%
251	94.82%	4.78%	0.40%

Table 2.10: Result of the Proposed System

Negassi, Goitom Araya, Awawdeh, and Faisal (2018) proposed the architecture of the intelligent license plate recognition system, Figure 2.26 shows the process of the proposed system.



Figure 2.26: Smart Car Plat Recognition System (Negassi, Goitom Araya, Awawdeh and Faisal, 2018)

The license plate number is detected by using Raspberry Pi, camera, and communication module, and subsequently the main method of processing the license plate using OCR template matching for character recognition, deciding whether to give the current vehicle a pass or not based on the predefined license plate information in the database, and the extracted license plate text is compared with the prior data set and to save the log information to send to the team. The graphical user interface is developed using Matlab and Figure 2.27 shows the graphical interface of the ALPR system.



Figure 2.27: Recognition Interface (Negassi, Goitom Araya, Awawdeh and Faisal, 2018)

Wong (2019) reported that there is an automatic license plate recognition system in the Sunway pyramid where drivers can pre-register their license plate number through an app and drive directly into the parking lot once they are registered. JeiShun says that the current accuracy rate for Malaysian license plates is 95%. Dason (2022) reported that Pay and Go Sdn Bdn has integrated Sarawak Pay in its application Pay and Go and launched LPR smart parking system in CityOne Mega Mall, Plaza Merdeka, The Spring and other supermarkets in Kuching, Malaysia. When a vehicle enters the parking lot, the camera automatically identifies the license plate and uploads it to the cloud space. Users only need to access the GO App and enter their license plate number before exiting the parking lot to pay with the e-wallet. Figure 2.28 shows the initial page of the application to select parking and Figure 2.29 shows the payment page when exiting the parking lot.

\leftarrow	Parking	■ Pay&Go	
	/	< Pa	ayment
Q Search	/		
CityOne I	Parking		S DAY
Plaza Me	rdeka	G	LOBAL
P Sarawak	Plaza		
P Wisma B	мк	PE Land Sdn Bhd (Th Address Lot 304, 3rd Elr. The Sr	e Spring Kuching)
P MetroCity	y Square	Persiaran Spring, 9330	0 Kuching
P The Sprin	ng	Amount	
¥		RM2.00	
P The Sum	mer Shopping Mall		
		C	onfirm
Figure 2.28	8 The Home Page to Select	Figure 2.29:	Payment Page.
	Parking	-	

2.4 Previous work on car plate recognition

The project's web and mobile applications need to integrate with Tan Wei Kun's ALPR system, so this section reviews his system to study his project implementation.

2.4.1 Introduction

ALPR automatic license plate recognition system is based on the development of artificial intelligence and computer vision technology. The use of image pre- processing and the application of convolutional neural networks in ALPR systems can improve recognition accuracy. Complex neural networks that require powerful computing power are obviously not suitable for application in IoT environment, so the author proposed a lightweight IoT-based ALPR solution. The author obtained a dataset of 400 images Malaysian car plate images and used it to train the YOLOv4-tiny model, migration learning is also performed to achieve better result. After that, the author used OpenVino to optimize the trained YOLOv4-tiny model.

The author then tuned the region of interest (ROI) so that license plates are located within the ROI, circumventing the possibility of collecting license plates from tilted angles. After the license plates are collected, character recognition is then performed. First, the author used OpenCv to segment each character and provide it to the Tesseract engine for character recognition. Subsequently, the best license plate number is selected. The author chose Up Squared and Ubuntu as the computer and operating system to run the ALPR code. The result of the experiment achieved 99.02% accuracy on the license plate recognition and 78.23% accuracy on the character recognition (TAN, 2021).

2.4.2 Methodology

The first step was the preparation of the dataset. The author used the vehicle dataset from the Plates Portal website, which has 400 images for training and 100 images for testing. The author also used LabelImg software to label the parts with license plates and output them in YOLO format. Figure 2.30 shows the labeling process.



Figure 2.30: Labelling Vehicle Number Plate Using LabelImg Software (TAN 2021).

Although YOLOV4 is fast in detection, it has corresponding requirements on the computer's computing speed, requiring a minimum of 8GB ram and a graphics card for training and detection. So, in contrast, the yolov4-tiny model is a lightweight network that is more suitable to use in embedded devices. Although the accuracy is only two-thirds of yoloV4, the accuracy can be improved by implementing migration learning. Figure 2.31 shows the comparison of speed and accuracy between YOLOv4 and YOLOv4tiny.



Figure 2.31: Comparison of Speed and Accuracy Between YOLOv4 and YOLOv4-Tiny (Bochkovskiy, 2020).

The author used geo-fencing and centroid tracking methods to frame the areas where vehicles may appear in the video. When a license plate enters this detection box, a license plate recognition operation is triggered, the geofencing method is shown in Figure 2.32, and an updated ID is given for the latest stationary video frame, this updated ID is used to ensure that the latest video frame will eventually be fed into the neural network for recognition.



Figure 2.32: Vehicle Entering Geofencing Area Represented by the Blue Box (TAN, 2021).

The video frame, after being processed by YOLOV4-tiny, the license plate has already been located, and the result is shown in Figure 2.33. The image is then preprocessed using OpenCV, which includes cropping, grayscaling, blurring, thresholding, dilation, and finding contours, and the image pre-processing process is shown in Figure 2.34. The purpose of image preprocessing is to allow better character recognition.



Figure 2.33: Bounding Box Figure 2.34: Image Processing Around the License Plate Processes (TAN, 2021). (TAN 2021).

After image preprocessing, character recognition can be performed directly using Tesseract OCR. Since there are long and short license plates in Malaysia, as shown in Figure 2.35, the result of Tesseract OCR for short license plates may be inaccurate, such as "1W9H0Y2" when it should be recognized as "WHY1902". The solution is to sort the character position of the result, move all the letters to the leftmost side, so that the left side must be all letters, and the right side will be all numbers.



Figure 2.35: Type of LPs in Malaysia- Long-Width LP and Short- Width LP (TAN, 2021).

Some license plates such as Figure 2.36 contain special characters '-', which are not needed, so when using OpenCV for contour search, setting a certain ratio of length to width to the contour will act as a filter to filter out this unwanted character. Tesseract OCR sometimes misidentifies the characters of license plates, and a common pair of very similar alphanumerics is shown in

Table 2.11. Through an empirical study, the first three characters of the license plate are letters, and the rest are numbers. By fixing the first three characters of license plate numbers as alphabets, the accuracy of recognition is greatly increased.



Figure 2.36: LP With Special Character "-" (TAN, 2021).

High Similarity in Alphanumeric Shape		
1	Ι	
7	Т	
9	g	

Table 2.11: Common Pairs of Alphanumeric That Are Similar (TAN, 2021).

Tesseract OCR will recognize the license plate six times and get six results. The length of the string result is also a concern, the length of output license plate text is not always 7 and the use of a pool of license plate numbers can solve this problem. For example, if the input license plate array is like Figure 2.37, this algorithm will iterate through each string license plate, set the weight of 3 for the string length of 7 and 1 for the rest, and finally only the license plate number with the maximum weight will be output. Finally, the final license plate will be uploaded to Firebase.

array eg = ['HJ9', 'HJ9109', 'HJ109', 'HJ10911', 'HJ109112']

Figure 2.37: Input LP Array Used in Pooling Algorithm (TAN, 2021).

2.4.3 Conclusion

The author used 400 images for training, where the accuracy of license plate location recognition was 99.02% and the accuracy of character recognition using 100 vehicle images was 78.23%. When using a series of methods such

as the geofencing technique, centroid tracking technique, and pooling algorithm, the final character recognition accuracy of 100% can be achieved. However, this system has the limitation, that it faces difficulty in recognizing low-resolution images and very skewed images, and Tesseract OCR does not recognize some characters that look alike very well.

2.5 Software Development Methodology

2.5.1 Waterfall Methodology

The waterfall methodology is a software development life cycle (SDLC) model that consists of a linear and sequential flow of phases. Each phase depends on the completion and verification of the previous one, and there is no going back once a phase is done. The phases of the waterfall methodology are Requirements, Analysis, Design, Implementation, Testing and Maintenance.



Figure 2.38: (A complete guide to the waterfall methodology, 2023).

The waterfall methodology is one of the oldest and most widely used SDLC models in software engineering. Table 2.12 shows the advantages and disadvantages of the waterfall methodology.

Advantages	Disadvantages
• It is simple and easy to	• It is rigid and inflexible to
understand and follow.	changing requirements or
• It provides a clear structure	customer feedback.
and milestones for project	• It is slow and costly due to its
management.	sequential nature and lack of
• It ensures high quality and	iteration.
reliability of the software	• It delays testing and feedback
product by emphasizing	until late in the development
thorough documentation and	process, which can lead to
testing.	more errors and rework.

Table 2.12: Advantages and Disadvantages of Waterfall Methodology.

Therefore, the waterfall methodology may not be suitable for every software development project. It may work well for projects that have fixed and well-defined requirements that are unlikely to change, ample resources and time available for development and stable and predictable technology environment.

2.5.2 Prototyping Methodology

Prototyping methodology is a software development methodology that focuses on the use of working models that are constantly refined based on feedback from the end user. Prototyping is most used to develop systems with significant end-user interaction and complex user interfaces. The phases of the prototyping methodology are Requirements, Design, Build Prototype, User Evaluation, Refining Prototype and Implement and Maintain.


Figure 2.39: Prototyping Methodology (Martin, 2022).

The main purpose of prototyping is to allow users of the software to evaluate developers' proposals for the design of the eventual product by actually trying them out, rather than having to interpret and evaluate the design based on descriptions. Prototyping also provides an understanding of the software's functions and potential threats or issues. Prototyping can help to confirm that the software meets the user's needs and expectations, and that the project estimates and deadlines are realistic.

The prototyping methodology combines the iterative system with a trial-and-error approach. In this methodology, the developers build a prototype, test it and refine it until it reaches an acceptable level of functionality to demonstrate to the client. Table 2.13 shows the advantages and disadvantages of the prototyping methodology.

Advantages	Disadvantages			
• It enhances user involvement	• It can be time-consuming and			
and satisfaction, as they can	costly, as multiple iterations			
see and influence the	and revisions may be required			
development process and	to achieve a satisfactory			
outcome.	prototype.			
• It reduces risks and	• It can create unrealistic			
uncertainties, as potential	expectations or confusion			
problems and issues can be	among users, as they may			
identified and resolved early in	assume that the prototype is a			
the project.	finished product or that all			
• It improves communication	features will be implemented			

Table 2.13: Advantages and Disadvantages of Prototyping Methodology.

• It facilitates innovation and creativity, as different ideas and options can be explored and experimented with.

as shown.

 It can compromise quality or security, as some aspects of the software may be overlooked or neglected in favor of speed or appearance.

Prototyping methodology is a flexible and user-centered software development methodology that can help to create better software products that meet user needs and expectations. However, it requires careful planning, management, communication, evaluation, documentation throughout the project lifecycle.

2.5.3 DevOps Methodology

DevOps is a methodology that aims to improve the collaboration and communication between software development and IT operations teams. DevOps also emphasizes the automation and integration of various processes and tools that support the software development life cycle, such as planning, coding, testing, deploying, monitoring and feedback.

The main goal of DevOps is to deliver software products faster and more reliably, while reducing the risks and costs associated with traditional software development methods. DevOps enables continuous delivery, which means that software updates can be released frequently and incrementally, rather than in large and infrequent batches. DevOps also fosters a culture of learning and experimentation, where teams can test new ideas and learn from failures quickly and safely.



Figure 2.40: DevOps Methodology (DevOps implementation roadmap and advantages, 2023).

Advantages	Disadvantages			
Improved customer	• Cultural and organizational			
satisfaction and loyalty, as	challenges, as teams may face			
software products can meet	resistance to change and need			
their needs and expectations	to adopt new mindsets and			
better and faster.	skills.			
• Increased productivity and	• Technical and operational			
efficiency, as teams can work	complexities, as teams may			
together more seamlessly and	need to deal with multiple			
leverage automation and	tools and platforms and ensure			
standardization to reduce	their compatibility and			
errors and waste.	interoperability.			
• Enhanced innovation and	• Resource and investment			
competitiveness, as teams can	constraints, as teams may need			
experiment with new features	to allocate more time and			
and technologies more easily	money to implement DevOps			

Table 2.14: Advantages and Disadvantages of DevOps Methodology.

	and respond to changing	practices and tools.
	market demands more agilely.	
•	Reduced costs and risks, as	
	teams can detect and fix issues	
	earlier in the development	
	process and avoid downtime	
	and security breaches.	

DevOps is not a one-size-fits-all solution, but rather a flexible and adaptable approach that can vary depending on the context and goals of the project. Therefore, teams should assess their current situation and needs, identify their challenges and opportunities, define their vision and objectives, and plan their strategy and roadmap for adopting DevOps. By doing so, teams can reap the benefits of DevOps while minimizing its drawbacks.

2.5.4 Conclusion

Overall, each methodology has its own strengths and weaknesses, and the choice of methodology depends on the specific requirements of the project. Waterfall may be suitable for simple projects with well-defined requirements, prototyping may be useful for projects with changing requirements, and DevOps may be best for projects with a focus on speed and agility.

2.6 System Usability Testing

System Usability Scale (SUS) is a reliable tool to test the usability of a system, and it is also "quick and dirty". The questionnaire consists of 10 questions, each with five choices, from strongly agree to strongly disagree. We can use it to evaluate a wide variety of products including but not limited to hardware, software, mobile devices, websites, and applications. (Affairs, 2022). SUS has several benefits, including the following:

- i. SUS is suitable for small scale and the results are reliable.
- ii. SUS can distinguish between usable and unavailable systems.
- iii. SUS is easy to manage for participants.

The following points need to be kept in mind when using SUS:

- i. Its scoring mechanism is a bit complicated.SUS can distinguish between usable and unavailable systems.
- ii. The scores are from 0-100, but cannot be treated as percentage scores, otherwise they will be interpreted incorrectly.
- iii. It requires normalization of scores to interpret results.
- iv. SUS is designed to test ease of use, not diagnostic.

Figure 2.41 shows the questions of System Usability Scale, the answering scale are from strongly disagree to strongly agree.

System Usability Scale Questionnaire	Strongly Disagree		S	trongly Agree
1. I think that I would like to use this product frequently.	1 2	3	4	5
2. I found the product unnecessarily complex.	1 2	3	4	5
3. I thought the product was easy to use.	1 2	3	4	5
4. I think that I would need the support of a technical person to be able to use this product.	1 2	3	4	5
5. I found the various functions in the product were well integrated.	1 2	3	4	5
6. I thought there was too much inconsistency in this product.	1 2	3	4	5
7. I imagine that most people would learn to use this product very quickly.	1 2	3	4	5
8. I found the product very awkward to use.	1 2	3	4	5
9. I felt very confident using the product.	1 2	3	4	5
10. I needed to learn a lot of things before I could get going with this product.	1 2	3	4	5

Figure 2.41: System Usability Scale (What Every Client Should Know about SUS Scores, 2022).

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter begins by discussing each phase of the DevOps approach. In addition, the project's Work Breakdown Structure (WBS) and Gantt Chart are created so that the project can be successfully completed within schedule. The chapter concludes with explanation of the development tools used.

3.2 Software Development Methodology

This project selects DevOps as the software development methodology as it emphasizes automation and continuous delivery. DevOps aims to deliver highquality software faster and more reliably than traditional methods. Figure 1.6 illustrates the DevOps model phase.



Figure 3.1: DevOps Methodology (DevOps implementation roadmap and advantages, 2023).

3.2.1 Plan

This project collects requirements through questionnaires and observations and uses this information as input to formulate the functional and non-functional requirements. Afterward, use case modeling can be performed according to the functional requirements. The relevant development tools are also confirmed at this stage. For example, this project uses React, ExpressJS, and Docker to build the web application, while using React Native to build the mobile application. In addition, Firebase is selected as the project's database and Algolia search is employed as the search service of the applications. Related AWS and GitHub services such as Github Actions, AWS Route53, AWS Application Load Balancer, AWS Certificate Manager, Elastic Compute Cloud (EC2), AWS Cloudwatch, and AWS Budgets must also be identified to design and implement the CI/CD process of the project. Finally, WBS and Gantt chart are created to ensure that the project can be delivered within the stipulated time.

3.2.2 Code

The code development phase of this project can be divided into 3 main parts. The first part includes using React framework, Ant Design Library, ExpressJS and Docker to develop and run web applications locally. In the second stage, the project started to use AWS services and Github Actions to design the entire CI/CD process, so that developer can redeploy the entire web project on AWS EC2 servers only by using the command git push. The last part is to use React Native framework and Ant Design UI library to develop mobile application. The main modules of web and mobile applications such as car access log module, category module, person module, user module and role module are also developed at this stage.

3.2.3 Build

This web project uses ExpressJS as the backend server to serve the React web application. The main build tools are npm, Docker and Github Actions. React project will generate static resources such as HyperText Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript (JS) after using the npm run build command, and these static resources can be hosted on the ExpressJS backend server. The ExpressJS server can then be built into a docker image and run it inside a docker container by utilizing Dockerfile and Docker Compose tool. To promote CI/CD flow, this project uses Github Actions services to automate the building process, so as long as the developer has a new code update in the GitHub repository, the GitHub workflow will be automatically executed and build the web project into Docker image. In addition to web applications, the project also uses tools such as npm and gradlew to build the React Native project into an apk file.

3.2.4 Test

The testing phase includes unit testing, system usability testing and on-site testing to ensure that the system meets the needs of user and runs smoothly in the working environment.

3.2.5 Release and Deploy

In the release and deploy development phase, Github Actions and GitHub runner is utilized to automatically build and deploy web projects. The specific operation includes registering the two AWS EC2 servers as the GitHub Runners, so that they can execute the workflow of the Github Actions. Next, define a CI/CD pipeline by Github Actions, such as destroying all docker images and docker containers on the host machine, and then use the new project code to rebuild the docker image and run it in the docker container of EC2. The user can access to the web application via inserting the project's domain name in the web browser. Furthermore, after using npm and gradlew to build the React Native mobile application into an apk file, this apk file is then uploaded to the Release section of the GitHub repository for user to download and use.

3.2.6 Operate

AWS's CloudWatch service is employed to monitor the EC2 servers and the infrastructure it runs on to ensure that everything is working as expected. If the status check of the EC2 server fails, CloudWatch will try to reboot the failing server.

3.2.7 Monitor

In the monitoring stage, data and feedback from the user is valuable to continuously improve the applications. Furthermore, this project implements AWS Budgets service to monitor the project's cost, When the budget of the project exceeds a certain threshold, an email will be sent to the developer and the EC2 service will be suspended.

3.3 Project Planning and Scheduling

3.3.1 Work Breakdown Structure (WBS)

- 0.0 Web and Mobile Applications Development for Smart Vehicle Entrance and Exit
- 1.0 Project Initialization
 - 1.1. Preliminary Planning
 - 1.1.1. Understanding Background of the Project
 - 1.1.2. Identify problem of Current Conventional Solution
 - 1.1.3. Determine Project Objectives
 - 1.1.4. Define Project Proposed Solution
 - 1.1.5. Confirm Project Approach
 - 1.1.6. Define Project Scope
 - 1.1.6.1. Identify Targeted User
 - 1.1.6.2. Define Modules Covered
 - 1.2. Literature Review
 - 1.2.1. Review on ALPR Technology
 - 1.2.2. Review Existing ALPR systems
 - 1.2.3. Review Tan Wei Kun's work
 - 1.2.4. Review Software Development Methodology
 - 1.2.5. Study System Usability Testing

1.3. Methodology and Work Plan

- 1.3.1. Explain Software Development Methodology
- 1.3.2. Develop Work Breakdown Structure
- 1.3.3. Develop Gantt Chart
- 1.3.4. Identify Software Development Tools

- 1.4. Requirement Identification
 - 1.4.1. Requirement Gathering
 - 1.4.1.1. Conduct Observation
 - 1.4.1.2. Conduct Questionnaire
 - 1.4.2. Requirement Specification
 - 1.4.2.1. List Functional Requirements
 - 1.4.2.2. List Non-Functional Requirements
 - 1.4.3. UML Modeling
 - 1.4.3.1. Create use case Diagram
 - 1.4.3.2. Create use case Description
- 2.0 System Development
 - 2.1. System Design
 - 2.1.1. Database design
 - 2.1.2. Web Application Architecture design
 - 2.1.3. Cloud Architecture Design
 - 2.1.4. Mobile Application Architecture Design

2.2. System Development

- 2.2.1. Web Application Development
 - 2.2.1.1. Car Access Log Module
 - 2.2.1.2. Category Module
 - 2.2.1.3. Person Module
 - 2.2.1.4. User Module
 - 2.2.1.5. Role Module
- 2.2.2. Mobile Application Development
 - 2.2.2.1. Car Access Log Module
 - 2.2.2.2. Category Module
 - 2.2.2.3. Person Module
 - 2.2.2.4. User Module
 - 2.2.2.5. Role Module
- 2.2.3. Create CI/CD Flow
- 2.2.4. Utilize AWS Service to Host Web Application
- 3.0 System Testing
 - 3.1. Conduct Unit Testing

- 3.2. Conduct System Usability Testing
- 3.3. Conduct On-site Testing
- 4.0 Project Closure
 - 4.1. System Deployment
 - 4.2. System Monitoring
 - 4.3. Finalize Report

3.3.2 Gantt Chart

		Name \checkmark	Start \checkmark	Finish 🗸	Duration \smallsetminus
1	0	> 1.0 Project Initializaiton	6/13/2022	9/16/2022	70 days
32	0	> 2.0 System Development	1/30/2023	4/3/2023	46 days
53	0	> 3.0 System Testing	4/4/2023	4/7/2023	4 days
57	0	> 4.0 Project Closure	4/10/2023	4/27/2023	14 days

Figure 3.2: Overview of Project Schedule.

		Name 🗸	Start \checkmark	Finish \checkmark	Duration \vee
1	0	➤ 1.0 Project Initialization	6/13/2022	9/16/2022	70 days
2	0	✓ 1.1. Preliminary planning	6/13/2022	6/30/2022	14 days
3	0	1.1.1. Understanding background o	6/13/2022	6/14/2022	2 days
4	0	1.1.2. Identify problem of current c	6/15/2022	6/17/2022	3 days
5	0	1.1.3. Determine project objectives	6/17/2022	6/20/2022	2 days
6	0	1.1.4. Define project proposed solu	6/20/2022	6/21/2022	2 days
7	0	1.1.5. Confirm project approach	6/22/2022	6/24/2022	3 days
8	0	✓ 1.1.6. Define project scope	6/27/2022	6/30/2022	4 days
9	0	1.1.6.1. Identify targeted user	6/27/2022	6/28/2022	2 days
10	0	1.1.6.2. Define modules covered	6/29/2022	6/30/2022	2 days
11	0	✓ 1.2. Literature review	7/1/2022	7/29/2022	21 days
12	0	1.2.1. Review on ALPR technology	7/1/2022	7/8/2022	6 days
13	0	1.2.2. Review existing ALPR systems	7/11/2022	7/14/2022	4 days
14	0	1.2.3. Review Tan Wei Kun's work	7/15/2022	7/21/2022	5 days
15	0	1.2.4. Review software developmen	7/22/2022	7/27/2022	4 days
16	0	1.2.5. Study system usability testing	7/28/2022	7/29/2022	2 days
17	0	✓ 1.3. Methodology and work plan	8/1/2022	8/26/2022	20 days
18	0	1.3.1. Explain software developmen	8/1/2022	8/3/2022	3 days
19	0	1.3.2. Develop work breakdown str	8/4/2022	8/9/2022	4 days
20	0	1.3.3. Develop Gantt Chart	8/10/2022	8/12/2022	3 days
21	0	1.3.4. Identify software developme	8/15/2022	8/26/2022	10 days
22	0	✓ 1.4. Requirement identification	8/29/2022	9/16/2022	15 days
23	0	✓ 1.4.1. Requirement gathering	8/29/2022	9/2/2022	5 days
24	0	1.4.1.1. Conduct observation	8/29/2022	8/30/2022	2 days
25	0	1.4.1.2. Conduct questionnaire	8/31/2022	9/2/2022	3 days
26	0	✓ 1.4.2. Requirement specification	9/5/2022	9/9/2022	5 days
27	0	1.4.2.1. List functional requireme	9/5/2022	9/7/2022	3 days
28	0	1.4.2.2. List non-functional requi	9/8/2022	9/9/2022	2 days
29	0	✓ 1.4.3. UML modeling	9/12/2022	9/16/2022	5 days
30	0	1.4.3.1. Create use case diagram	9/12/2022	9/13/2022	2 days
31	0	1.4.3.2. Create use case descripti	9/14/2022	9/16/2022	3 days

Figure 3.3: Project Initialization Schedule.

		Name \checkmark	Start ∨	Finish \checkmark	Duration \smallsetminus
1	0	> 1.0 Project Initializaiton	6/13/2022	9/16/2022	70 days
32	0	➤ 2.0 System Development ① :	1/30/2023	4/3/2023	46 days
33	0	✓ 2.1. System Design	1/30/2023	2/8/2023	8 days
34	0	2.1.1. Database Design	1/30/2023	2/1/2023	3 days
35	0	2.1.2. Web Application Architecture	2/1/2023	2/2/2023	2 days
36	0	2.1.3. Cloud Architecture Design	2/3/2023	2/6/2023	2 days
37	0	2.1.4. Mobile Application Architect	2/7/2023	2/8/2023	2 days
38	0	✓ 2.2. System Development	2/8/2023	4/3/2023	39 days
39	0	✓ 2.2.1. Web Application Develop	2/8/2023	2/23/2023	12 days
40	0	2.2.1.1. Car Access Log Module	2/8/2023	2/10/2023	3 days
41	0	2.2.1.2. Category Module	2/10/2023	2/13/2023	2 days
42	0	2.2.1.3. Person Module	2/14/2023	2/16/2023	3 days
43	0	2.2.1.4. User Module	2/17/2023	2/20/2023	2 days
44	0	2.2.1.5. Role Module	2/21/2023	2/23/2023	3 days
45	0	✓ 2.2.2. Mobile Application Develo	2/24/2023	3/7/2023	8 days
46	0	2.2.2.1. Car Access Log Module	2/24/2023	2/27/2023	2 days
47	0	2.2.2.2. Category Module	2/27/2023	2/28/2023	2 days
48	0	2.2.2.3. Person Module	3/1/2023	3/2/2023	2 days
49	0	2.2.2.4. User Module	3/3/2023	3/6/2023	2 days
50	0	2.2.2.5. Role Module	3/6/2023	3/7/2023	2 days
51	0	2.2.3. Create CI/CD Flow	3/8/2023	3/13/2023	4 days
52	0	2.2.4. Utilize AWS Service to Host	3/13/2023	4/3/2023	16 days

Figure 3.4: System Development Schedule

		Name \vee	Start \smallsetminus	Finish 🗸	Duration \vee
1	0	> 1.0 Project Initializaiton	6/13/2022	9/16/2022	70 days
32	0	> 2.0 System Development	1/30/2023	4/3/2023	46 days
53	0	➤ 3.0 System Testing	4/4/2023	4/7/2023	4 days
54	0	3.1. Conduct Unit Testing	4/4/2023	4/5/2023	2 days
55	0	3.2. Conduct System Usability Testing	4/6/2023	4/7/2023	2 days
56	0	3.3. Conduct On-site Testing	4/7/2023	4/7/2023	1 day
57	0	> 4.0 Project Closure	4/10/2023	4/27/2023	14 days

Figure 3.5: System Testing Schedule.

	Name 🗸	Start \checkmark	Finish 🗸	Duration \checkmark
1 ()	> 1.0 Project Initializaiton	6/13/2022	9/16/2022	70 days
32 🔾	> 2.0 System Development	1/30/2023	4/3/2023	46 days
53 ()	> 3.0 System Testing	4/4/2023	4/7/2023	4 days
57 🔿	✓4.0 Project Closure ① ⋮	4/10/2023	4/27/2023	14 days
58 🔾	4.1. System Deployment	4/10/2023	4/13/2023	4 days
59 🔾	4.2. System Monitoring	4/14/2023	4/20/2023	5 days
60 🔾	4.3. Finalize Report	4/14/2023	4/27/2023	10 days

Figure 3.6: Project Closure Schedule.

May 1	5 May 22	May 29	Jun 5	Jun 12	Jun 19	Jun 26	Jul 3	Jul 10	Jul 17	Jul 24	Jul 31	Aug 7	Aug 14	Aug 21	Aug 28	Sep 4	Sep 11	Sep 18
1 ()	1.0 Project Initialization		0 :															
2 ()	✓ 1.1. Preliminary planning						H in the second s											
з О	1.1.1. Understanding bac	ckground of the proje	ct															
4 ()	1.1.2. Identify problem o	f current conventiona	al solution															
5 ()	1.1.3. Determine project	objectives																
6 ()	1.1.4. Define project prop	posed solution																
7 ()	1.1.5. Confirm project ap	proach																
8 ()	✓ 1.1.6. Define project so	оре					-											
9 ()	1.1.6.1. Identify target	ed user																
10 ()	1.1.6.2. Define module	es covered																
0 11	✓ 1.2. Literature review							_	-									
12 ()	1.2.1. Review on ALPR te	chnology																
13 ()	1.2.2. Review existing ALI	PR systems																
14 ()	1.2.3. Review Tan Wei Ku	in's work																
15 ()	1.2.4. Review software de	evelopment methodo	logy															
16 🔾	1.2.5. Study system usab	ility testing																
17 ()	~ 1.3. Methodology and wo	ork plan											-	-				
18 ()	1.3.1. Explain software de	evelopment methodo	logy															
19 🔿	1.3.2. Develop work brea	akdown structure																
20 ()	1.3.3. Develop Gantt Cha	art]					
21 ()	1.3.4. Identify software d	levelopment tools																
22 ()	✓ 1.4. Requirement identifie	cation																
23 ()	✓ 1.4.1. Requirement gat	hering																
24 ()	1.4.1.1. Conduct obser	rvation																
25 ()	1.4.1.2. Conduct quest	tionnaire																
26 🔿	1.4.2. Requirement spe	cification															1	
27 ()	1.4.2.1. List functional	requirements																
28 ()	1.4.2.2. List non-functi	ional requirements																
29 🔿	✓ 1.4.3. UML modeling																	
30 ()	1.4.3.1. Create use cas	e diagram																
31 ()	1.4.3.2. Create use cas	e description																



		Jan 1 2023	Jan 8	Jan 15	Jan 22	Jan 29	Feb 5	Feb 12	Feb 19	Feb 26	Mar 5	Mar 12	Mar 19	Mar 26	Apr 2
1	0	> 1.0 Project Initia	lizaiton												
32	0	∼2.0 System Deve	lopment	0 :				_	-	-	-	-	_	-	
33	0	× 2.1. System De	esign												
34	0	2.1.1. Databa	ase Design												
35	0	2.1.2. Web A	opplication Architecture	Design											
36	0	2.1.3. Cloud	Architecture Design												
37	0	2.1.4. Mobile	e Application Architectu	re Design											
38	0	∨2.2. System De	evelopment						_	_	_	_	_	_	
39	0	× 2.2.1. Web /	Application Developm	ent											
40	0	2.2.1.1. Ca	ar Access Log Module												
41	0	2.2.1.2. Ca	ategory Module												
42	0	2.2.1.3. Pe	erson Module												
43	0	2.2.1.4. Us	ser Module												
44	0	2.2.1.5. Ro	ole Module												
45	0	× 2.2.2. Mobi	le Application Develop	oment						_					
46	0	2.2.2.1. Ca	ar Access Log Module												
47	0	2.2.2.2. Ca	ategory Module												
48	0	2.2.2.3. Pe	erson Module												
49	0	2.2.2.4. Us	ser Module												
50	0	2.2.2.5. Ro	ole Module												
51	0	2.2.3. Create	CI/CD Flow												
52	0	2.2.4. Utilize	AWS Service to Host W	eb Application											

Figure 3.8: System Development Timeline.



Figure 3.9: System Testing Timeline.



Figure 3.10: Project Closure Timeline.

3.4 Technologies and Development Tools

3.4.1 React and React Native

React and React Native are both JavaScript frameworks used to develop web and mobile applications, JavaScript XML (JSX) language is used in them, which is an extension of the JavaScript syntax that looks a lot like XML. It is a syntax that combines JavaScript and XML markup language, JSX is used to declare elements in both React and React native development. The only difference between them is the rendering interface. React is responsible for rendering components to the web, while react-native renders the components to the phone through the rendering interface of Objective-C (iOS platform) or Java (Android platform). There are two main benefits of using React for development, one is that React utilizes the DIFF algorithm when rendering, which re-renders the page only when there is a change in the DOM node, saving computational overhead. The second benefit is that React supports a componentized coding scheme, which allows the developer to develop many reusable components and thus save time.

3.4.2 NPM

NPM is a package manager, it is used primarily for installing and managing packages, or software libraries, that can be easily integrated into Node.js projects. NPM can also help to create a production-ready build of the React and React Native applications.

3.4.3 React-Redux

Redux can store and manage the state of the application. Think of Redux as a global variable that can be accessed and modified by React components. In addition, when the state in the Redux is updated, all components that refer to the state will be re-rendered. Redux has three main components: action creators, store, and reducers, the relationships are illustrated in Figure 3.3.

The current mainstream and usage of redux is to use the React-Redux library. React-redux separates the UI component from the redux, using a container to wrap the UI component and let the component communicate with the Redux through the container. React-redux workflow is shown in Figure 3.4.



Figure 3.11: Redux Workflow



Figure 3.12: React-Redux Workflow

3.4.4 Android Studio

Google android studio is an Android development environment with built-in Android SDK and AVD manager to run Android emulator. The React-Native project under development can be deployed to the Android emulator to view the developed interface.

3.4.5 Firebase

Firebase's Firestore and Firebase's Storage act as the cloud database to store the vehicle data and allowing the client to run Create, Read, Update and Delete (CRUD) operations on the them. Firebase has Spark program and Blaze program, Spark program is a free program, providing 1GB of free storage, providing 20,000 times a day the number of documents writes, 50,000 times the number of documents reads, and 20,000 times the number of document deletions. The Blaze program is a pay-as-you-go price plan that includes the services of the free solution, but requires payment when the free balance is exceeded, including a charge of \$0.108 per GiB when the free storage space exceeds 1 GB. The prices for the number of documents writes, reads, and deletes are shown in Figure 3.5.

US (us)	•		
	Free quota per day	Price beyond the free quota (per unit)	Price unit
Document Reads	50,000	\$0.06	per 100,000 documents
Document Writes	20,000	\$0.18	per 100,000 documents
Document Deletes	20,000	\$0.02	per 100,000 documents
Stored Data	1 GiB storage	\$0.18	GiB/Month

Figure 3.13: Google Cloud Service Price

3.4.6 Algolia

Algolia is a search-as-a-service provider that helps to deliver fast and relevant search results. Algolia provides a range of features that make it easy to integrate search into the React and React Native applications. These include a flexible API that allows the developer to control the search experience.

3.4.7 AWS Route53

AWS Route 53 is a cloud Domain Name System (DNS) provided by AWS. It helps to translate domain names into IP addresses that can be used to route traffic to various resources like Amazon EC2 instances, Elastic Load Balancers, S3 buckets, and other AWS services.

3.4.8 AWS Load Balancer

AWS Application Load Balancer (ALB) is a highly available and scalable load balancer service provided by AWS. It is used to distribute incoming traffic

across multiple targets, such as EC2 instances. It provides advanced features like path-based routing and advanced health checks,

3.4.9 AWS Certificate Manager

AWS Certificate Manager (ACM) provides a simple and easy way to obtain and manage SSL/TLS certificates for the website, which can encrypt the web traffic using Hypertext Transfer Protocol Secure (HTTPS).

3.4.10 AWS EC2

EC2 enables the developer to create and manage virtual machines, in the cloud. In this project, EC2 instances are used to host the web application.

3.4.11 AWS CloudWatch

In this project, AWS CloudWatch is used to monitor the health of EC2 instances. It can help to reboot the instance if any one of the instances did not pass the status check.

3.4.12 AWS Budgets

AWS Budgets help to monitor AWS usage and costs. It allows the developer to set custom cost and usage budgets, when the usage or costs exceed the thresholds, it can help to alert the developer and stop the EC2 service, this is to avoid unexpected costs.

3.4.13 ExpressJS

ExpressJS is a popular open-source web application framework for Node.js that simplifies the process of building server-side web applications. It is used to serve the React application in this project.

3.4.14 Docker

Docker is a platform that enables developers to package, distribute, and run applications in a containerized environment. In this project, Docker is used to

run the ExpressJS web server in an isolated and reproducible environment, which can make it easier to deploy and manage.

3.4.15 Git and GitHub

In this project, Git is employed to manage the changes in the code and GitHub is used to host the project's repositories. GitHub plays a significant role in this project; it has a tool for continuous integration and provides a platform to release this project's mobile application.

3.4.16 Github Actions

Github Actions is a CI/CD platform that allows developers to automate software development workflows, it helps to create custom workflows to automate any task, including building and deploying applications. In this project, Github Actions is employed to automatically deploy the web project on the EC2 instances with the help of GitHub Runner.

CHAPTER 4

PROJECT SPECIFICATION

4.1 Introduction

This section discusses the use of observation and onsite survey to identify and gather user requirements. The only user of this project is the manager of the Site A's condominium, so only he will be interviewed. Through the analysis of the collected data, the requirement specification, use case diagram and use case description are formulated. In addition, the requirements specification is divided into functional and non-functional requirements in order to identify user requirements more accurately.

4.2 Fact Finding

The fact-finding of this project will be carried out in the form of observation and onsite questionnaire survey.

4.2.1 Observation

Using observation to collect data is an effective method because it can better understand the needs of users, which will help to discover needs that cannot be found through questionnaires.

A field investigation at Site A's condominium was conducted. There are security guard house and security gate at the entrance. Vehicles can enter and exit through the entrance. There are unregistered and registered vehicles. If the vehicle is registered, the security guard will open the security gate allowing the vehicle directly to access without recording the entry and exit time of the vehicle. If it is an unregistered visitor, the security guard will use paper and pen to record the visitor's license plate number, owner's phone number, and vehicle entry and exit time and fill in the remarks column. The purpose of the remarks column is to record more information about the vehicle such as whether the vehicle is a Grab vehicle.

Therefore, the behavior of the security guard can be divided into two situations, encountering a registered vehicle and encountering an unregistered

visitor. When encountering a registered vehicle, the security guard will perform the following actions:

- i. Walk out from the security guard'shouse.
- ii. Open the security gate.
- iii. Allow the vehicle to access.

When encountering unregistered visitors, security guard will perform the following actions:

- i. Walk out from the security guard'shouse.
- ii. Ask the car owner for the phone number.
- iii. Record the visitor's license plate number, owner's phone number, vehicle entry and remarks inside a book
- iv. Open the security gate.
- v. Allow the vehicle to access.

From the field observation, it can be found that the current method does not record the entry and exit logs of registered vehicles and relies on the use of paper and pen to record the personal information of visitors. Paper records are easily damaged and difficult to manage, so this project will develop the user specifications based on these pain points. Relevant photos of the onsite visit are attached in the appendix part as **Appendix A**.

4.2.2 Questionnaire

This project uses Google Forms as a survey tool. The questionnaire has a total of ten questions, which will be answered by Site A's condominium manager.



Figure 4.1: Role as a Security Guard.

According to the bar chart in Figure 4.1, it can be found that the security guard is only responsible for the range of the security gate, and is not responsible for the management of the parking lot. Security guard is mainly responsible for monitoring the entrance of the condominium.



Figure 4.2: Frequency to view car access log.

According to the pie chart in Figure 4.2, it can be found that the manager needs to check the car access log every day.



3) What kind of information do you need to see in the car access log? 1 response

Figure 4.3: Information of Car Access Log.

According to the bar chart in Figure 4.3, it can be found that the manager needs to obtain vehicle information from the car access log, which includes the license plate number, the name of the owner, and the time of entry and exit of the vehicle.





According to the bar chart in Figure 4.4, it can be found that manager use three methods to view car access logs. The first is to use paper records, the second is to use spreadsheets or databases on a computer, and the third is to use a mobile app or web app to view records.



5) What are some challenges or difficulties that you face when searching for car access log records?

Figure 4.5: Difficulties in searching car access records.

According to the bar chart in Figure 4.5, it can be found that the manager did not encounter any problems in searching the car access log. Although the manager has no problems using the traditional search method, the manager hopes to be able to monitor the vehicle entry and exit records in real time.



6) How important is it for you to be able to register new car owners in the system? 1 response

Figure 4.6: Importance of registering car owners.

Based on the bar chart in Figure 4.6, manager is required to rate the importance of registering new car owners in the system on a scale of 1 to 5. The result shows that the manager is very much in need of the ability to register new car owners.



7) What kind of information do you need to collect from new car owners?

Figure 4.7: Information collected from new car owners.

According to the bar chart in Figure 4.7, it can be found that the manager needs to collect personal information such as name, phone number, and email address from the car owners. In addition, the manager also hopes to classify the car owners, such as classifying them into resident or visitor categories.



Figure 4.8: Current Solution to categorize car owners.

According to the bar chart in Figure 4.8, it can be found that the manager still obtains the classification of car owners from a paper-based registration list.



9) How familiar are you with role and user management systems?

Figure 4.9: Familiarity in using role and management system.

Based on the bar chart in Figure 4.9, manager is asked to rate their confidence in using the role and management functionality in the system on a scale of 1 to 5. The results show that manager is very confident that he can use the role and management function well.





According to the bar chart in Figure 4.10, it can be found that using the role and management function has two benefits for manager. The first is that people who use this system can read vehicle entry and exit records more safely. The second is that people with different roles can be given different system permissions.

4.3 Requirement Specification

Requirement specifications include functional and non-functional requirements. In addition, the functional requirements of the project are divided into web application functional requirements and mobile application functional requirements.

4.3.1 Web Application Functional Requirements

4.3.1.1 User Account

- WEB-1. The web application should allow user to log into their accounts by username and password.
- WEB-2. The web application should allow the user to logout from the account.

4.3.1.2 Car Access Log

- WEB-3. The web application should allow the user to view the car access log in real time.
- WEB-4. The web application should allow users to do basic search on the car access log based on a single search field such as search by car plate number, car owner's name, car owner's phone no, car owner's category or car access type (Enter or Exit).
- WEB-5. The web application should allow users to do advance filter search on the car access log based on multiple selective search fields such as the combination of car plate, car owner's name, car owner's phone no, car owner's category, car access type (Enter or Exit) and the date range.
- WEB-6. The web application should allow the user to view the car owner's personal information from the car access log.

4.3.1.3 Category Module

- WEB-7. The web application should allow the user to view categories.
- WEB-8. The web application should allow the user to add a new category.
- WEB-9. The web application should allow the user to edit category.
- WEB-10. The web application should allow the user to remove category.

4.3.1.4 Person Module

- WEB-11. The web application should allow the user to view the registered car owners' personal information.
- WEB-12. The web application should allow the user to register new car owner.
- WEB-13. The web application should allow the user to edit the registered car owner's personal information.
- WEB-14. The web application should allow the user to remove the car owner.
- WEB-15. The web application should allow the user to search the car owner by name. car plate number or phone number.

4.3.1.5 User Module

- WEB-16. The web application should allow the user to view all created accounts that are able to assess the system.
- WEB-17. The web application should allow the user to create a new user account and assign a role for it.
- WEB-18. The web application should allow the user to edit the user account.
- WEB-19. The web application should allow the user to remove the user account.

4.3.1.6 Role Module

- WEB-20. The web application should allow the user to view all the role.
- WEB-21. The web application should allow the user to create a new role.
- WEB-22. The web application should allow the user to decide which web and mobile pages this role can view.
- WEB-23. The web application should allow the user to remove the role.

4.3.2 Mobile Application Functional Requirements

4.3.2.1 User Account

- MB-1. The mobile application should allow user to log into their accounts by username and password.
- MB-2. The mobile application should allow the user to logout from the account.

4.3.2.2 Car Access Log

- MB-3. The mobile application should allow the user to view the car access log in real time.
- MB-4. The mobile application should allow users to do basic search on the car access log by car plate number.
- MB-5. The mobile application should allow users to do advance filter search on the car access log based on multiple selective search fields such as the combination of car plate, car owner's name, car owner's phone no, car owner's category, car access type (Enter or Exit) and the date range.
- MB-6. The mobile application should allow the user to view the car owner's personal information from the car access log.

4.3.2.3 Category Module

- MB-7. The mobile application should allow the user to view the categories.
- MB-8. The mobile application should allow the user to add a new category.
- MB-9. The mobile application should allow the user to edit the category name.
- MB-10. The mobile application should allow the user to remove the category.

4.3.2.4 Person Module

- MB-11. The mobile application should allow the user to view the registered car owners' personal information.
- MB-12. The mobile application should allow the user to register a new car owner.
- MB-13. The mobile application should allow the user to edit the registered car owner's personal information.
- MB-14. The mobile application should allow the user to remove the car owner.
- MB-15. The mobile application should allow the user to search for the car owner by name. car plate number or phone number.

4.3.2.5 User Module

- MB-16. The mobile application should allow the user to view all created accounts that are able to assess the system.
- MB-17. The mobile application should allow the user to create a user new account and assign role for it.
- MB-18. The mobile application should allow the user to edit the user account.
- MB-19. The mobile application should allow the user to remove the user account.

4.3.2.6 Role Module

- MB-20. The mobile application should allow the user to view all the roles.
- MB-21. The mobile application should allow the user to create a new role.
- MB-22. The mobile application should allow the user to decide which web and mobile pages this role can view.
- MB-23. The mobile application should allow the user to remove the role.

4.3.3 Non-Functional Requirements

1) **Performance requirements**

- a) Any operation of the user on the webpage or mobile phone application will return the result within four seconds.
- b) The system must monitor the car access log in real time, and the new car access log must be reflected to the user within one second.
- c) When the user uses the system for the first time, the system must render the page within four seconds.

2) Security requirements

- a) When a user logs in, the system will verify the user's username and password.
- b) The system will render corresponding pages for users with different permissions.
- c) The webpage will be encrypted using HTTPS.

3) Usability requirements

a) The system must support the use of a single command to rebuild the mobile application.

- b) The system must support one-click redeployment of web applications to cloud servers.
- c) Web applications should be able to run on any host machine that only has docker installed.
- d) Mobile applications and web applications should allow users to be proficient in using the functions within ten minutes.

4) Availability requirements

 a) Mobile phone and web application services should be available to users in 99.9% of the time.

5) Recoverability

- a) The system must automatically restart the AWS server within 2 minutes, if the AWS cloud server crashes due to AWS internal reasons,
- b) The system supports redeployment to the AWS server within 30 seconds if the web application crashes.

5) Portability

- a) The web application should run on any host machine that supports docker.
- b) The mobile app can run on Android phones running Android 5.0 or above.

Table 4.1 shows the mapping between the web and mobile application's functional requirements and their corresponding use case ID to facilitate the construction of use case description.

Functional Requirement ID	Use Case ID
WEB-1	1
WEB-2	2
WEB-3	3
WEB-4	4
WEB-5	5
WEB-6	6

Table 4.1: Mapping between Functional Requirement ID and Use Case ID.

WEB-7	7
WEB-8	8
WEB-9	9
WEB-10	10
WEB-11	11
WEB-12	12
WEB-13	13
WEB-14	14
WEB-15	15
WEB-16	16
WEB-17	17
WEB-18	18
WEB-19	19
WEB-20	20
WEB-21	21
WEB-22	22
WEB-23	23
MB-1	24
MB-2	25
MB-3	26
MB-4	27
MB-5	28
MB-6	29
MB-7	30
MB-8	31
MB-9	32
MB-10	33
MB-11	34
MB-12	35
MB-13	36
MB-14	37
MB-15	38

MB-16	39
MB-17	40
MB-18	41
MB-19	42
MB-20	43
MB-21	44
MB-22	45
MB-23	46

4.4 Use Case Modelling

4.4.1 Web Application Use Case Diagrams

4.4.1.1 User Account



Figure 4.11: User Account Use Case Diagram (Web Application).
4.4.1.2 Car Access Log



Figure 4.12: Car Access Log Use Case Diagram (Web Application).

4.4.1.3 Category Module



Figure 4.13: Category Module Use Case Diagram (Web Application).

4.4.1.4 Person Module



Figure 4.14: Person Module Use Case Diagram (Web Application).

4.4.1.5 User Module



Figure 4.15: User Module Use Case Diagram (Web Application).

4.4.1.6 Role Module





4.4.2 Mobile Application Use Case Diagram

4.4.2.1 User Account



Figure 4.17: User Account Use Case Diagram (Mobile Application).

4.4.2.2 Car Access Log



Figure 4.18: Car Access Log Use Case Diagram (Mobile Application).

4.4.2.3 Category Module



Figure 4.19: Category Module Use Case Diagram (Mobile Application).

4.4.2.4 Person Module



Figure 4.20: Person Module Use Case Diagram (Mobile Application).

4.4.2.5 User Module



Figure 4.21: User Module Use Case Diagram (Mobile Application).

4.4.2.6 Role Module





4.5 Use Case Description

Table 4.2: Use Case Description of Login (Web application).

Use Case Name: Login	ID: 1	Importance Level:
		High
Primary Actor: Manager	Use Case Type: Detail, Real	
Stakeholders and Interests:		
Manager –wants to login and use the web	application	on.
Use Case Description:		
Describe how the manager login to his a	ccount to	access the web
application.		

Trigger: When a manager wants to access and use the application.

Relationships:

Association	: Manager
Include	: Verify Username and Password
Extend	: Display Login Error Message
Generalization	:-

Normal Flow of Events:

- 1. The manager opens chrome browser.
- 2. The manager access the "alprtech.link" website.
- 3. The manager logs in his account by typing username and password.
- 4. The system verifies the username and password.

If the username and password are not valid.

Perform exceptional flow E-1.

5. The manager login to the web application successfully and will be directed to the web application's home page.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays the login error message.
- 2. The manager reenters the username and password.

 Table 4.3:
 Use Case Description of Logout (Web application).

Use Case Name: Logout	ID: 2	Importance Level:
		High
Primary Actor: Manager	Use Cas	e Type: Detail, Real

Stakeholders and Interests:

Manager –wants to logout from the web application.

Description:

Describes how the manager logout from the web application.

Trigger: When a manager wants to logout from the web application.

Relationships:

Association : Manager Include: Clear Browser Local Storage Extend : -Generalization : -

Normal Flow of Events:

- 1. The manager clicks the logout button.
- 2. The system displays a confirmation message.
- 3. The manager confirms to logout.
- 4. The manager is logout from the web application and redirected to the login page.
- 5. The system clears the browser local storage that store the user login information.

Sub-flows:

Alternate/Exceptional Flows:

Use Case Name: View Car Access Log	ID: 3	Importance Level:
		High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager –wants to view car access log.		
Description:		
Describes how the manager views the car a	access log.	
Trigger: When a manager wants to view th	e car acce	ss log
inggen when a manager wants to view an		
Relationships:		
i como nompor		
Association : Manager		
Include:		
Extend : -		
Generalization : -		
Normal Flow of Events:		
1. The manager navigates to the home	page of th	e web application.
2. The system displays a list of car acco	ess log.	
3. The manager views all the displayed	car acces	s log.
Sub-flows:		
Alternate/Exceptional Flows		

 Table 4.4:
 Use Case Description of View Car Access Log (Web application).

	C	ID 4	T
Use Case Name: Basic Search	ID: 4	Importance Level:	
Access Log	Access Log High		
Primary Actor: Manager		Use Cas	e Type: Detail, Real
Stakeholders and Interests:			
Manager –wants to search the c	car access lo	g.	
Description			
	1 4		
Describes how the manager sea	arches the ca	r access I	og.
Trigger: When a manager want	ts to search t	he car acc	cess log.
Relationships:			
-			
Association : Ma	nager		
Include : Va	lidate Input		
Extend : Sea	arch by Car I	Plate Nun	nber, Search by Car
Owner's Name, Search	h, by Car Ov	vner's Ph	one Number, Search by
Car Access Type, Sear	rch by Car C	wner's C	ategory, Display
Validation Error Mess	age		
Generalization :			
Normal Flow of Events:			
1. The manager navigates to	o the home r	page of th	e web application.
2. The manager selects one	of the search	h fields (s	search by car plate
number name phone nu	mber access	stype or (category)
2 The second sec			
5. The manager provides se		ule searc	
4. The manager clicks search	ch button to	pertorm s	earch.

 Table 4.5:
 Use Case Description of Basic Search on Car Access Log (Web application)

If the search field is empty.

Perform exceptional flow E-1.

5. The system returns the search result.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays the validation error message.
- 2. The manager provides the search data again.

 Table 4.6:
 Use Case Description of Filter Search on Car Access Log (Web application)

Use Case Name: Filter Search on Car	ID: 5	Importance Level:
Access Log		High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager – wants to perform filter search on	the car a	ccess log.
Description:		
Describes how the manager performs filter	search on	the car access log.
Trizzen When a manager monto to reaform	filter and	nah an tha ann annaa
Ingger: when a manager wants to perform	i filter sea	rch on the car access
log.		

Relationships:

Association	: N	/Ianager					
Include	: S	earch by	v Dat	e Ran	ige, Valida	ate Input	
Extend	:	Search b	by C	Car P	late Num	ber, Search	by Car
Owner's Nam	e, Sear	ch, by (Car (Owne	r's Phone	Number, S	earch by
Car Access	Type,	Search	by	Car	Owner's	Category,	Display
Validation Erro	or Mes	sage					
Generalization	•						

Normal Flow of Events:

- 1. The manager navigates to the home page of the web application.
- 2. The manager clicks the filter button.
- 3. The system shows the filter drawer that consists of multiple search fields.
- 4. The manager selects the start and end date.
- 5. The manager can selectively provide car plate number, car owner's name, car owner's category, car owner's phone number as input data to perform filter search.
- 6. The manager clicks the search button.

If the date range field is empty.

Perform exceptional flow E-1.

- 7. The system returns the search result.
- 8. The manager closes the filter drawer.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays the validation error message.
- 2. The manager provides the date range again.

Table 4.7:Use Case Description of View Car Owner's Personal Information
(Web application)

Use Case Name: View C	Car Owner's	ID: 6	Importance Level:
Personal Information			High
Primary Actor: Manager	•	Use Cas	e Type: Detail, Real
Stakeholders and Interes	sts:		
Manager –wants to view	the car owner's pe	ersonal in	formation from the car
access log.	-		
8.			
Description:			
Describe how the mana	ager views the car	owner's p	ersonal information
from the car access log.			
Trigger: When a manage	ar wants to view the	o or own	ar's parsonal
Trigger. when a manage		e car own	er s personar
information from the car	r access log.		
Relationships:			
Association	: Manager		
Include	:		
Extend	:		
Generalization	:		
Normal Flow of Events:			
Tronnar Tiow of Events.			
1 1		6.1	
1. The manager navi	gates to the home p	page of th	e web application.
2. The manager click	the more button	from the c	ar access log list.
3. The system shows	s the drawer that co	nsists of t	he car owner's personal
information.			

- 4. The manager views the car owner's personal information.
- 5. The manager closes the drawer.

Sub-flows:

Alternate/Exceptional Flows:

 Table 4.8:
 Use Case Description of View Category (Web application).

Use Case Name: View	Category	ID: 7	Importance Level:
			High
Primary Actor: Manage	r	Use Cas	e Type: Detail, Real
Stakeholders and Intere	sts:		
Manager – wants to view	v categories		
Description:			
Describes how the man	ager views the cat	egories	
Deserves now the man	uger views the eat	egones	
Trigger: When a manag	er wants to view t	he categori	es.
Relationships:			
Association	: Manager		
Include	:		
Extend	:		
Generalization	:		
Normal Flow of Events	:		
1. The manager nav	igates to the categ	ory page of	f the web application.
2. The system displa	ays a table listing	the categor	ies.
3. The manager nav	igates through the	category li	ist.

Sub-flows:

Alternate/Exceptional Flows:

 Table 4.9:
 Use Case Description of Add Category (Web application).

Use Case Name: Add C	Category	ID: 8	Importance Level:
			High
Primary Actor: Manage	er	Use Cas	e Type: Detail, Real
Stakeholders and Intere	ests:		
Manager –wants to add	l a category.		
Description:			
Describes how the man	ager adds a categor	y.	
Trigger: When a manage	per wants to add a c	atagory	
Trigger. When a manag		ategory.	
Relationships:			
Relationships.			
Association	: Manager		
Include	: Validate Input		
Extend	: Display Validat	ion Error	Message
Generalization	:		
Normal Flow of Events	3:		
1. The manager nav	vigates to the catego	ory page of	f the web application.
2. The manager clic	cks the add button.	-	-
3. The system show	vs a modal contains	an input f	ield asking for category

name.

- 4. The manager types a category name in the input field.
- 5. The manager clicks the ok button.

If the manager did not provide any category name.

Perform exceptional flow E-1.

If the manager provides a duplicate category name.

Perform exceptional flow E-2.

- 6. The system adds a new category.
- 7. The system shows a success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays a validation error message.
- 2. The manager types the category name again.
- E-2
 - 1. The system alerts the manager that a same category name already exists.
 - 2. The manager types the new category name again.

Table 4.10: Use Case Description of Edit Category (Web application)

Use Case Name: Edit Category	ID: 9	Importance Level:
		High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager – wants to edit a category.		

Description:

Describes how the manager edits a category.

Trigger: When a manager wants to edit a category.

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error Message
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the category page of the web application.
- 2. The manager clicks the edit button from the category list.
- 3. The system shows a modal contains an input field asking for a new category name.
- 4. The manager types a new category name in the input field.
- 5. The manager clicks the ok button.

If the manager did not provide any category name.

Perform exceptional flow E-1.

If the manager provides the same category name as before.

Perform exceptional flow E-2.

If the manager provides the duplicate category name.

Perform exceptional flow E-3.

- 6. The system updates the category name.
- 7. The system shows a success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays a validation error message.
- 2. The manager types the category name again.

E-2

- 1. The system closes the modal.
- E-3
 - 1. The system alerts the same category name already exists.
 - 2. The manager types the new category name again.

Table 4.11: Use Case Description of Remove Category (Web application).

Use Case Name: Remov	ve Category	ID: 10	Importance Level
Ose Case Maine. Remov	ve category	ID. 10	
			High
Primary Actor: Manage	r	Use Cas	e Type: Detail, Real
Stakeholders and Interest	sts:		
Managerwants to rem	ove a category		
Wants to rem	ove a category.		
Description:			
Describes how the mana	ager removes a cate	gory.	
	0	0,	
Trigger: When a manag	er wants to remove	a categor	у.
Relationships:			
Relationships.			
Association	: Manager		
Include	: Display Alert M	essage	
Extend	:		
Generalization	:		
Relationships: Association	: Manager		
Association	: Manager		
Include	: Display Alert M	essage	
Include	: Display Alert M	essage	
Extend	:		
Generalization	:		

Normal Flow of Events:

- 1. The manager navigates to the category page of the web application.
- 2. The manager clicks the remove button from the category list.
- 3. The system shows an alert modal to warn the manager.
- 4. The manager clicks the confirm button.
- 5. The system deletes the category.
- 6. The system shows a success message.
- 7. The system closes the alert modal.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.12: Use Case Description of View Car Owners' Personal Information(Web application).

Use Case Name: View Car Owners'	ID: 11	Importance Level:		
Personal Information High				
Primary Actor: Manager Use Case Type: Detail, Real				
Stakeholders and Interests:				
Manager –wants to view the car owners' personal information.				
Description:				
Describes how the manager view the car owners' personal information.				
Trigger: When a manager wants to view the car owners' personal				
information.				

Relationships:			
Association	: Manager		
Include	:		
Extend	:		
Generalization	:		
Normal Flow of Events	:		

- 1. The manager navigates to the person page of the web application.
- 2. The system displays a table listing all the registered car owners.
- 3. The manager clicks on the view button to view more detail information.
- 4. The system navigates to the person detail page.
- 5. The system shows all the car owner's detail information.

Sub-flows:
Alternate/Exceptional Flows:

|--|

Use Case Name: Register Car Owner	ID: 12	Importance Level:		
		High		
Primary Actor: Manager	Use Cas	e Type: Detail, Real		
Stakeholders and Interests:				
Manager –wants to register a new car owner.				

Description:

Describes how the manager registers a new car owner.

Trigger: When a manager wants to register a new car owner.

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the person page of the web application.
- 2. The manager clicks on the register button.
- 3. The system navigates to the registration form page.
- 4. The manager provides the car owner's name, car plate number, phone number, category, and person detail in the form.
- 5. The manager clicks the submit button.
- 6. The system validates all the input fields.

If the manager provides invalid format of data

Perform exceptional flow E-1.

If the manager did not fill all the necessary input fields.

Perform exceptional flow E-2.

If the manager provides a duplicate car plate number.

Perform exceptional flow E-3.

- 7. The system shows a loading message.
- 8. The system adds a car owner.
- 9. The system shows the success message.
- 10. The system navigates to the person page.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system shows an error message asking the manager to provide correct data in the corresponding field.
- 2. The manager provides the data in correct format.

E-2

- 1. The system shows an error message asking the manager to fill all the required fields.
- 2. The manager fills all the required input fields.

E-3

- 1. The system alerts the manager that the current car plate number already exists.
- 2. The manager fills a new car plate number.

Table 4.14: Use Case Description of Edit Car Owner's Personal Information (Web application).

Use Case Name: Edit Car Owner's	ID: 13	Importance Level:		
Personal Information		High		
Primary Actor: Manager	Use Cas	e Type: Detail, Real		
Stakeholders and Interests:				
Manager – wants to edit the car owner's personal information.				
Description:				
Describes how the manager edits the car owner's personal information.				

Trigger: When a manager wants to edit the car owner's personal information.

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the person page of the web application.
- 2. The manager clicks on the edit button from the list of car owners.
- 3. The system navigates to the edit person page.
- 4. The manager provides the new car owner's name, car plate number, phone number, category, or person detail in the form.
- 5. The manager clicks the submit button.
- 6. The system validates all the input fields.

If the manager provides invalid format of data

Perform exceptional flow E-1

If the manager leaves the necessary input fields empty.

Perform exceptional flow E-2

If the manager provides a duplicate car plate number.

Perform exceptional flow E-3

- 7. The system shows a loading message.
- 8. The system updates the car owner.
- 9. The system shows the success message.
- 10. The system navigates to the person page.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system shows an error message asking the manager to provide correct data in the corresponding field.
- 2. The manager provides the data in correct format.

E-2

- 1. The system shows an error message asking the manager to fill all the required input fields.
- 2. The manager fills all the required input fields.

E-3

- 1. The system alerts the manager that the current car plate number already exists.
- 2. The manager fills a new car plate number.

Table 4.15: Use Case Description of Remove Car Owner (Web application)

Use Case Name: Remove Car Owner	ID: 14	Importance Level:		
		High		
Primary Actor: Manager	Use Cas	e Type: Detail, Real		
Stakeholders and Interests:				
Manager – wants to remove the car owner.				
Description:				
Describes how the manager removes the car owner.				
Trigger: When a manager wants to remove the car owner.				

Relationships:

Association	: Manager
Include	: Display Alert Message
Extend	:
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the person page of the web application.
- 2. The manager clicks on the remove button from the list of car owners.
- 3. The system displays a confirmation modal.
- 4. The manager clicks the ok button.
- 5. The system deletes the car owner.
- 6. The system shows the success message.
- 7. The system closes the confirmation modal.

Sub-flows:

Alternate/Exceptional Flows:

T-1.1. / 1C. II C	D	C C = 1 C = 0	$\gamma_{} = 1 - 1$	
$13 \text{ me} \Delta 16' 1 \text{ set ase}$	Description of	E Nearch Clar C	wher(wen	annucation
1000 1.10. 000 0000	Description 0			upplication,

Use Case Name: Search Car Owner	ID: 15	Importance Level:
		High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager – wants to search the car owner.		

Description:

Describes how the manager searches the car owner.

Trigger: When a manager wants to search the car owner.

Relationships:

Association	: Manager			
Include	:			
Extend	: Search by Name, Search by Car Plate Number,			
Search by Phone Number				
Generalization	:			

Normal Flow of Events:

- 1. The manager navigates to the person page of the web application.
- 2. The manager input the search data in the search field.
- 3. The system will perform query on the database.
- 4. The system returns the search result.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.17: Use Case Description of View all Created User Accounts (Web application).

Use Case Name: View all Created User	ID: 16	Importance Level:
Accounts		High
Primary Actor: Manager	Use Case Type: Detail, Real	

Stakeholders and Interests:

Manager -wants to view all created user accounts.

Description:

Describes how the manager views all created user accounts.

Trigger: When a manager wants to view all created user accounts.

Relationships:

Association	: Manager
Include	:
Extend	:
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the user page of the web application.
- 2. The system displays table listing all the user accounts.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.18: Use Case Description of Create new User Account (Web application)

Use Case Name: Create new User Account	ID: 17	Importance Level:
		High

Prima	ary Actor: Manager		Use Case Type: Detail, Real	
Stake	holders and Interest	ts:	<u> </u>	
Mana	ager –wants to creat	e a new user accou	int.	
Desci	ription:			
Desci	ribes how the manage	ver creates a new u	iser account	
Deser		ger creates a new c		
Trigg	ger: When a manage	r wants to create a	new user account.	
Relat	ionships:			
	Association	Monogor		
	Association	: Manager	a Validata Input	
	Include : Assign User Role, Validate Input			
	Extend	: Display Validati	on Error Message	
	Generalization	:		
Norm	al Flow of Events			
Norm	ial Flow of Events:			
1.	The manager navig	gates to the user pa	age of the web application.	
2.	2. The manager clicks the add button.			
3.	3. The system shows a modal containing a form, the form contains input			
	fields such as username, password, email, phone number and role.			
4.	4. The manager provides all the necessary data (username, password and			
	role)			
5.	5. The manager clicks the ok button.			
	If the manager did not provide all the required data.			
	Perform exceptio	nal flow E-1.		
	If the manager pro	vides a duplicate u	isername.	
	Perform exceptio	nal flow E-2.		
6.	The system created	d a new user accou	int and assign the corresponding	
	role to it.			

- 7. The system shows a success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system shows the error message asking the manager to complete all the required input fields.
- 2. The manager completes all the required input fields.

E-2

- 1. The system shows the alert message notify the manager that the same username already exists.
- 2. The manager types a new username.

Table 4.19: Use Case Description of Edit User Account (Web application)

Use Case Name: Edit User Account	ID: 18	Importance Level: High	
Primary Actor: Manager	Use Case Type: Detail, Real		
Stakeholders and Interests:	•		
Manager –wants to edit the user account.			
Description:			
Describes how the manager edits the user account.			
Trigger: When a manager wants to edit the user account.			

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error Message
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the user page of the web application.
- 2. The manager clicks the edit button from list of user accounts.
- 3. The system shows a modal containing a form, the form contains input fields such as username, password, email, phone number and role.
- 4. The manager provides all the necessary data (username, password and role)
- 5. The manager clicks the ok button.
 - If the manager did not provide any new data.
 - Perform exceptional flow E-1.
 - If the manager did not provide all the required data.
 - Perform exceptional flow E-2.
 - If the manager provides a duplicate username.
 - Perform exceptional flow E-3.
- 6. The system updates the user account.
- 7. The system shows a success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

1. The system closes the modal.

E-2

- 1. The system shows the error message asking the manager to complete all the required input fields.
- 2. The manager completes all the required input fields.
- E-3
 - 1. The system shows the alert message notify the manager that the same username already exists.
 - 2. The manager types a new username.

Table 4.20: Use Case Description of Remove User Account (Web application)

Use Case Name: Remov	ve User Account	ID: 19	Importance Level:	
			High	
Primary Actor: Manager		Use Cas	Use Case Type: Detail, Real	
Stakeholders and Interes	sts:			
Manager –wants to reme	ove the user accoun	ıt.		
Description:				
Description:				
Describes now the mana	Describes how the manager removes the user account.			
Trigger: When a manager wants to remove the user account.				
Relationships:				
Association	: Manager			
Include	: Display Alert M	essage		
Extend	:			
Generalization	:			
Normal Flow of Events:

- 1. The manager navigates to the user page of the web application.
- 2. The manager clicks on the remove button from the list of user accounts.
- 3. The system displays a confirmation modal.
- 4. The manager clicks the ok button.
- 5. The system deletes the user account.
- 6. The system shows the success message.
- 7. The system closes the confirmation modal.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.21: Use Case Description of View Roles (Web application)

Use Case Name: View Roles	ID: 20	Importance Level: High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager –wants to view all the roles.		
Description:		
Describes how the manager views all the ro	oles.	
Trigger: When a manager wants to view all	the roles	

Relationships:	
Association	: Manager
Include	:
Extend	:
Generalization	:
Normal Flow of Events	
 The manager na The system disp 	vigates to the role page of the web application. Plays a table listing all the roles.
Sub-flows:	
Alternate/Exceptional F	Plows:

Table 4.22: Use Case Description of Create new Role (Web application)

	ID AI	
Use Case Name: Create new Role	ID: 21	Importance Level:
		TT* 1
		High
Primary Actor: Manager	Use Cas	e Type: Detail. Real
	0.50 0005	
Stakeholders and Interests:		
Manager wants to create a new role		
Wanager – wants to create a new role.		
Description:		
Describes how the manager creates a new 1	ole.	
Trigger: When a manager wants to create a	new role	

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error Message
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the role page of the web application.
- 2. The manager clicks the add button.
- 3. The system shows a modal asking the manager to input a role name.
- 4. The manager types a role name in the input field.
- 5. The manager clicks the ok button.
- 6. The system validates the input field.
 If the manager leaves the input field empty.
 Perform exceptional flow E-1.
 If the manager provides a duplicate role name.
 Perform exceptional flow E-2.
- 7. The system shows the success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system shows a validation error message.
- 2. The manager types the role name again.

E-2

- 1. The system alerts the manager that the same role name already exists.
- 2. The manager types a new role name.

Use Case Name: Assign Pages to Role	ID: 22	Importance Level:	
		High	
Primary Actor: Manager	Use Cas	e Type: Detail, Real	
Stakeholders and Interests:			
Manager –wants to assign pages to a role.			
Description:			
Describes how the manager assigns page	ges to a rol	le.	
Trigger: When a manager wants to assign	pages to a	role.	
Relationships:			
Association : Manager			
Include :			
Extend :			
Generalization :			
Normal Flow of Events:			
1. The manager navigates to the role p	age of the	web application.	
2. The manager clicks the edit button	from the li	st of roles.	
3. The system displays a modal with c	3. The system displays a modal with checkboxes for the manager to		
assign the pages this role has access	s to.		
4. The manager clicks on the checkbo	xes.		
5. The manager clicks the ok button.			
If the checkboxes are the same.			
Perform exceptional flow E-1			
6. The system assigns the pages to the	role.		
o. The system assigns the pages to the	1010.		

Table 4.23: Use Case Description of Assign Pages to Role (Web application)

7. The system shows the success message.	7.	The system	shows the	success	message.
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8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

1. The system closes the modal.

Table 4.24: Use Case Description of Remove Role (Web application).

Use Case Name: Remov	ve Role	ID: 23	Importance Level: High
Primary Actor: Manage	y Actor: Manager Use Case Type: Detail, Real		e Type: Detail, Real
Stakeholders and Intere	sts:		
Manager –wants to rem	ove a role.		
Description:			
Describes how the m	anager remove a r	ole.	
Trigger: When a manag	er wants to remove	a role.	
Relationships:			
Association	: Manager		
Include	: Display Alert M	lessage	
Extend	:		
Generalization	:		

Normal Flow of Events:

- 1. The manager navigates to the role page of the web application.
- 2. The manager clicks the remove button from the list of roles.
- 3. The system displays a confirmation modal.
- 4. The manager clicks the ok button.
- 5. The system deletes the role.
- 6. The system shows the success message.
- 7. The system closes the confirmation modal.

Sub-flows:

Alternate/Exceptional Flows:

Use Case Name: Login	ID: 24	Importance Level
Use Case Maine. Login	ID. 24	Importance Level:
		High
		8
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager – wants to login and use the mobil	e applicat	ion.
Description:		
Description.		
Describes how the manager login his accou	int to acce	ess mobile application.
		11
Trigger: When a manager wants to access a	and use th	e application.

T-1.1. 1 05. II /	O D		-1.11 11 41 · ·
Lable 4 Zor Use (ase Description	m of Login (N)	onlie application)
14010 1.20.000	Cube Debeliptic		oone uppneution)

Relationships:

Association	: Manager
Include	: Verify Username and Password
Extend	: Display Login Error Message
Generalization	: -

Normal Flow of Events:

- 1. The manager opens the application.
- 2. The manager logs in his account by typing username and password.
- 3. The system verifies the username and password.

If the username and password are not valid.

Perform exceptional flow E-1.

4. The manager login to the mobile application successfully and will be directed to the mobile application's home page.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays the login error message.
- 3. The manager enters the username and password again.

Table 4.26: Use Case Description of Logout (Mobile application)

Use Case Name: Logout	ID: 25	Importance Level:
		High
Primary Actor: Manager	Use Case Type: Detail, Real	
Stakeholders and Interests:		
Manager – wants to logout from the mobile application.		

Describes how the manager logout from the mobile application.

Trigger: When a manager wants to logout from the mobile application.

Relationships:

Association	: Manager
Include	: Clear Local AsyncStorage
Extend	:-
Generalization	:-

Normal Flow of Events:

- 1. The manager clicks the logout from the navigation pane.
- 2. The system displays a confirmation message.
- 3. The manager confirms to logout.
- 4. The manager is logout from the mobile application and redirected to the login page.
- 5. The system clears the local AsyncStorage that store the user login information.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.27: Use Case Description of View Car Access Log (Mobile application).

Use Case Name: View Car Access Log	ID: 26	Importance Level:
		High

Primary Actor: Manager	Use Case Type: Detail, Real
Stakeholders and Interests:	
Manager –wants to view car access log.	
Description:	
Describes how the manager view the car ac	ccess log.
Trigger: When a manager wants to view the	e car access log.
Relationships:	
Association : Manager	
Include:	
Extend :-	
Generalization : -	
Normal Flow of Events:	
1. The manager navigates to the home p	page of the mobile application.
2. The system displays a list of car acce	ess log.
3. The manager views all the displayed	car access log.
Sub-flows:	
Alternate/Exceptional Flows:	

Table 4.28: Use Case Description of Basic Search on Car Access Log (Mobile application)

Use Case Name: Basic Search on Car	ID: 27	Importance Level:
Access Log		High

Primary Actor: Manager	Use Case Type: Detail, Real		
Stakeholders and Interests:			
Manager –wants to search the car acces	s log.		
Description:			
Describes how the manager search the o	car access log.		
Trigger: When a manager wants to sear	ch the car access log		
Trigger. when a manager wants to sear	ch me cai access log.		
Relationships:			
Kelutonsinps.			
Association : Manager			
Include :			
Extend :			
Generalization :			
Normal Flow of Events:			
1. The manager navigates to the home page of the web application.			
2. The manager types the car plate number in the search field.			
3. The manager hits the enter on keyboard.			
4. The system returns the search result.			
Sub-flows:			
Alternate/Exceptional Flows:			

Use Case Name: Filter Search on Car ID: 28 **Importance Level:** Access Log High Use Case Type: Detail, Real Primary Actor: Manager Stakeholders and Interests: Manager –wants to perform filter search on the car access log. Description: Describes how the manager perform filter search on the car access log. Trigger: When a manager wants to perform filter search on the car access log. **Relationships:** Association : Manager Include : Search by Date Range, Validate Input Extend : Search by Car Plate Number, Search by Car Owner's Name, Search, by Car Owner's Phone Number, Search by Car Access Type, Search by Car Owner's Category, Display Validation Error Message Generalization : Normal Flow of Events: 1. The manager navigates to the home page of the web application. 2. The manager clicks the filter icon. 3. The system shows the filter drawer that consists of multiple search fields.

Table 4.29: Use Case Description of Filter Search on Car Access Log (Mobile application).

4. The manager selects the start and end date.

- 5. The manager can selectively provide car plate number, car owner's name, car owner's category, car owner's phone number as input data to perform filter search.
- The manager clicks the submit button.
 If the date range field is empty.

Perform exceptional flow E-1.

- 7. The system returns the search result.
- 8. The system closes the filter drawer.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays the validation error message.
- 2. The manager provides the date range again.

Table 4.30: Use Case Description of View Car Owner's Personal Information(Mobile application).

Use Case Name: View Car Owner's	ID: 29	Importance Level:	
Personal Information		High	
Primary Actor: Manager	Use Cas	e Type: Detail, Real	
Stakeholders and Interests:			
Manager –wants to view the car owner's pe	ersonal in	formation from the car	
access log.			
Description:			
Describes how the manager views the car owner's personal information			
from the car access log.			
Trigger: When a manager wants to view the car owner's personal			
information from the car access log.			

Relationships:			
Association	: Manager		
Include	:		
Extend	:		
Generalization	:		

Normal Flow of Events:

- 1. The manager navigates to the home page of the web application.
- 2. The manager clicks the more button from the car access log list.
- 3. The system shows the drawer that consists of the car owner's personal information.
- 4. The manager views the car owner's personal information.
- 5. The manager closes the drawer.

Sub-flows:

Alternate/Exceptional Flows:

Use Case Name: View Category	ID: 30	Importance Level: High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager –wants to view categories.		

Describes how the manager views the categories

Trigger: When a manager wants to view the categories

Relationships:

Association: ManagerInclude:Extend:Generalization:

Normal Flow of Events:

- 1. The manager navigates to the category page of the mobile application.
- 2. The system displays category list.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.32: Use Case Description of Add Category (Mobile application).

Use Case Name: Add Category	ID: 31	Importance Level: High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakaholdars and Interasts:		
Stakeholders and interests.		
Manager – wants to add a category.		

Describes how the manager adds category.

Trigger: When a manager wants to add category.

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error Message
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the category page of the mobile application.
- 2. The manager clicks the add button.
- 3. The system shows a modal contains an input field asking for category name.
- 4. The manager types a category name in the input field.
- 5. The manager clicks the ok button.

If the manager did not provide any category name.

Perform exceptional flow E-1.

If the manager provides the duplicate category name.

Perform exceptional flow E-2.

- 6. The system adds a new category.
- 7. The system shows a success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays a validation error message.
- 2. The manager types the category name again.

E-2

- 1. The system alerts the manager that same category name already exists.
- 2. The manager types the new category name again.

Table 4.33: Use Case Description of Edit Category (Mobile application).

Use Case Name: Edit C	ategory	ID: 32	Importance Level: High
Primary Actor: Manage	r	Use Cas	e Type: Detail Real
T Tilling Tietor. Wallage		050 045	ie Type: Detail, Real
Stakeholders and Intere	sts:		
Manager –wants to edit	a category.		
Description:			
Describes how the man	ager edits a cat	tegory.	
Trigger: When a manag	er wants to edi	it a catego	ory.
Relationships:			
1			
A •			
Association	: Manager		
Include	: Validate Input		
Extend	: Display Va	lidation E	Error Message
Generalization	:		

Normal Flow of Events:

- 1. The manager navigates to the category page of the mobile application.
- 2. The manager clicks the more button from the category list.
- 3. The manager clicks the edit selection.
- 4. The system shows a modal contains an input field asking for a new category name.
- 5. The manager types a new category name in the input field.
- 6. The manager clicks the ok button.

If the manager did not provide any category name.

Perform exceptional flow E-1.

If the manager provides the same category name as before.

Perform exceptional flow E-2.

If the manager provides duplicate category name.

Perform exceptional flow E-3.

- 9. The system updates the category name.
- 10. The system shows a success message.
- 11. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system displays a validation error message.
- 2. The manager types the category name again.

E-2

1. The system closes the modal.

E-3

- 3. The system alerts the same category name already exists.
- 4. The manager types the new category name again.

Use C	Case Name: Remove Category	ID: 33	Importance Level: High	
Prima	ary Actor: Manager	Use Cas	e Type: Detail, Real	
Stake	holders and Interests:			
Mana	ager –wants to remove a car owned	er's catego	ory.	
Desci	ription:			
Desci	ribes how the manager removes a	a car owne	er's category.	
Trian	when a manager wants to rea		n autocomi	
Ingg	er: when a manager wants to rer	nove a ca	r owner's category.	
Dalat	ionshino.			
Relat	ionsmps:			
	Association · Managar			
	Association . Manager	ant Massa	~	
	Entend	ert Messag	ge	
	Extend :			
	Generalization :			
NT				
Norm	hal Flow of Events:			
1				
1.	The manager navigates to the ca	itegory pa	ige of the mobile application.	
2.	2. The manager clicks the more button from the category list.			
3.	3. The manager clicks the remove selection.			
4.	4. The system shows an alert modal to warn the manager.			
5.	5. The manager clicks the confirm button.			
6.	6. The system deletes the category.			
7.	The system shows a success me	ssage.		
8.	The system closes the alert mod	al.		

Table 4.34: Use Case Description of Remove Category (Mobile application).

Sub-flows:

Alternate/Exceptional Flows:

Table 4.35: Use Case Description of View Car Owners' Personal Information (Mobile application).

Use Case Name: View Car Owner	s' ID: 34	Importance Level: High			
Personal Information					
Primary Actor: Manager	Use Cas	e Type: Detail, Real			
Stakeholders and Interests:					
Manager – wants to view the car ov	vners' persor	nal information.			
Description					
Description.	1	1			
Describes how the manager view t	he car owner	s' personal information.			
Trigger: When a manager wants to	view the car	owners' personal			
information.					
Relationships:					
Association : Manage	r				
Include :					
Extend :					
Generalization :					
Normal Flow of Events:					
1. The manager navigates to th	1. The manager navigates to the person page of the mobile application.				
2. The system displays the list of registered car owners.					
2 The manager alights on the a	3. The manager clicks on the one of the car owners.				

- 4. The system navigates to the person edit page.
- 5. The system shows the car owner's detail information.
- 6. The manager views the personal information.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.36: Use Case	Description	of Register C	ar Owner (Mobile application)
	1	0	(11 /

Use Case Name: Registe	er Car Owner	ID: 35	Importance Level: High
Primary Actor: Manager	r	Use Cas	e Type: Detail, Real
Stakeholders and Interes	sts:		
Manager –wants to regis	ster a new car	owner.	
Description:			
Describes how the man	or registers a	new car	owner
Deserves now the man			owner.
Trigger: When a manage	er wants to reg	gister a ne	w car owner.
Relationships:			
Association	: Manager		
Include	: Validate In	put	
Extend	: Display Va	lidation E	rror
Generalization	:		

Normal Flow of Events:

- 1. The manager navigates to the person page of the mobile application.
- 2. The manager clicks on the add button.
- 3. The system navigates to the add page.
- 4. The manager provides the car owner's name, car plate number, phone number, category, and person detail in the form.
- 5. The manager clicks the submit button.
- 6. The system validates all the input fields.If the manager did not fill all the necessary input fields.

Perform exceptional flow E-1.

If the manager provides a duplicate car plate number.

Perform exceptional flow E-2.

- 7. The system shows a loading message.
- 8. The system adds a car owner.
- 9. The system shows the success message.
- 10. The system navigates to the person page.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system shows an error message asking the manager to fill all the required fields.
- 2. The manager fills all the required input fields.
- E-2
 - 1. The system alerts the manager that the current car plate number already exists.
 - 2. The manager fills a new car plate number.

Table 4.37: Use Case Description of Edit Car Owner's Personal Information (Mobile application).

Use Ca	ase Name: Edit Car Owner's	ID: 36	Importance Level: High	
Person	al Information			
Primar	Primary Actor: Manager Use Case Type: Detail, Real			
Stakeh	olders and Interests:			
Manag	er –wants to edit the car owner'	s persona	l information.	
Descri	ption:			
Descri	bes how the manager edits the c	ar owner'	s personal information.	
Trigge	r: When a manager wants to edi	t the car o	wner's personal information.	
Relatio	onships:			
	Association : Manager			
]	Include : Validate Inj	put		
]	Extend : Display Val	lidation E	rror	
Generalization :				
Norma	l Flow of Events:			
1. ′	The manager navigates to the pe	erson page	e of the mobile application.	
2. 7	The system displays the list of r	egistered	car owners.	
3. 7	The manager clicks on the one o	of the car	owners.	
4. ′	The system navigates to the pers	son edit p	age.	
5. 7	The manager provides the new o	ear owner	's name, car plate number,	
1	phone number, category, or pers	on detail	in the form.	
6. 7	The manager clicks the submit b	outton.		
7. 7	The system validates all the inpu	ut fields.		

If the manager leaves the necessary input fields empty.

Perform exceptional flow E-1

If the manager provides a duplicate car plate number.

Perform exceptional flow E-2

8. The system shows a loading message.

9. The system updates the car owner.

10. The system shows the success message.

11. The system navigates to the person page.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system shows an error message asking the manager to fill all the required input fields.
- 2. The manager fills all the required input fields.
- E-2
 - 1. The system alerts the manager that the current car plate number already exists.
 - 2. The manager fills a new car plate number.

Table 4.38: Use Case Description of Remove Car Owner (Mobile application).

Use Case Name: Remove Car Owner	ID: 37	Importance Level: High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager –wants to remove the car ow	mer.	

Describes how the manager removes the car owner.

Trigger: When a manager wants to remove the car owner.

Relationships:

Association	: Manager
Include	: Display Alert Message
Extend	:
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the person page of the mobile application.
- 2. The manager clicks the more button from the list of car owners.
- 3. The manager clicks on the remove selection.
- 4. The system displays a confirmation modal.
- 5. The manager clicks the ok button.
- 6. The system deletes the car owner.
- 7. The system shows the success message.
- 8. The system closes the confirmation modal.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.39: Use Case Description of Search Car Owner (Mobile application).

Use Case Name: Search Car Owner	ID: 38	Importance Level: High

Prima	ary Actor: Manager	Use Case Type: Detail, Real	
Stake	holders and Interests:		
Mana	ger –wants to search the car own	ier.	
Desci	ription:		
Desci	ribes how the manager searches t	he car owner.	
Trigg	er: When a manager wants to sea	arch the car owner.	
Relat	ionships:		
	Association Manager		
	Association : Manager		
	Extend : Search by	Name Search by Car Plate Number	
	Search by Phone Number	Ivanie, Search by Car Flate Ivaniber	
	Generalization :		
Norm	al Flow of Events:		
1.	The manager navigates to the pe	erson page of the mobile application.	
2.	The manager input the search da	ata in the search field.	
3.	The system will perform query	on the database.	
4.	4. The system returns the search result.		
Sub-f	lows:		
Alterr	nate/Exceptional Flows:		

Table 4.40: Use Case Description	of	View	all	Created	User	Accounts	(Mobile
application).							

Use Case N	Jame: View all Created	ID: 39	Importance Level: High
User Acco	unts		I man a second
Primary Ac	ctor: Manager	Use Cas	e Type: Detail, Real
Stakeholde	rs and Interests:		
Manager –	wants to view all created us	ser accour	its.
Description	1:		
Describes l	now the manager view all c	reated use	er accounts.
	C		
Tui a a su XX	1		
Irigger: w	nen a manager wants to vie	ew all crea	ated user accounts.
Deletionsh			
Relationsh	ips:		
Asso	ociation · Manager		
Inclu	ide :		
Exte	nd :		
Gene	eralization :		
Normal Flo	ow of Events:		
1. The	manager navigates to the us	ser page o	f the mobile application.
2. The	system displays listing of th	ne user ac	counts.
3. The	3. The manager clicks on a user account from the list.		
4. The	system shows a model cont	aining all	the account's information.
5. The	5. The manager closes the model.		
Sub-flows:			
1			

Table 4.41: Use Case Description of Create new User Account (Mobile application)

	ID 40	.			
Use Case Name: Create new User	ID: 40 Importance Level: H				
Account					
Primary Actor: Manager	Use Cas	e Type: Detail, Real			
Stakeholders and Interests:					
Manager –wants to create a new user	account.				
Description:					
Describes how the manager creates a	new user a	account.			
Trigger: When a manager wants to cre	eate a new	user account.			
Relationships:					
Association : Manager					
Include : Assign Use	er Role, V	alidate Input			
Extend : Display Va	lidation E	rror Message			
Generalization :	Generalization :				
Normal Flow of Events:					
Normal Prow of Events.					
1. The manager navigates to the user page of the mobile application.					
2. The manager clicks the add button.					

- 3. The system shows a modal containing a form, the form contains input fields such as username, password, email, phone number and role.
- 4. The manager provides all the necessary data (username, password and

role)

5. The manager clicks the ok button.

If the manager did not provide all the required data.

Perform exceptional flow E-1.

If the manager provides a duplicate username.

Perform exceptional flow E-2.

- 6. The system created a new user account and assign the corresponding role to it.
- 7. The system shows a success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

- 1. The system shows the error message asking the manager to complete all the required input fields.
- 2. The manager completes all the required input fields.
- E-2
 - 1. The system shows the alert message notify the manager that the same username already exists.
 - 2. The manager types a new username.

Table 4.42: Use Case Description of Edit User Account (Mobile application)

Use Case Name: Edit User Account	ID: 41	Importance Level: High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager –wants to edit the user accou	int.	

Describes how the manager edits the user account.

Trigger: When a manager wants to edit the user account.

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error Message
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the user page of the mobile application.
- 2. The manager clicks the more button from list of user accounts.
- 3. The manager clicks the edit selection.
- 4. The system shows a modal containing a form, the form contains input fields such as username, password, email, phone number and role.
- 5. The manager provides all the necessary data (username, password and role)
- 6. The manager clicks the ok button.

If the manager did not provide any new data.

Perform exceptional flow E-1.

If the manager did not provide all the required data.

Perform exceptional flow E-2.

If the manager provides a duplicate username.

Perform exceptional flow E-3.

- 7. The system updates the user account.
- 8. The system shows a success message.
- 9. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

1. The system closes the modal.

E-2

- 1. The system shows the error message asking the manager to complete all the required input fields.
- 2. The manager completes all the required input fields.

E-3

- 1. The system shows the alert message notify the manager that the same username already exists.
- 2. The manager types a new username.

 Table 4.43: Use
 Case
 Description
 of
 Remove
 User
 Account
 (Mobile application).

Use Case Name: Remove User	ID: 42	Importance Level: High	
Account			
Primary Actor: Manager	Use Cas	e Type: Detail, Real	
Stakeholders and Interests:			
Manager – wants to remove the user account			
Description:			
Describes how the manager removes t	he user ac	count.	
Trigger: When a manager wants to rer	nove the u	user account.	

Relationships:

Association	: Manager
Include	: Display Alert Message
Extend	:
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the user page of the mobile application.
- 2. The manager clicks on the more button from the list of user accounts.
- 3. The manager clicks on the remove selection.
- 4. The system displays a confirmation modal.
- 5. The manager clicks the ok button.
- 6. The system deletes the user account.
- 7. The system shows the success message.
- 8. The system closes the confirmation modal.

Sub-flows:

Alternate/Exceptional Flows:

Table $4.44 \cdot$	Use Case	Description	of View	Roles	(Mohile	application)
1 abie 4.44.	Use Case	Description	UI VIEW	Ruies	(moone	application

Use Case Name: View Roles	ID: 43	Importance Level: High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests: Manager –wants to view all the roles.		

Describes how the manager views all the roles.

Trigger: When a manager wants to view all the roles.

Relationships:

Association: ManagerInclude:Extend:Generalization:

Normal Flow of Events:

- 1. The manager navigates to the role page of the mobile application.
- 2. The system displays a table listing all the roles.

Sub-flows:

Alternate/Exceptional Flows:

Table 4.45: Use Case Description of Create new Role (Mobile application).

Use Case Name: Create new Role	ID: 44	Importance Level: High
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager – wants to create a new role.		

Describes how the manager creates a new role.

Trigger: When a manager wants to create a new role.

Relationships:

Association	: Manager
Include	: Validate Input
Extend	: Display Validation Error Message
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the role page of the mobile application.
- 2. The manager clicks the add button.
- 3. The system shows a modal asking the manager to input a role name.
- 4. The manager types a role name in the input field.
- 5. The manager clicks the ok button.
- 6. The system validates the input field.

If the manager leaves the input field empty.

Perform exceptional flow E-1.

If the manager provides a duplicate role name.

Perform exceptional flow E-2.

- 7. The system shows the success message.
- 8. The system closes the modal.

Sub-flows:

Alternate/Exceptional Flows:

E-1

1. The system shows a validation error message.

2. The manager types the role name again.

E-2

- 1. The system alerts the manager that the same role name already exists.
- 2. The manager types a new role name.

Table 4.46: UseCaseDescriptionofAssignPagestoRole(Mobileapplication).

Use Case Name: Assign	Pages to	ID: 45	Importance Level: High
Role	-		
Primary Actor: Manager	ſ	Use Cas	e Type: Detail, Real
Stakeholders and Interes	sts:		
Manager – wants to assig	gn pages to a r	ole.	
Description:			
Describes how the mana	iger assigns pa	iges to a r	ole.
Trigger: When a manage	er wants to ass	sign pages	s to a role.
		010	
Relationships:			
Association	: Manager		
Include	:		
Extend	:		
Generalization	:		
Normal Flow of Events:			
1 The manager nay	vigates to the r	ole nage (of the mobile application
2. The manager alieks the more bytten from the list of roles			
2. The manager checks the more button from the list of fores.			
3. The manager clicks the edit selection.			

4.	The system displays a modal with checkboxes for the manager to
	assign the pages this role has access to.
5.	The manager clicks on the checkboxes.
6.	The manager clicks the ok button.
7.	The system shows the loading message.
8.	The system assigns the pages to the role.
9.	The system shows the success message.
10.	The system closes the modal.
Sub-fl	ows:
Alterna	ate/Exceptional Flows:

Use Case Name: Remove Role	ID: 46	Importance Level: High
	U C	
Primary Actor: Manager	Use Cas	e Type: Detail, Real
Stakeholders and Interests:		
Manager –wants to remove a role.		
Description:		
Describes how the manager remove a	role.	
Trigger: When a manager wants to ren	nove a ro	le.

Table 4.47: Use Case Description of Remove Role (Mobile application)

Relationships:

Association	: Manager
Include	: Display Alert Message
Extend	:
Generalization	:

Normal Flow of Events:

- 1. The manager navigates to the role page of the mobile application.
- 2. The manager clicks more button from the list of roles.
- 3. The manager clicks the remove selection.
- 4. The system displays a confirmation modal.
- 5. The manager clicks the ok button.
- 6. The system shows the loading message.
- 7. The system deletes the role.
- 8. The system shows the success message.
- 9. The system closes the confirmation modal.

Sub-flows:

Alternate/Exceptional Flows:
CHAPTER 5

SYSTEM DESIGN

5.1 Introduction

In this chapter, an overview of the system architecture design for this project will be discussed first. The system architecture can be divided into three parts, namely mobile application architecture, web architecture and cloud services architecture. After discussing the system architecture, the database design of this project is also discussed. The database design is divided into three parts, namely logical entity relationship diagram, physical entity relationship diagram and data dictionary.



5.2 Overview of System Architecture Design

Figure 5.1: Overview of System Architecture Design.

This project architecture design mainly has four components, user, developer, database, and cloud. In the database layer, it has the Firebase and Algolia services, Firebase plays the most important role, it is responsible to handle CRUD data operations and it supports real-time update functionality. At the same time, Firebase has an extension plug-in, that is, Algolia. Algolia is used as the search service of this project because Firebase's native data search capabilities are not excellent, for example, Firebase does not support fuzzy queries. Using Algolia can facilitate the project to query data and realize paging functionality. The relationship between Firebase and Algolia is a parent-child relationship. For example, when new data is inserted into the Firebase collection, the data will be synchronized to the Algolia database. Any operation on the data in the Firebase database will be reflected in the Algolia database.

The mobile application of this project is built using the React Native framework. User can directly access Firebase and Algolia services through the mobile application to operate and retrieve data. The detailed architecture of mobile applications will be discussed in **Section 5.4**.

The web application for this project is built using the React framework, which then uses the Node.js Express framework to serve the React application. In order to ensure that the web application can run in different Linux environments, the project uses Docker to dockerize the Node.js web application. Finally, the project's web application runs in Docker container on the AWS servers. The detailed architecture of web applications will be discussed in **Section 5.5**.

This project utilizes five main AWS cloud services, which are Route53, Certificate Manager, AWS Load Balancer, EC2 and Cloud Watch services. The web application of this project runs on the EC2 instances of AWS, and user access the web application of the project by accessing the instances. In addition, this project also uses Github Actions to promote CI/CD flow. Any git push by the developer on the project will cause the project to be redeployed on the AWS server. The detailed cloud architecture will be discussed in **Section 5.6**.

5.3 The React Architecture



Figure 5.2: React Architecture (ReactJS – architecture, 2023).

At the core of React's architecture is the concept of components, which are modular building blocks. Components can be composed together to form more complex UIs, and they can also be reused across different parts of an application. The React App is the root of the React application, the react application starts with it. It typically consists of one or more components that are responsible for rendering the UI of the application and it is often used to manage the application state and to pass down data to the child components. A React Component is a modular building block that encapsulates a piece of UI functionality. It is typically reusable and can be composed together with other components. React UI Components are pre-built components that can be used to create the UI of the application. They typically handle common UI tasks such as input validation, button click handling, and form submission. For example, the buttons, forms, text inputs, and dropdowns are React UI Component.

React Third-Party Components are components that are developed by third-party developers and can be imported into a React application to provide additional functionality. For example, the project uses Router Management (React Router and React Navigator) to manage the navigation in React and React Native Application, Animation Management (react-animations) is responsible for adding animations to the project's component. Other than that, the State Management (Redux) helps to manage the state of the React and React Native application, in this project, it is mainly used to store user information so that the currently logged in user information is available in all components. For the REST API Management (Firebase and Algolia), the project use Firebase and Algolia native function to send request to the Firebase and Algolia. It is often used in the React and React native applications to fetch data from the servers and update the UI accordingly.

5.4 The Mobile Application Architecture



Figure 5.3: Mobile Application Architecture.

There are two main layers in the Mobile Application system architecture, namely the presentation layer and the database layer. The React Native Component of this project is responsible for business logic processing and information display. By calling the native functions of Firebase and Algolia, client can send requests and receive the response data. When the returned data updates the state in the React native's component, it will cause the component to re-render and update information to the page. In addition, React Native can also monitor the collections of Firebase. When the monitored collections change, Firebase will push the changed data to the monitoring components.

Developer uses GitHub's Release to publish the latest apk file, and user download it through the GitHub link.



5.5 The Web Architecture

Figure 5.4: Web Architecture

The architecture design of this web project is mainly composed of react, NodeJS, ExpressJS, docker and the database services (Firebase and Algolia).

The npm run build command in React project is to create a production ready version of the application which consists of static html, css and javascript and they are ready to be hosted on Express.js server. Server.js is a JavaScript file that contains the code to start an Express.js server. The express.static() method is used to serve static files. By running `npm run start` command, it will start the Express.js server that runs on 8000 port and serve the React application.

The Dockerfile is a text file that contains instructions for building a Docker image, that is to build the Express.js web application to a docker image in this project. Docker Compose is a tool for defining and running multi-container Docker applications. It uses a YAML file, called docker-compose.yml. Docker-compose.yml is used to define and configure Docker services that run as a part of a Docker Compose application.

The Dockerfile to be run is specified in the docker-compose.yml file. Docker Compose uses `docker compose up -d` command to package the express.js web project into a docker image and run the docker image in the docker container to provide services to users. In this project, it maps port 8000 in the container to port 80 on the host machine. This means that accessing port 80 of the host machine will access the Express.js web application running on port 8000 in the docker container.

The entire web project runs in a docker container. This web project mainly includes presentation layer and database layer, and React Component is responsible for processing the corresponding business logic and information display. After using npm to install related Firebase and Algolia's library in the React project, the React Web project can send requests to the database and process the returned results by calling their respective functions. The returned result will update the state of React Component. Once the state of React is updated, the current component will be re-rendered to present the latest data to the user. In addition, Firebase has the feature of real-time update. The React web project can monitor the collections of Firebase. If the data in the collection changes, Firebase will return the changed data to the corresponding React Component.

Target Group Monitor HTTPS Port:443 EC2 Invoke via Domain (Redirect to port:443) https://alprtech.link Monitor Amazon Route 53 EC2 GitHub Actions AWS Certificate Manage AWS Budget Alerts & Notification **Budget creation** Actions ng ceive alerts when the budget exceeds s to cost control per the requirement

5.6

The Cloud Architecture

Figure 5.5: Cloud Architecture

In the cloud architecture, the main components are Route53, Certificate Manager, AWS Load Balancer, EC2, Amazon CloudWatch, AWS Budgets, Developer and Github Actions. This section will first explain the purpose of each cloud service, and then the entire project flow is presented.

Amazon Route 53 is a reliable DNS web service. Domain name for this project is purchased from it, and it helps to convert domain names to IP addresses. It can also configure traffic routing policies to direct traffic to the servers where the project is running.

Certificate manager provides SSL/TLS certificates. SSL/TLS certificates will ensure that the web pages are encrypted by HTTPS, which will secure network communications and help protect sensitive information.

AWS ALB routes incoming traffic to backend servers, the backend servers refer to the EC2 instances. It is designed to handle Hypertext Transfer Protocol (HTTP) and HTTPS traffic and use round robin algorithms to distribute traffic across the EC2 instances. AWS Target Groups are a logical grouping of backend servers that are registered with an ALB. The ALB routes the request to the appropriate target group based on the routing rules defined in the load balancer configuration.

AWS CloudWatch is a monitoring and observability service provided by AWS. It can monitor the status checks of the EC2 instances and automatically take action when status check fails. The status checks can detect issues such as network connectivity problems, hardware issues, or software configuration errors. The issues are AWS internal issues.

EC2 instance is a virtual server in the AWS cloud that can run applications or services. Each instance runs on a physical host machine that is located in one of the AWS data centers.

Github Actions is a powerful automation tool. In this project, it allows the developer to build, test, and deploy web application directly from the GitHub repository to the EC2 instances. It provides a way to automate the entire software development workflow, from code changes to deployment, in a single place.

AWS Budgets is a free service provided by AWS that helps to manage AWS cost and usage. In this project, the budget is 12 USD per month. When the cost exceeds the budget thresholds, it will send an email to the developer and take corresponding actions on the EC2 instances.

Next, the entire cloud architecture process is discussed. First of all, developer must establish connection with the two AWS's EC2 instances, GitHub Runner is installed on the them so that Github Actions workflow can be executed when there is a new git push on GitHub repository. Automate tasks are defined in Github Actions. It will first stop and remove all docker images and docker containers from the host machine and Github Actions will execute docker compose up -d command to repackage Express.js web application into docker image, and run it in host machine's docker container. This entire process will be executed on the two AWS EC2 instances. In this way, the entire web project is redeployed on EC2 instances.

After that, the whole flow of users accessing web application in EC2 instances is discussed. By entering https://alprtech.link in the browser, the

traffic will be brought to the Route53 service. The Route53 of the project defines that traffic pointing to the domain name alprtech.link is directed to AWS Application Load Balancer. Application Load Balancer listens on port 80 and listens on port 443 with the help of AWS certificate manager. At the same time, the traffic going toward the port 80 is redirected to port 443 to ensure that the HTTPS encryption service is used. The main purpose of Application Load Balancer in the project is to provide higher stability. By bundling two EC2 instances into a Target Group, Application Load Balancer can direct traffic to the EC2 instances. If one of the EC2 instances fails, at least another server is still up and running.

Amazon CloudWatch is responsible for monitoring the health of EC2 instances. If the status check of EC2 instances failed. The Amazon CloudWatch will try to reboot the failing instances. This project also uses the AWS Budgets service to control costs, when the project cost reaches 12 USD, AWS Budgets will send an email to the developer and stop the AWS EC2 service.

5.7 Database design

This section will discuss Logical Entity Relationship Diagram and Physical Entity Relationship Diagram. These ERD diagrams show the relationship between each collection in Firebase's Firestore. In addition, this chapter also discusses the data dictionary of each Firestore collection to show the attribute and description of each field. Firestore uses the NoSQL method to store data. This project has five collections, and all data is stored in these five collections.

5.7.1 Logical Entity Relationship Diagram



Figure 5.6: Logical Entity Relationship Diagram

5.7.2 Physical Entity Relationship Diagram



Figure 5.7: Physical Entity Relationship Diagram.

5.7.3 Data Dictionary

Field Name	Data Type	Description	Key	FK Reference Collection	Nullable
id	String	Unique	PK, AI	-	No
		Document ID			
category	String	Category name	-	-	No
createdAt	Timestamp	Datetime when	-	-	No
		this document			
		was created			

 Table 5.1: Data Dictionary (Category Collection).

 Table 5.2: Data Dictionary (Registration Collection).

Field Name	Data Type	Description	Key	FK Reference Collection	Nullable
id	String	Unique	PK, AI	-	No
		Document			
		ID			
carPlate	String	Category	-	-	No
		name			
name	String	Car owner's	-	-	No
		name			
phoneNumber	String	Car owner's	-	-	No
		phone			
		number			
detail	String	Car owner's	-	-	Yes
		phone detail			
category	String	Category	FK	category	No
		collection's			
		document id			
		of this car			
		owner			

createdAt	Timestamp	Datetime	-	-	No
		when this			
		document			
		was created			

Table 5.3: Data Dictionary (Carpark Collection)

Field Name	Data Type	Description	Key	FK Reference Collection	Nullable
id	String	Unique Document ID	PK, AI	-	No
carPlate	String	Car plate number	-	-	No
enterOrExit	String	Determine the car access type, it is enter or exit	-	-	No
image	String	Car plate image URL link	-	-	No
ownerID	String	Registration collection's document id of this record	FK	registration	No
createdAt	Timestamp	Datetime when this document was created	-	-	No

 Table 5.4:
 Data Dictionary (Role Collection).

Field				FK	
Name	Data Type	Description	Key	Reference Nullab	Nullable
				Collection	

id	String	Unique	PK, AI	-	No
		Document ID			
role	String	Role name	-	-	No
authorizer	String	Which user	-	-	No
		authorize this			
		role			
authAt	String	Date time when	-	-	No
		the user			
		authorizes this			
		role			
menuList	String	The mobile and	-	-	No
		web pages that			
		this role can			
		view			
createdAt	Timestamp	Datetime when	-	-	No
		this document			
		was created			

 Table 5.5:
 Data Dictionary (User Collection).

Field Name	Data Type	Description	Key	FK Reference Collection	Nullable
id	String	Unique	PK, AI	-	No
		Document			
		ID			
username	String	Account's	-	-	No
		username			
password	String	Account's	-	-	No
		password			
email	String	User's email	-	-	Yes
phoneNumber	String	User's	-	-	Yes
		phone			
		number			
					•

role	String	Role	FK	role	No
		collection's			
		document id			
		of this			
		account			
createdAt	Timestamp	Datetime	-	-	No
		when this			
		document			
		was created			

CHAPTER 6

SYSTEM IMPLEMENTATION

6.1 Introduction

This chapter discusses the implementation details of ALPR web and mobile applications. It includes packaging React Native project into APK and publishing them on GitHub release, setting up AWS services to host the ALPR web application, and using Github Actions to automatically redeploy the web project on EC2 instances. In addition, this chapter lists the Firestore, Algolia functions and custom functions used by the project. Finally, all the pages and functions of Mobile and Web applications will be displayed in detail and the corresponding functions will be explained with section code.

6.2 Build React Native Application and Publish on GitHub

Android requires all applications to have a digital signature before they are allowed to be installed on the user's mobile phone. The first step is to generate an Android signature key, which can be achieved with the help of the JDK tool. Navigate to the bin directory of jdk and execute the following command: "keytool -genkeypair -v -keystore my-release-key.keystore -alias my-key-alias -keyalg RSA -keysize 2048 -validity 10000". This command requires the password for the keystore and the corresponding key, as well as some distribution-related information.After that, a my-release-key.keystore key file will be generated in the current bin directory.



Figure 6.1: Generate Key File.

Move this key file to the android/app folder in the React Native project. Then edit the gradle.properties under the project directory /android/, and add variables in this file. The added code is shown in Figure 6.2.



Figure 6.2: Edit gradle.properties file.

Edit android/app/build.gradle in the project directory, and add the signature configuration from Figure 6.3:



Figure 6.3: Edit build.gradle File.

After that, open a terminal and navigate to the root directory of the React Native project. Execute the following command:

- i. cd android
- ii. gradlew assembleRelease

The first line of command means to enter the android directory. The second line of commands means to execute the gradlew script file in the current directory and package the react native project into an apk file. After that, apk file will be generated in the directory an of android/app/build/outputs/apk/release. This apk file is ready to be installed on the user's phone.



Figure 6.5: Directory of Apk File.

This apk file can then be uploaded to GitHub for users to download. Figures 6.6, 6.7, and 6.8 shows the steps to upload apk to GitHub Release.

0	<> c	ode 💿 Issues	11 Pull requests 🕟 Actions 🗄	Projects 🕛 S	Security 🗠 Insights	
	ų	master 👻	Go to file Add file *	<> Code -	About	钧
	4	hahaong fix login	check … 2 w	eeks ago 🕚 31	rnALPR for utar ☆ 0 stars	
		.bundle	completed Home	8 months ago	 1 watching 	
		tests	completed Home	8 months ago	😵 0 forks	
		algoliasearch	done a lot	month		
		android	add max-length on text input field	2 weeks ago	Releases 1	
		арі	fix login check	2 weeks ago	S weeks ago	
		assets	filter search in home.jsx under dev	last month		
		components	remove console.log&fix add check	3 weeks ago	Packages	
		constants	user credentail will auto logout wh	3 weeks ago	No packages published	
		firebase	doing category page, this is a versi	2 months ago	Publish your first package	

Figure 6.6: GitHub Project Repository.

Alpr APK file Latest			· / û
and this 3 weeks ago - 12 commits to master since this release	♥ 1.0	-O- 6ef024f	
Alpr APK file			
▼Assets (3)			
		38.2 MB	2 weeks ago
Source code (zip)			3 weeks ago
Source code (tar.gz)			3 weeks ago
9			



Releases Tags				
♡ 1.0 -✓ Existing tag				
Alpr APK file				
Write Preview				
$\vdash B \ I \ \equiv \diamondsuit \ \mathscr{O} \ \boxminus \ \equiv \wr \equiv \ \mathfrak{S} \ \textcircled{O} \ \varsigma \ \backsim$	Fevious tag: auto 🔹 Generate release notes			
Alpr APK file				
Attach files by dragging & dropping, selecting or pasting them.	EU			
Alpr.apk	(38.2 MB) ×			
\downarrow Attach binaries by dropping them here or selecting them.				
Set as a pre-release This release will be labeled as non-production ready				
Set as the latest release This release is labeled as the latest for this repository.				
Update release	_			



6.3 Setup AWS Services.

This section discussed the steps to setup AWS EC2 instances, use the Amazon CloudWatch to monitor EC2 instances, use the Route53 services purchasing project's domain name, and use the AWS Certificates Manager to apply for a certificate and secure the domain name with HTTPS encryption. Afterward, the steps to setup the AWS Application Load Balancer and configuration of Route53 to direct incoming traffic to the load balancer are discussed. In addition, this part also discussed the use of AWS Budgets to monitor the cost of the project and take corresponding measures when the threshold is exceeded.

6.3.1 Setup AWS EC2 instances.

First log in to the AWS account, navigate to the home page of EC2, and click the launch instance button to start a server to host the ALPR web project. Figure 6.9 shows the home page of the AWS EC2 service.

aws Services Q Search		[Alt+S]		
New EC2 Experience X	Launch instance To get started, launch an Amazon EC2 instance, which is a virtual server in the cloud.	Service health		
EC2 Dashboard	Launch instance A	AWS Health Dashboard [
Events	Launch instance	Region		
Tags	Launch instance from template	Asia Pacific (Sydney)		
Limits	Note: Your instanting launch in the Asia	Status		
▼ Instances		O This service is operating normally		
Instances Instance Types	Scheduled er ents C	Zones		
Launch Templates		7		
Spot Requests	Asia Pacific (Sydney)	Zone name Zone ID		
Savings Plans	No scheduled events	ap-southeast-2a apse2-az3		
Reserved Instances		ap-southeast-2b apse2-az1		
Dedicated Hosts Capacity Reservations	Migrate a server	ap-southeast-2c apse2-az2		
▼ Images		Enable additional Zones		

Figure 6.9: AWS EC2 Homepage.

Once AWS navigates to the page for configuring the EC2 instance, provide a server's name and select the Ubuntu version 22.04 LTS operating system. Figure 6.10 shows the step of entering the server's name and choosing the operating system.



Figure 6.10: Provide Server name and Choose OS.

Choose the t2.micro configuration, which provides a CPU core and 1 GB of ram. Then choose to create a security group that accepts SSH, HTTPS, and HTTP traffic. Figure 6.11 shows the steps to choose the instance type and create a network security group.

t2.micro Family: t2 1 vCPU 1 GiB Memory Current gene On-Demand Linux pricing: 0.0146 USD per Hour On-Demand Windows pricing: 0.0192 USD per Hour On-Demand SUSE pricing: 0.0146 USD per Hour On-Demand RHEL pricing: 0.0746 USD per Hour	Free tier eligible eration: true All generations Compare instance types
▼ Network settings Info	Edit
Network Info	
vpc-0725219415d59aff6	
Subnet Info	
Subnet Info No preference (Default subnet in any availabil	lity zone)
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info	lity zone)
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable	lity zone)
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info	lity zone)
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info A security group is a set of firewall rules that control fi instance.	lity zone) the traffic for your instance. Add rules to allow specific traffic to reach your
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info A security group is a set of firewall rules that control f instance. C Create security group	lity zone) the traffic for your instance. Add rules to allow specific traffic to reach your Select existing security group
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info A security group is a set of firewall rules that control t instance. C Create security group We'll create a new security group called 'laura	lity zone) the traffic for your instance. Add rules to allow specific traffic to reach your Select existing security group
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info A security group is a set of firewall rules that control t instance. C Create security group We'll create a new security group called 'launce	lity zone) the traffic for your instance. Add rules to allow specific traffic to reach your Select existing security group ch-wizard-1' with the following rules:
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info A security group is a set of firewall rules that control t instance. Create security group We'll create a new security group called 'launce We'll create a new security group called 'launce Allow SSH traffic from Heles up accepted to your instance Anyon	lity zone) the traffic for your instance. Add rules to allow specific traffic to reach your Select existing security group ch-wizard-1' with the following rules: where
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info A security group is a set of firewall rules that control f instance. Create security group We'll create a new security group called 'laund We'll create a new security group called 'laund Allow SSH traffic from Helps you connect to your instance	lity zone) the traffic for your instance. Add rules to allow specific traffic to reach your Select existing security group ch-wizard-1' with the following rules: where 0.0/0
Subnet Info No preference (Default subnet in any availabil Auto-assign public IP Info Enable Firewall (security groups) Info A security group is a set of firewall rules that control to instance. Image: Create security group We'll create a new security group called 'launce Image: Create and Create to your instance Image: Allow SSH traffic from Helps you connect to your instance Image: Allow HTTPS traffic from the internet To set up an endpoint, for example when creating	lity zone) the traffic for your instance. Add rules to allow specific traffic to reach your Select existing security group ch-wizard-1' with the following rules: where 0.0/0 g a web server

Figure 6.11: Choose Instance Type and Create Network Security Group.

Finally, give this server an 8G storage space, and click the launch instance button to start this server. Then repeat the same steps to start one more instance. Figure 6.12 shows the steps to set the storage and launch instance. The steps to install docker, GitHub runner and run the web project will be discussed in **Section 6.4**.

Configure storage info Advar X B GiB gp2 Root volume (Not encrypted) Free tier eligible customers can get up to 30 GB of EBS General Purpose (SSD) or Magnetic storage	nced	Free tier: In your hours of 12 micro Regions in which instance usage o month, 30 GiB o IOs, 1 GB of snap bandwidth to the	r first year includes 750 X o (or t3.micro in the t2.t2.micro is unavailable) on free tire AMIs per FEBS storage, 2 million schots, and 100 GB of internet.
And new volume The selected AMI contains more instance store volumes than the instance allows. Only the first 0 instance store volumes from the AMI will be accessible from the instance			Launch instance Review commands
• Advanced details Info	Edit		

Figure 6.12: Set Storage and Launch Instance.

6.3.2 Use AWS Amazon CloudWatch to Monitor EC2 instances.

First select the EC2 instance, click status check, and then create status check alarm. Figure 6.13 shows the create status check alarm steps.

	sitive) < 1 > 🧿
■ Name ▼ Instance ID	Instance state ▼ Instance type ▼ Status
alpr_server_2 i-030acdfa9126a	128d6 ⊙ Stopped ⊕Q t2.micro –
✓ alpr_server_1	477f5 ⊘ Running ⊕ Q t2.micro ⊘ 2/2
Details Security Networking	Storage Status checks Monitoring Tags
Status checks Info	2218934547765 (alor server 1) from rupping your applications
Status checks detect problems that may impair i_038e	zz 10034347713 (atpl_server_1) noni running your applications.
Status checks detect problems that may impair i-038e: Actions	
Status checks detect problems that may impair i-038e Actions Create status check alarm	Instance status checks
Status checks detect problems that may impair i-038e Actions Create status check alarm Report Instance status 20	Instance status checks Instance reachability check passed

Figure 6.13: Create Status Check Alarm.

Then create a new alarm, select reboot for the alarm action, select five minutes for the alarm thresholds period, and select 1 for the consecutive period, so when the status check of this EC2 instance fails once within five minutes, AWS CloudWatch will reboot this instance. Figure 6.14 shows the step to create CloudWatch alarm action. Repeat the same steps for the second instance.

Manage CloudWatch alarms Info Create or edit a CloudWatch alarm that monitors CloudWatch Add or edit alarm Info You can create a new alarm or edit an existing alarm.	h metrics for the instance.
 Create an alarm Create an alarm for i-038e22188345477f5 Search for alarm Find an alarm to modify Q Select an existing alarm to edit 	C Edit an alarm Edit an existing alarm for i-038e22188345477f5
Alarm action Info Specify the action to take when the alarm is triggered. Reboot	•
Alarm thresholds Specify the metric thresholds for the alarm.	
Group samples by Average Alarm when	Type of data to sample Status check failed: either
Failing Consecutive period 1	Period 5 Minutes
Alarm name awsec2-i-038e22188345477f5-GreaterThanOrEqualToTI	hreshold-StatusCheckFailed
	Cancel

Figure 6.14: CloudWatch Alarm Action

6.3.3 Use AWS Route53 to purchase domain name.

First, navigate to the main interface of Route53, select the Registered Domain page, and then click Register domain. Figure 6.15 shows the Route53 domain page.

Dashboard Hosted zones Health checks	The new We've re We are o	r Route 53 console experier designed the Route 53 conso continuing to make improvement	nce is now available ple to make it easier to use. Try o ents to the user experience base	but the new console. d on your feedback, sta	¥ y tuned!
IP-based routing CIDR collections Traffic flow	Register Domain	domains Transfer Domain	Domain Billing Report		3 0
Traffic policies Policy records	Q Search domain	s by prefix		≪ ≪ Displaying 1	to 1 out of 1 domains 🔌
Domains	Domain Name	 Privacy Protection 	Expiration Date	Auto Renew	Transfer Lock
Registered domains Pending requests	alprtech.link	All contacts	March 31, 2024	~	×

Figure 6.15: Route53 Domain Page.

Then search for the domain name of the project, click add to cart, and then click the continue button to purchase the domain name. Figure 6.16 shows the step to purchase the project's domain name.

alprtech		online - \$25	5.00 -	Check
Availability for 'alprtech	n.online'			
Domain Name	Status	Price /1 Year	Action	
alprtech.online	X Unavailable			
Related domain sugge	stions			
Domain Name	Status	Price /1 Year	Action	
alprtech.link	🖌 Available - In Cart	\$5.00	Add to cart	
alprtech.net	 Available 	\$11.00	Add to cart	
alprtech.ninja	 Available 	\$18.00	Add to cart	
alprtech.tv	🗸 Available	\$32.00	Add to cart	
alprtechgroup.com	 Available 	\$13.00	Add to cart	
alprtechgroup.online	 Available 	\$25.00	Add to cart	
alprtechnology.net	🖌 Available	\$11.00	Add to cart	
alprtechnology.online	 Available 	\$25.00	Add to cart	
alprtechsolutions.com	 Available 	\$13.00	Add to cart	
alprtek.com	✓ Available	\$13.00	Add to cart	
alprtek.net	 Available 	\$11.00	Add to cart	

Figure 6.16: Purchase Project's Domain Name.

Navigate To Route53's hosted zones page, the domain name of the project will be inserted into the record table of Route53 as a name server record. Figure 6.17 shows the name server record in Route53.

Route 53 X Route 53 Noted 200es alprtech.link Daabboard Delete zone Test record Configure query logging Hosted zones Hosted zone Test record Configure query logging Hosted zones Hosted zone Test record Configure query logging Hosted zone Hosted zone Edit hosted zone UP-based routing Clip collections Edit hosted zone details Edit hosted zone Traffic foolicis Policy records Import zone file Create record Policy records C Delete record Type V Routing pol Alias V Value/Route traffic to V Traffic foologing requests Neosliver Inbound endpoints Ightech.link NS Simple No ms-558.awsdm-50.net. Outbound endpoints Ightech.link SOA Simple No ms-558.awsdm-50.snet. Traffic policie.	aws III Services Q Search	[Alt+5]	
Dashboard Delete zone Test record Configure query logging Hosted zones + Hosted zone details Edit hosted zone Health checks Edit hosted zone Edit hosted zone * Hosted zones Records (2) DNSSEC signing Hosted zone tags (0) CDR collections Records (1/2) inte Traffic policies Policy records The following table lists the existing records in alpretch.link. You car't delete the SOA record or the NS record named alpretch.link. Allos ▼ < 1 > ② Domains Records tags records in alpretch.link. You car't delete the SOA record or the NS record named alpretch.link. Allos ▼ < 1 > ③ Policy records @ Return records by property or volue Type ▼ Routing ▼ Allas ▼ Value/Route traffic to ▼ TT Resolver VPCs Integrate.link. NS Simple No ns-538.awsdm-03.net. VPCs Libound endpoints alpretch.link. SOA Simple No ns-538.awsdm-03.net. awd	Route 53 ×	Route 53 > Hosted zones > alprtech.link	
Hosted zones Edit hosted zone Hosted zones Edit hosted zone Hosted zones Edit hosted zone Hosted zones Records (2) DNSSEC signing Hosted zone tags (0) ClDe collections Records (2) DNSSEC signing Hosted zone tags (0) Traffic flow Records (1/2) info Hosted zone flig Ceater record Import zone flig Traffic policies Import zone flig Ceater record Import zone flig Ceater record Import zone flig Ceater record Import zone flig Import zone f	Dashboard	eum alprtech.link 🗤	Delete zone Test record Configure query logging
 P-based routing CIDR collections Traffic flow Traffic flow Traffic policies Policy records Destate records in alpretch.link. You car't delete the SOA record or the NS record named alpretch.link. Policy records Dentains: Registered domains Pending requests Record name Type ▼ Routin ▼ Into ▼ Alias ▼ Value/Route traffic to ▼ TT rs-558 anxidns-03.net. ms-21489 anxidns-03.net. ans- 1489 anxidns-05.com. algretch.link SOA Simple - No ms-538 anxidns-03.net. ans.d 900 	Hosted zones Health checks	Hosted zone details	Edit hosted zone
 Traffic flow Traffic policies Policy records Densins Registered domains Pending requests Record name Type ▼ Routin ▼ Inter ▼ Alias ▼ Value/Route traffic to ▼ TT Traffic policies Record name Type ▼ Routin ▼ Inter ▼ Alias ▼ Value/Route traffic to ▼ TT rs-558.anxdns-05.net. rs-1489.anxdns-05.com. alptrechlink SOA Simple - No ns-558.anxdns-05.net.anxd 900 	 IP-based routing CIDR collections 	Records (2) DNSSEC signing Hosted zone tags (0)	
▼ Domains: Q. Filter records by property or volue Type ▼ Routing pol ▼ Alias ▼ < 1 > ● Registered domains: Pending requests: ■ Record name ▼ Type ▼ Routin ▼ Alias ▼ Value/Route traffic to ▼ ▼ Resolver vpCs ipleptech.link NS Simple - No rs-558 anodrs-05.net. rs-2024 anodrs-05.com. 17. Urbound endpoints Outbound endpoints: □ algreech.link SOA Simple - No ns-558 anodrs-05.com. 17.	 Traffic flow Traffic policies Policy records 	C Delete record Import zone file Create record	NS record named alpritecklink.
Registered domains Image: Constraint of the second name <	▼ Domains	Q. Filter records by property or value	Type Routing pol Alias Al
Resolver VPCs ipliptech.link Inbound endpoints indeprocess Outbound endpoints indeprocess indeprocess indeprocess indeprocess indeprocess	Registered domains Pending requests	■ Record name ▼ Type ▼ Routin	▼ Alias ▼ Value/Route traffic to ▼ TTL (s
Outbound endpoints DA Simple - No ns-538.awsdns-03.net.awsd 90	Resolver VPCs Inbound endpoints	alprtech.link NS Simple	ns-538.awsdns-03.net. ns-2024.awsdns-61.co.uk. ns-1409.awsdns-58.org. ns-42.awsdns-05.com.
Rules	Outbound endpoints Rules	alprtech.link SOA Simple	- No ns-538.awsdns-03.net. awsd 900

Figure 6.17: Name Server Record in Route53.

6.3.4 Use AWS Certificate Manager to Secure Domain Name with HTTPS.

First, navigate to the request certificate page of the AWS certificate manager. Click to request a public certificate. Enter the domain name of the project, select DNS validation, and click the request button.

AWS Certificate × Manager (ACM)	AWS Certificate Manager > Certificates > Request certificate Request certificate
Request certificate Import certificate AWS Private CA	Chrificate type Info AM certificates can be used to explore accure communications access across the internet or within an internal network. Choose the type of certificate for AcH to provide. • Request a public certificate from Amazon. By default, public certificates are trusted by browsers and operating systems. • Request a private certificate from Amazon. By default, public certificates are trusted by browsers and operating systems. • Request a private certificate from Amazon. By default, public certificates are trusted by browsers and operating systems. Requesting a private certificate requires the creation of a private certificate authority (CA). To create a private CA, visit AWS Private Certificate Authority Cancel Next

Figure 6.18: AWS Certificate Manager Page.

AWS Certificate Manager > Certificates > Request certificate > Request public certificate Request public certificate	
Domain names Provide one or more domain names for your certificate.	
Fully qualified domain name Info alprtech.link	
Add another name to this certificate You can add additional names to this certificate. For example, if you're requesting a certificate for "www.example.com", you might want to add the name "example.com" so that customers can reach your site by either name.	n
Validation method info Select a method for validating domain ownership. • DNS validation - recommended Choose this option if you are authorized to molify the DNS configuration for the domains in your certificate request. • Email validation Choose this option if you do not have permission or cannot obtain permission to modify the DNS configuration for the domains in your certificate request.	
Key algorithm Info Select an encryption algorithm. Some algorithms may not be supported by all AWS services.	
RSA 2048 RSA is the most widely used key type. ECDSA P 256 Equivalent in cryptographic strength to RSA 3072. ECDSA P 384 Equivalent in cryptographic strength to RSA 7680.	

Figure 6.19: Request Public Certificate for Domain Name

Figure 6.20 shows the page of the list of certificates, the project's domain name is still in the pending state. Click on the certificate ID to check the certificate detail.

AWS Certificate	×	() Launch	announcement						
Manager (ACM)		You can	now issue Elliptic Curve Digital S	ignature Algorithm (ECDSA) certifi	cates from ACM.	Learn more [2	and <u>let us</u>	know what	<u>you think</u> .
ist certificates		View all acm:Lis think.	l of your certificates stCertificates now supports n	nore details in each certificate sumr	mary. You can als	so view up to 5	00 certifica	tes per pag	e in the certi
nport certificate									
WS Private CA 🛛 🛛		AWS Cer	rtificate Manager 📏 Certificate	15					
		Cert	tificates (1)						
			Certificate ID	Domain name	▽	Туре	⊽	Status	*
			4cbc30c1-aca0-44b0-90fb- 41e9e2c0e657	alprtech.link		Amazon Issu	ued	Pend	ing validatio

Figure 6.20: List of certificates

Click the Create Records in Route53 button, this step is to use the Route53 DNS to validate the domain name of the project. After validation, the status of the certificate will change to success.

cbc30c1-aca0-44	b0-90fb-41e9e	2c0e657					Dele
Certificate status							
Identifier			Status				
4cbc30c1-aca0-44b0-90fb-41e96	2c0e657		Pending validation	Info			
ARN							
armaws:acm:ap-southeast-2	:270020915828:certificate/4c	bc30c1-aca0-44b0-90fb-41e9e2c0e657					
Type							
Amazon Issued							
Domains (1)		1			Create	e records in Route 53	Export to CSV 🕑
						R	< 1
Domain	Status	Renewal status	Туре	CNAME name		CNAME value	
alprtechlink	Pending validation		CNAME	d8182b40d0e3aea6143 ech.link.	3a5801d6ca063.alprt	D _77c53f63404ede7e4b7b kxpyp.acm-validations.aw	32239c55d2a0.btsc s.
Details							
in use		Serial number	Requested at		Renewal elig	gibility	
No		N/A	March 31, 2023, 17:06	5:13 (UTC+08:00)	Ineligible		
Domain name		Public key info	Issued at				
alprtech.link		RSA 2048	N/A				
Number of additional names		Signature algorithm	Not before				
0		SHA-256 with RSA	N/A				
		Can be used with	Not after				
		CloudFront, Elastic Load Balancing, API Gateway and other Internated services.	N/A				

Figure 6.21: Validate Domain Name in Certificate Detail Page.

6.3.5 Setup AWS Application Load Balancer.

Navigate to the load balancer interface of EC2 and click the create load balancer button, then choose to create an Application Load Balancer and give the application load balance a name.







Load Balancer Page.



ne Application Load Bal nequest attributes. Whe oplicable, it selects a tar	CallUII LOAD DataTICET Info lancer distributes incoming HTTP and HTTPS traffic across multiple targets such as Amazon EC2 instances, microservices, and containers, hen the load balancer receives a connection request, it evaluates the listener rules in priority order to determine which rule to apply, and i rget from the target group for the rule action.
How Elastic Lo	oad Balancing works
Basic configurati	ion
Name must be unique wit	thin your AWS account and can't be changed after the load balancer is created.
alpr_alb	
alpr_alb A maximum of 32 alphane	umeric characters including hyphens are allowed, but the name must not begin or end with a hyphen.
alpr_alb A maximum of 32 alphane Scheme Info Scheme can't be changed	umeric characters including hyphens are allowed, but the name must not begin or end with a hyphen.
alpr_alb A maximum of 32 alphani Scheme Info Scheme can't be changed Internet-facing An internet-facing loa	umeric characters including hyphens are allowed, but the name must not begin or end with a hyphen. I after the load balancer is created. ad balancer routes requests from clients over the internet to targets. Requires a public subnet. Learn more 🔀
alpr_alb A maximum of 32 alphani Scheme Info Scheme can't be changed Internet-facing An internet-facing loa Internal An internal load balar	umeric characters including hyphens are allowed, but the name must not begin or end with a hyphen. I after the load balancer is created. ad balancer routes requests from clients over the internet to targets. Requires a public subnet. Learn more 🚺
alpr_alb A maximum of 32 alphani Scheme Info Scheme can't be changed Internet-facing An internet-facing loa Internal An internal load balar IP address type Info Select the type of IP addr	umeric characters including hyphens are allowed, but the name must not begin or end with a hyphen. I after the load balancer is created. ad balancer routes requests from clients over the internet to targets. Requires a public subnet. Learn more 🔀 ncer routes requests from clients to targets using private IP addresses.
alpr_alb A maximum of 32 alphani Scheme (Info) Scheme can't be changed Internet-facing An internet-facing face Internat An internat load balar IP address type (Info) Select the type of IP addre IPv4 Recommended for int	umeric characters including hyphens are allowed, but the name must not begin or end with a hyphen. I after the load balancer is created. ad balancer routes requests from clients over the internet to targets. Requires a public subnet. Learn more 🗹 ncer routes requests from clients to targets using private IP addresses. resses that your subnets use. ternal load balancers.

Figure 6.24: Provide a Load Balancer Name.

Select all subnets in the network mapping option, because the EC2 instances of the project run in different subnets, it is to ensure that every subnet is within the scope of the load balancer.

Network mapping Info The load balancer routes traffic to targets in the selected subnets, and in accordance with your IP address settings.	
VPC Info Select the virtual private cloud (VPC) for your targets. Only VPCs with an internet gateway are enabled for selection. The selected VPC can't be changed after the load balancer is created. To confirm the VPC for your targets, view your target groups 2. • • • • • • • • • • • • • • • • • • • • • • • • • •	2
Mappings Info Select at least two Availability Zones and one subnet per zone. The load balancer routes traffic to targets in these Availability Zones only. Availability Zones that are not supported by the load balancer or the VPC are not available for selection.	ad
✓ ap-southeast-2a (apse2-az3) ✓ ap-southeast-2b (apse2-az1)	
ap-southeast-2c (apse2-az2)	

Figure 6.25: Select all the Subnet of VPC.

Create a security group for this load balancer. This security group is responsible for defining the inbound rule to ensure that the load balancer can receive HTTP and HTTPS traffic.

Security groups Info A security group is a set of firewall rules that control the traffic to yo	r load balancer.		
Security groups Select un to 5 security group [2] Create new security group [2] default sg-of90af46139a86b42 X VPC: vpc-0725219415d59aff6		• C	

Figure 6.26: Choose to Create Security Group

Security Groups Create security group Create security group and create security group into Create security group name info alpr_Ib_security_group Create security group name info alpr_Ib_security_group Create security group into Create security grou	Services Q	Search		[Alt+S]	
curity group acts as a virtual firewall for your instance to control inbound and outbound traffic. To create a new security group, complete the fields below.	> Security Groups	> Create security group			
Curlty group acts as a virtual firewall for your instance to control inbound and outbound traffic. To create a new security group, complete the fields below.	aata cacuri	hu aroun			
curity group acts as a virtual firewall for your instance to control inbound and outbound traffic. To create a new security group, complete the fields below. Basic details iecurity group name info alpr_lb_security_group wane cannot be edited after creation. Description info Allows SSH access to developers PC info Q vpc-0725219415d59aff6 X Type info Protocol info Protocol info Protocol info Protocol info Anywhere-I▼ Q 0.0.0.0/0 X HTTP TCP 443 Anywhere-I▼ Q 0.0.0.0/0 X	eate securi	Ly group Info			
Basic details Security group name info alpr_lb_security_group Anne cannot be edited after creation. Description info Allows SSH access to developers PPC info Q vpc-0725219415d59aff6 X Type info Protocol info Port range info Source info ITTP TCP 80 Anywhere-I▼ Q 0.0.0.0/0 X ITTPS TCP 443 Anywhere-I▼ Q 0.0.0.0/0 X	ecurity group acts as a	virtual firewall for your instance	to control inbound and outbound traf	fic. To create a new security group, complet	e the fields below.
ecurity group name info alpr.lb_security_group alpr.lb_security_group mer cannot be edited after creation. Pescription info Allows SSH occass to developers PPC info Q vpc-0725219415d59aff6 X Type info Protocol info Port range info Source info IHTTP TCP 80 Anywhere-L▼ Q 0.0.0.0/0 X IHTTPS ▼ TCP 443 Anywhere-L▼ Q	Basic details				
alpr_Lb_security_group Same cannot be edited after creation. Description infe Allows SSH access to developers PPC infe Q vpc-0725219415d59aff6 X Type infe Type infe Protocol infe Port range infe Source infe Anywhere-L▼ Q 0.0.0.0/0 X HTTPS ▼ TCP 443 Anywhere-L▼ Q 0.0.0.0/0 X	Security group name	Info			
ame cannot be edited after creation. Description info Allows SSH access to developers PC info Q vpc-0725219415d59aff6 X Type info Protocol info Port range info Source info HTTP TCP 80 Anywhere-I▼ Q 0.0.0/0 X HTTPS TCP 443 Anywhere-I▼ Q 0.0.0/0 X	alpr_lb_security_grou	p			
Description Info Allows SSH access to developers VPC Info Q vpc-0725219415d59aff6 X Type Info Protocol Info Port range Info Source Info HTTP TCP 80 Anywhere-L▼ Q 0.0.0/0 X HTTPS TCP 443 Anywhere-L▼ Q 0.0.0/0 X	ame cannot be edited aft	er creation.			
Allows SSH access to developers VPC info Q vpc-0725219415d59aff6 X Type info Protocol info Port range info Source info HTTP TCP 80 Anywhere-L▼ Q 0.0.0/0 X HTTPS TCP 443 Anywhere-L▼ Q 0.0.0/0 X	Description Info				
PPC info X nbound rules info X Type info Protocol info Source info HTTP TCP 80 Anywhere-I ▼ Q IHTTPS TCP 443 Anywhere-I ▼ Q	Allows SSH access to	levelopers			
No. max No. Max <t< td=""><td>/PC Info</td><td></td><td></td><td></td><td></td></t<>	/PC Info				
Type Protocol Info Port range Info Source Info HTTP ▼ TCP 80 Anywhere-I▼ Q 0.0.00/0 × HTTPS ▼ TCP 443 Anywhere-I▼ Q 0.0.00/0 × 0.0.0.00/0 × 0.0.0.00/0 × 0.0.0.0	Q vpc-0725219415	159aff6	,	K	
nbound rules info Type info Protocol info Port range info Anywhere-I TCP 80 Anywhere-I Q 0.0.0/0 X HTTPS TCP 443 Anywhere-I Q 0.0.0/0 X				·	
nbound rules info Type info Protocol info Port range info Source info TCP 80 Anywhere-I▼ Q 0.0.0/0 X HTTPS ▼ TCP 443 Anywhere-I▼ Q 0.0.0/0 X					
Type Info Protocol Info Port range Info Source Info HTTP ▼ TCP 80 Anywhere-I▼ Q HTTPS ▼ TCP 443 Anywhere-I▼ Q	Inbound rules In	o			
HTTP ▼ TCP 80 Anywhere-I▼ Q HTTPS ▼ TCP 443 Anywhere-I▼ Q 0.0.0.0/0 X 0.0.0.0/0 X 0.0.0.0/0 X 0.0.0.0/0 X	Type Info	Protoco	l Info Port range Info	Source Info	
HTTPS ▼ TCP 443 Anywhere-I▼ Q. 0.0.0.0/0 × 0.0.0.0/0 × 0.0.0.0/0 × 0.0.0.0/0 × 0.0.0.0/0 ×	HTTP	▼ ТСР	80	Anywhere-I 🔻	Q
HTTPS ▼ TCP 443 Anywhere-I▼ Q 0.0.0.0/0 ×<					0000/0 X
HTTPS ▼ TCP 445 Anywhere-I▼ Q 0.0.0.0/0 ×					
0.0.0.0/0 ×	HTTPS	▼ TCP	443	Anywhere-I V	Q
					0.0.0.0/0 🗙

Figure 6.27: Create a Security Group.

After that, click the create a target group button, the purpose is to include EC2 instances in the target group, so that the load balancer can direct the traffic to the target group.

Listener H	ITTP:80		Remove
Protocol HTTP	Port : 80 1-65535	Default action Info Forward to Select a target group Create target group []]	• C
Listener tags Consider adding t	- optional ags to your listener. Tags ena	bble you to categorize your AWS resources so you can more easily manage them.	
Add listene	er tag		

Figure 6.28: Click Create Target Group.

Select instances as the target type and give a target group name, keep other settings as default, click next.

Specify group details

Your load balancer routes requests to the targets in a target group and performs health checks on the targets.

Basic configuration

Settings in this section can't be changed after the target group is created.

Choose a target type

Instances

- Supports load balancing to instances within a specific VPC.
- Facilitates the use of Amazon EC2 Auto Scaling 🗹 to manage and scale your EC2 capacity.

IP addresses

- Supports load balancing to VPC and on-premises resources.
- Facilitates routing to multiple IP addresses and network interfaces on the same instance.
- Offers flexibility with microservice based architectures, simplifying inter-application communication.
- Supports IPv6 targets, enabling end-to-end IPv6 communication, and IPv4-to-IPv6 NAT.

Lambda function

- Facilitates routing to a single Lambda function.
- Accessible to Application Load Balancers only.

Application Load Balancer

- Offers the flexibility for a Network Load Balancer to accept and route TCP requests within a specific VPC.
- Facilitates using static IP addresses and PrivateLink with an Application Load Balancer.

Target group name alprEC2Targets A maximum of 32 alphanumeric characters including hyphens are allowed, but the name must not begin or end with a hyphen. > Tags - optional Consider adding tags to your target group. Tags enable you to categorize your AWS resources so you can more easily manage them. Cancel Next

Figure 6.29: Create a Target Group.

At the target groups screen, add the two EC2 instances to the target group.

Q Filter resources by property or valu	10					< 1 > (
Instance ID	▼ Name	⊽ State			Zone	♥ Subnet ID
i-030acdfa9126a28d6	alpr_server_2	⊘ running	launch-wizard-4		ap-southeast-2c	subnet-0d5b87e668419a0
i-038e22188345477f5	alpr_server_1	⊘ running	launch-wizard-4		ap-southeast-2b	subnet-02faf415c1b6f63ae
			0 selected			
		Ports f	for the selected instances			
		Ports fo 80	or routing traffic to the selected instand	ces.		
		1-6553	5 (separate multiple ports with comma	at a		
			Include as pending below			
		2 selections are now pe	siding below, include more or register t			
eview targets						
eview targets						
eview targets Targets (2)						Remove all pending
Targets (2) All V Q. Filter res	ources by property or value]		Remove all pending
Targets (2) All Remove Health status 	ounces by property or value v Instance ID x	7 Name 🔻	Port ⊽ State ⊽	Security groups 5	r Zone ⊽	Remove all pending
eview targets Targets (2) All Filter res Remove Health status X Peeces 	v Instance ID v I-038e22188345477f5	7 Name ⊽ alpr_server_1	Port ⊽ State ⊽ 80 ⊘ running	Security groups launch-wizard-4	r Zone ♥ ap-southeast-2b	Remove all pending < 1 > @ Subnet ID v subnet-02taf415c1b5f6 pe
eview targets Targets (2) All	v Instance ID v I-038e221883454775 I-030xcfra91262866	7 Name v alpr_server_1 alpr_server_2	Port ♥ State ♥ 80 @running 80 @running	Security groups launch-wizard-4 launch-wizard-4	7 Zone v ap-southeast-2b ap-southeast-2c	Remove all pending < 1 > Submet ID submet-02/bf415c1b6f6 se submet-02/bf475c66s se
eview targets Targets (2) All	courses by property or value V Instance ID V I-038e2218834547775 I-030ec5fa9126a2866	v Name v alpr_server_1 alpr_server_2	Port V State V 80 Oruming 80 Oruming	Security groups launch-wizard-4 launch-wizard-4	zone v ap-southeast-2b ap-southeast-2c	Remove all pending (1) (Subnet ID (Subnet-02faf415c1b6f8bas subnet-0d5b87e668414
eview targets Targets (2) All All	ources by property or value v Instance ID S	v Name v alpr_server_1 alpr_server_2	Port V State V 80 Ørunning 80 Ørunning	Security groups launch-wizard-4 launch-wizard-4	7 Zone ♥ ap-toutheast-2b ap-toutheast-2c	Remove all pending < 1 > @ Subnet 10 subnet-025h87e668a se subnet-055h87e668a se

Figure 6.30: Assign EC2 Instances to Target Group.

Navigate to the load balancer screen and select to forward the HTTP traffic to the target group and lastly click the create load balancer button to create this application load balancer.

otocol Port Default action Info ITTP : 80 Select a target group Image: Create target Q, Image: Create target Q, Image: Create target tope Instance IPV4 Image: Create target Q, Image: Create target D, Image: Create tar	Listener HTTP:80				Remove
ATTP € 80 Forward to Select a target group ▲ C 1-65535 Create target Q C stener tags - optional alprEC2targets Target type lostance IPv4 HTTP	Protocol Port		Default action	I Info	
1-65535 Create target Q stener tags - optional alprEC2targets Target type Instance IPV4 HTTP	HTTP 🔻 : 80		Forward to	Select a target group	C
alprEC2targets HTTP Target type Instance IPv4	1-655	35	Create target	Q	
nsider adding tags to your listener. Tags enable you to categorize your AWS resources or you can manage and M	listener tags - optiona Consider adding tags to your l	l istener. Tags enable you to categ	orize your AWS r	alprEC2targets HTTP Target type: Instance, IPv4 exounces by you can more easily manage und	

Figure 6.31: Load Balancer Forward HTTP Traffic to Target Group.

ummary eview and confirm your configurations	s. Estimate cost 🛂		
Basic configuration Edit oad balancer name not defined Internet-facing IPv4	Security groups Edit default sg-0f90af46139a86b42	Network mapping Edit VPC vpc-0725219415d59aff6 2 Subnet not defined	Listeners and routing Edit HTTP:80 defaults to Target group not defined
Add-on services Edit		Tags Edit None	
Attributes Certain default attributes v 	will be applied to your load balancer. You car	n view and edit them after creating the load	balancer.

Figure 6.32: Click to Create Load Balancer.

Navigate to the load balancer home page, select the alpr-lb load balancer, and click add listener button to add another listener that listens to HTTPS traffic.

VS Services	Q D Q Sydney ▼
New EC2 Experience X Tell us what you think	EC2 > Load balancers
EC2 Dashboard	Load balancers (1/1)
EC2 Global View	Elastic Load Balancing scales your load balancer capacity automatically in response to changes in incoming traffic
Events	
lags	C Actions V Create load balancer
imits	Q Filter by property or value
nstances	< 1 > ©
nstances	Nama V DNS nama V State
nstance Types	Viane V Divisinanie V State
aunch Templates	alpr-lb 🗍 alpr-lb-345623229.ap-sou 📀 Active
pot Requests	
avings Plans	
Reserved Instances	=
Dedicated Hosts	Load balancer: alpr-lb X
Capacity Reservations	Oetails Listeners Network mapping Security Monit Security Security Monit Security Security
mages	
MIs	
MI Catalog	Listeners (2) A listener checks for connection requests on its part and protocol. Traffic request by the listener
lastic Block Store	is routed according to its rules.
/olumes	C Actions V Add listener
Snapshots	Q Search
.ifecycle Manager	
ifecycle Manager	< 1 > @
ifecycle Manager Ietwork & Security	< 1 > (c)
ifecycle Manager Ietwork & Security security Groups	 < 1 > ● Protocol:Port [2] ▼ Default action [2]
ifecycle Manager Ietwork & Security iecurity Groups Lastic IPs	Protocol:Port [2] Default action [2]

Figure 6.33: Add HTTPS Listener.

Select to listen on Port 443, forward the traffic to the EC2 target group, and then provide the SSL certificate which has been created by the AWS certificate manager before, and finally click the add button. The load balancer is now listening to Port 443 and Port 80, all the HTTP and HTTPS traffic will be forwarded to the target group.

dd listener		
Details arn:aws:elasticloadbalancing	southeast-2:270020915828:loadbalancer/app/alpr-lb/bd372fe35a398d50	
Listener details A listener is a process that checks for determine how the load balancer rou	nnection requests using the port and protocol you configure. The rules that you define for requests to its registered targets.	a liste
Protocol Port HTTPS V : 443 1-65535		
Specify the default actions for traffic	this listener. Default actions apply to traffic that does not meet the conditions of rules on	your
 The default actions for traffic listener. Rules can be configured after The forward to info 	this listener. Default actions apply to traffic that does not meet the conditions of rules on the listener is created.	your ve
 Target group 	this listener. Default actions apply to traffic that does not meet the conditions of rules on ne listener is created. Remov Weight (0-999)	your ve
 Target group alprEC2targets Target type: Instance, IPv4 	this listener. Default actions apply to traffic that does not meet the conditions of rules on ne listener is created.	your ve
 Target group alprEC2targets Target type: Instance, IPv4 Select a target group 	this listener. Default actions apply to traffic that does not meet the conditions of rules on ne listener is created.	your ve
 I. Forward to Info Target group alprEC2targets Target type: Instance, IPv4 Select a target group Create target group [2] 	this listener. Default actions apply to traffic that does not meet the conditions of rules on the listener is created. Remov Weight (0-999) HTTP 1 Traffic distribution 00	ve ve

Figure 6.34: Listen to Port 443 and Forward to the Target Group.
Secure listener settings Info
Security policy Your load balancer uses a Secure Socket Layer (SSL) negotiation configuration, known as a security policy, to negotiate SSL connections with clients.
ELBSecurityPolicy-TLS13-1-2-2021-06 (recommended)
Compare security policies 🖸
Default SSL/TLS certificate The certificate used if a client connects without SNI protocol, or if there are no matching certificates. This certificate will automatically be added to your listener certificate list. From ACM alprtech.link 4cbc30c1-aca0-44b0-90fb-41e9e2c0e657 C
Request new ALM certificate C
Tags - optional Consider adding tags to your listener. Tags enable you to categorize your AWS resources so you can more easily manage them.
Cancel Add

Figure 6.35: Add the SSL certificate from AWS Certificate Manager.

On the listener screen of the load balancer, click the HTTP rule, then click manage rules, and redirect the HTTP traffic to HTTPS. In this way, when the user enters http://alprtech.link in the browser, it will automatically redirect to https://alprtech.link.

Listene	rs Network mapp	Security Monitoring	Integrations Attribu	tes lags	
Listen	iers (2)				
A listener	r checks for connection requ	uests on its port and protocol. Traffic received by	the listener is routed according to	its rules.	
G	Actions v	Add listener			
Q Se	arch			< 1 >	Ô
	Protocol:Port 🖸	▼ Default action [2]	▼ Rules	🖸 🔻 ARN 🔻	Sec
_		Forward to target group			
	HTTPS:443	 alprEC2targets: 1 (100%) Group-level stickiness: Off 	1 rule	D ARN	ELE
		Pedirect to HTTPS://#/bost]:4/	3/#{path}2#{query}	7	
	HTTP:80	Ctatus sode: HTTD 701	<u>1 rule</u>	🗇 ARN	No

Figure 6.36: Select Rule of HTTP Listener.

2 > Load balancers > al	or-lb > HTTP:80 listener	
TTP:80		Actions V
Details Rules Ta	ıgs	
Listener rules (1) Info		Rule limits C Manage rules
Default (last)		
Rule ARN		
If (all match)		
Request is not otherwise	routed	
Then		
Redirect to HTTPS://#{hostStatus code: HTTP_301	}:443/#{path}?#{query}	
Priority	Tags	
default	0	

Figure 6.37: Click Manage Rules.

Rules 🔄 🖋	11 😔	alpr-lb HTTP:8	io ~ 🖸
Select the rule to edit. Each rul	e mute one action of type forward, redirect, fixed respon	ise.	Cancel Upd
alpr-lb HTTP:80 (1 ru	les)		
Rule limits for condition value	alues, wildcards, and total rules.		
	Edit Ru	le	
RULE ID	IF (all match)	THEN	
last arn4ab72 ▼	✓Requests otherwise not routed	1. Redirect to	Ô
		HTTPS HTTPS H	e: #{port}
1		Original host, path, query	•
1		301 - Permanently moved	
		Switch to full URL	
1			

Figure 6.38: Redirect HTTP traffic to HTTPS.

6.3.6 Configure Route53 to Direct Traffic to Load Balancer

Create a record in Route53 to route the traffic to the Load Balancer of the project. On the Route53 page, click the create record button, select to create a simple routing template, and click the define simple record button.

ublic alp	ortech.link Info				D
Hoste	d zone details				
Records (3)	DNSSEC signing	Hosted zone t	tags (0)	1	
Records	(3) Info			K	
Automatic m	(3) into ode is the current search beh	avior optimized for tes	at nitter results. To ch	ange mode s go to s	ettings.
G	Delete record	mport zone file	Create recor	-d	
C Q Filter	Delete record	mport zone file ue	Create recor	^{-d}	Туре
C Q Filter I	Delete record	mport zone file ue	Create recon	Routin V	Type
C C C C Filter r	Delete record I records by property or val cord name ortech.link	mport zone file ue	Create recon	Routin V	Type
C C C C C C C C C C C C C C C C C C C	Delete record I records by property or val cord name ortech.link	mport zone file	Create recon	Routin V	Differ

Figure 6.39: Create Record for Load Balancer



Figure 6.40: Choose Simple Routing Template.

Edit Delete	Define simple record	(s).
Record name	Туре	Value/Route traffic to TTL (seconds)
	Define simple records to	this list, then choose Create records.

Figure 6.41: Click Define Simple Record.

Next, on the define simple record screen, select type A record, the type A record can route traffic to load balancer. Select the load balancer created before and click the define simple record button to let Route53 routes the traffic this load balancer successfully. Now users can access the web service on the EC2 instance through the Uniform Resource Locator (URL).

Define simple record	
Record name Info fo route traffic to a subdomain, entr plog.example.com, enter blog. If you domain.	er the subdomain name. For example, to route traffic to leave this field blank, the default record name is the name of th
subdomain	alprtech.link
Keep blank to create a record for the	e root domain.
Record type Info The DNS type of the record determi DNS queries.	nes the format of the value that Route 53 returns in response to
A – Routes traffic to an IPv4 a	address and some AWS resources
hoose when routing traffic to AWS eanstalk, ELB, or S3. For example:	resources for EC2, API Gateway, Amazon VPC, CloudFront, Elasti 192.0.2.44.
Choose when routing traffic to AWS ecanstalk, ELB, or S3. For example: Value/Route traffic to Info (The option that you choose determi pecify where you want to route intr Alias to Application and Class	resources for EC2, API Gateway, Amazon VPC, CloudFront, Elasti 192.0.2.44. Ines how Route 53 responds to DNS queries. For most options, yo ernet traffic. ic Load Balancer
Choose when routing traffic to AWS Beanstalk, ELB, or S3. For example: Value/Route traffic to info The option that you choose determi pecify where you want to route intu Alias to Application and Class Asia Pacific (Sydney) [ap-sout	resources for EC2, API Gateway, Amazon VPC, CloudFront, Elasti 192.0.2.44. Ines how Route 53 responds to DNS queries. For most options, ye ernet traffic. ic Load Balancer
Choose when routing traffic to AWS leanstalk, ELB, or S3. For example: Alue/Route traffic to info The option that you choose determin pecify where you want to route into Alias to Application and Class Asia Pacific (Sydney) [ap-sout Q dualstack.alpr-lb-345623	resources for EC2, API Gateway, Amazon VPC, CloudFront, Elasti 192.0.2.44. Ines how Route 53 responds to DNS queries. For most options, yo ernet traffic. ic Load Balancer heast-2] 229.ap-southeast-2.elb.amazonaws.com
Choose when routing traffic to AWS Beanstalk, ELB, or S3. For example: Value/Route traffic to info The option that you choose determi pecify where you want to route into Alias to Application and Class Asia Pacific (Sydney) [ap-sout Q dualstack.alpr-lb-345623 Wias hosted zone ID: 21GM30XH42	resources for EC2, API Gateway, Amazon VPC, CloudFront, Elasti 192.0.2.44. Ines how Route 53 responds to DNS queries. For most options, yo ernet traffic. ic Load Balancer heast-2] 229.ap-southeast-2.elb.amazonaws.com
Choose when routing traffic to AWS leanstalk, ELB, or S3. For example: Value/Route traffic to Info The option that you choose determing pecify where you want to route init Alias to Application and Class Asia Pacific (Sydney) [ap-sout Q dualstack.alpr-lb-345623 Was hosted zone ID: 21GM30XH42 Valuate target health lefect Yes if you want Route 53 to u esource is healthy. Yes	resources for EC2, API Gateway, Amazon VPC, CloudFront, Elasti 192.0.2.44. Ines how Route 53 responds to DNS queries. For most options, ye erret traffic. ic Load Balancer theast-2] 229.ap-southeast-2.elb.amazonaws.com PM65 set this record to respond to DNS queries only if the specified AW
Choose when routing traffic to AWS Beanstalk, ELB, or S3. For example: Value/Route traffic to Info The option that you choose determin peoply where you want to route into Alias to Application and Class Asia Pacific (Sydney) [ap-sout Q. dualstack.alpr-lb-345623 Ulas hosted zone ID: 21GM30XI442 Evaluate target health elect: Yes if you want Route 53 to u source is healthy. Yes	resources for EC2, API Gateway, Amazon VPC, CloudFront, Elasti 192.0.2.44. Ines how Route 53 responds to DNS queries. For most options, yo ernet traffic. ic Load Balancer theast-2] 229.ap-southeast-2.elb.amazonaws.com PM6S see this record to respond to DNS queries only if the specified AW

Figure 6.42: Route Traffic to the Load Balancer.

6.3.7 Use AWS Budgets to Monitor Cost

Navigate to AWS Budgets page, click the create budget button, provide a budget name, and provide a monthly budget of 12 USD. When the budget meets a certain threshold, an email will be sent to remind the usage of the budget. Then select to stop EC2 instances on the action page when all budgets are used up.

AWS Billing > Budgets > Overview		×
Overview Info		
Budgets (1) Info	nload CSV Actions	Create budget
Q Find a budget		Show all budgets 🔻
		< 1 > ©
Name	▲ Thresholds	▼ Actions
My Monthly Cost Budget	О К	Standby (1)
•		Þ

Figure 6.43: Click Create Budget Button.

alor budget	
Names must be between 1-100 characters.	
Set budget amount Period Daily budgets do not support enabling forecasted alerts, or Monthly Budget renewal type • Recurring budget Recurring budget Expiring budget Expiring budget Expiring budget Expiring monthly budgets stop renewing at the end of the Start month Apr 2023 Budgeting method Info Fixed Create a budget that tracks against a single monthly budget	daily budget planning.
Enter your budgeted amount (\$)	
Last month's cost: \$4.38	
Last month's cost: \$4.58 12.00 udget scope info id filtering and use advanced options to narrow the set of o cope options All AWS services (Recommended) Track any cost incurred from any service for this account as part of the budget scope	cost information tracked as part of this budget O Filter specific AWS cost dimensions Select specific dimensions to budget against. For example, you can select the specific service "EC2" to budget against.
Last month's cost: \$4.38 12.00 udget scope info Id filtering and use advanced options to narrow the set of other set of other set of the set of	cost information tracked as part of this budget Filter specific AWS cost dimensions Select specific dimensions to budget against. For example, you can select the specific service "EC2" to budget against.

Figure 6.44: Set Budget Limit.

Budget amour	ıt		
Your budgeted among To change your budge	ount: \$12.00 ted amount, go back to step 2.		
▼ Alert #1		Remove	
Set alert thresho	ld		_
Threshold When should this aler	t be triggered?	Trigger How should this alert be triggered?	
100	% of budgeted amount 🔹	Actual 🔻	
Notification prefe Select one or more no	erences tification preferences to receive alerts.		
Email recipients Specify the email recip	pients you want to notify when the threshold h	i has exceeded.	
alprtechonline@g thammauleun@g	gmail.com, mail.com		
Maximum number of (email recipients is 10.		
Amazon SNS A	lerts - Optional Info		
AWS Chatbot A	Merts		
+ Add alert three	shold	_	
		Cancel Previous New	ct

Figure 6.45: Send Emails When Thresholds Are Met.

 Alert #1 (1 actions attached) 	
Threshold	Email recipients
100%	alprtechonline@gmail.com,
	thammauleun@gmail.com
Threshold measured against	
Actual Costs	Amazon SNS
	Not configured
Action #1	Remove
AWS Budgets requires specific IAM permiss don't have proper permissions configured ar AWS Budgets can't run your configured action provided managed policies so your AWS Bud you use these IAM policies to be sure you do AWS Budgets when a new functionality is in managed policy by default. For details about	ions to run an action on your behalf. If you ad assigned for the user and for AWS Budgets, ons. To ensure proper configuration, we've lgets actions work as intended. We recommend n't have to update your existing IAM policy for cluded. We will add new capabilities to the t managed policies, see Managed policies [2].
Select IAM role Ensure that this IAM role has preconfigured permissions that	t will allow AWS Budgets to run the action.
alpronline	•
C Alternatively, you can manually create an IAM role 🔀	
Which action type should be applied when the budg	get threshold has been exceeded?
Automate instances to stop for EC2 or RDS	
Stop EC2/RDS instances	
• Stop EC2	
○ Stop RDS	
Select region	
Asia Pacific (Svdnev) ap-southeast-2	•
Choose EC2/RDS instances	
Choose instances	<u>۸</u>
✓ i-030acdfa9126a28d6	
✓ i-038e22188345477f5	
Do you want to automatically run this action when	this threshold is exceeded?
○ No	
• Yes	
How do you want to be plotted when this action is	
I lise the same alert settings when you defined the	nis threshold
 Use different alert settings 	is an colora
Add action	
	Cancel Previous Next

Figure 6.46: Stop EC2 Instances When Threshold Is Met.

6.4 Use Github Actions to Deploy ALPR Web Application on EC2 Instances

Only Docker is needed to run the web project, so use SSH to connect to the two EC2 instances, install Docker, and start the Docker service in the background.

Instances (1/2) Info					
C Connect	Instance state 🔻	Actions 🔻	Launch inst	tances 🔹	
Q Find instance by attrib	a (case-sensitive)				< 1 > 🔘
■ Name ▼	Instance ID	Instance sta	ate 🔻	Instance type	▼ Status chec
alpr_server_2	i-030acdfa9126a28d6	Θ Stopped	⊕⊝	t2.micro	-
alpr_server_1	i-038e22188345477f5	🔗 Running	ÐQ	t2.micro	⊘ 2/2 chec
1					ł

Figure 6.47: EC2 Home Page.

EC2 Instance Connect	Session Manager	SSH client	EC2 serial conso	e	
nstance ID					
🗗 i-038e22188345477	f5 (alpr_server_1)				
Public IP address					
3 .25.71.17					
Jser name					
Enter the user name defined ubuntu.	in the AMI used to launch th	e instance. If you did	n't define a custom user	name, use the default	user name,
ubuntu					
ubuntu					
ubuntu					

Figure 6.48: Use SSH to Connect EC2 Instance.



Figure 6.49: EC2 Instance's Command Line Interface.



Figure 6.50: Command to Install Docker.

After installing Docker, the next step is to connect the two EC2 instances with the GitHub Repository. The relevant installation and configuration code of GitHub Runner can be found in GitHub Repository's setting, and then install GitHub Runner in the command line interface of EC2 instances and run the GitHub Runner service. So that when the developer executes a git push to the project's repository, GitHub will automatically copy the entire project code to these EC2 instances and redeploy the web project again.

<> Code 💿 Issues 👫	Pull requests	🕽 Actions 🖽 Projects 🛈 Security 🗠 Insights 🕸 Settings		
ঞ্চি General		Runners	New self-hosted n	unner
Access A Collaborators		Host your own runners and customize the environment used to run jobs in your GitHub Actions wor about self-hosted runners.	kflows. Learn mo	ore
Code and automation		Runners	Status	
운 Branches		🗃 ip-172-31-13-221 (self-hosted) (Linux) (X64) (alpr_runner1)	• Idle	
♡ Tags En Rules	Beta) v	runner2 (self-hosted) Linux (X64) (alpr_runner2)	Offline	
Actions	^			
General Runners				

Figure 6.51: GitH

GitHub Repository Runners Page.

downloading and configuring the Corporate Terms of Service, as an	uires that you download, configure, and execute the GitHub Actions Runner. E e GitHub Actions Runner, you agree to the GitHub Terms of Service or GitHub pplicable.
Runner image	
○ 🗯 macOS	Linux
Architecture	
x64	•
Download	
# Create a Tolder	d actions-nunnen
» mkuir actions-runner aa c	u actions-runner
<pre>% curl -o actions-runner-li</pre>	и раскаде
https://github.com/actions/	/runner/releases/download/v2.303.0/actions-runner-linux-x64-2.303.0.tar.g
# Optional: Validate the ha	ash
<pre>\$ echo "e4a9fb7269c1a156eb5</pre>	d5369232d0cd62e06bec2fd2b321600e85ac914a9cc73 actions-runner-linux-x64-
2.303.0.tar.gz" shasum -a	3 256 -c
# Extract the installer	
<pre>\$ tar xzf ./actions-runner-</pre>	linux-x64-2.303.0.tar.gz
Configure	
onfigure	
# Create the runner and sta	art the configuration experience
# Create the runner and sta \$./config.shurl https:/ # last stan run it!	art the configuration experience //github.com/hahaong/ReactAdmintoken AN2N2WGMCGA74XU76XU63Q3EIO4DI
# Create the runner and sta \$./config.shurl https:/ # Last step, run it! \$./run.sh	art the configuration experience //github.com/hahaong/ReactAdmintoken AN2N2WGMCGA74XU76XU63Q3EIO4DI
# Create the runner and sta \$./config.shurl https:/ # Last step, run it! \$./run.sh	art the configuration experience //github.com/hahaong/ReactAdmintoken AN2N2WGMCGA74XU76XU63Q3EIO4DI
<pre>configure # Create the runner and sta \$./config.shurl https:/ # Last step, run it! \$./run.sh Jsing your self-hosted runner</pre>	art the configuration experience //github.com/hahaong/ReactAdmintoken AN2N2WGMCGA74XU76XU63Q3EIO4DI
<pre># Create the runner and sta \$./config.shurl https:/ # Last step, run it! \$./run.sh Jsing your self-hosted runner # Use this YAML in your work</pre>	art the configuration experience //github.com/hahaong/ReactAdmintoken AN2N2WGMCGA74XU76XU63Q3EIO4DI *flow file for each ich

Figure 6.52: Codes to Install, Configure and Run GitHub Runner.



Figure 6.53: Github Actions's YML file.

```
25 lines (17 sloc) 610 Bytes
```

```
1 const express = require('express')
    const path = require("path")
2
3 // const history = require('connect-history-api-fallback');
4 const PORT = 8000;
 5 const app = express()
 6
    // app.use(history()); // 注册处理前端采用history模式的路由
7
8
9
10 app.use(express.static(path.join( dirname, "ReactAdmin", "build")))
11
12 app.get('*', function (request, response){
       console.log("entered")
13
14
       response.sendFile(path.resolve(__dirname, 'ReactAdmin', 'build','index.html'))
15
     })
16
17
18
    // app.get("/",(req,res)=>{
    // res.send("server")
19
20 // })
21
22 app.listen(PORT,()=>{
23
        console.log(`Server listening on PORT ${PORT}`)
24 })
```

Figure 6.54: Server.js file that Starts Express Server.

```
8 lines (5 sloc) 100 Bytes
1 FROM node:16-alpine as base
2 COPY . /app/
3 WORKDIR /app/
4 RUN npm install
5 CMD ["npm","run","start"]
6
7
8
```

Figure 6.55: Dockerfile That Builds Docker Image.

```
13 lines (12 sloc)
                     234 Bytes
      version: '2.2'
  1
  2
       services:
  3
        alpr_server:
  4
           container name: alpr server
           image: alpr_server
  5
           restart: on-failure:0
  6
           build:
  7
  8
               context: .
               dockerfile: dockerfile
  9
 10
               target: base
 11
           ports:
 12
             - "80:8000"
 13
```

Figure 6.56: docker-compose.yml to Configure Docker Service.

6.5 Firestore, Algolia Functions and Custom Functions Used in Project

The implementation of web and mobile applications follows the Figure 6.57 design diagram for the most part. There are three layers: Presentation Layer, Middle Layer, and Firestore Function Layer. Presentation is responsible for displaying interface and processing business logic, the middle layer is responsible for connecting the presentation layer and firebase function layer, and it exposes a series of methods of operating Firestore to the presentation layer. The Firestore function layer is a series of methods to operate the database, such as creating, retrieving, updating, and deleting data. Tables 6.1, 6.2, and 6.3 show the functions used in the project.



Figure 6.57: React and React Native Process Data Flow Design.

Function	Parameters	Description
reqAllCarparkList	-	Get the list of car access
		logs.
reqLimitCarparkList		Get the first 10 car
		access logs
reqCategoryList		Get the list of
		categories
reqRoleList		Get the list of roles
reqUserList		Get the list of users
reqCheckDuplicationCategory	data	Check for duplicate
List		category names
reqCheckDuplicationPersonLis	data	Check for duplicate car
t		plate numbers
reqCheckDuplicationUserList	data	Check for duplicate
		usernames
reqCheckDuplicationRoleList	data	Check for duplicate role
		names
reqUpdateCategory	id, data	Update the category
		name

able 6.1:	1: List of Fu	nction End	points.
able 6.1:	1: List of Fu	nction End	point

reqUpdateUser	id, data	Update the user account
reqUpdatePerson	id, data	Update the car's owner
		informationr
reqUpdateRole	id, data	Update the role
reqDeleteCategory	id	Delete the category
reqDeleteRole	id	Delete the role
reqDeleteUser	id	Delete the user account
reqDeletePerson	id	Delete the car owner
reqPersonById	id	Get the specific car
		owner's information
reqRoleById	id	Get the specific role's
		information
reqSearchUser	searchData	Search for the specific
		user account
reqCategoryById	id	Get the specific
		category's information
reqAddPerson	data	Add a car owner
reqAddRole	data	Add a role
reqAddCategory	data	Add a category
reqAddUser	data	Add a user account

 Table 6.2:
 List of Firestore Native Functions

Function	Parameters	Description
onSnapshot	Collection,	Listen to the collection in
	call back	real-time, when there is
	function	update on the collection's
		document, the call back
		function will be called.
query	Collection,	Set query rules on the
	rules	specific collection
getDocs	Query	Get the list of documents
		based on the query rule

getDoc	Document	Get the specific document
addDoc	Collection,	Add a document to the
	data	collection
updateDoc	Document,	Update the document with
	data	the data
deleteDoc	Document	Delete the document

Table 6.3: Algolia Function.

Function	Parameters	Description
search	search string, {	Query the database based on search
	filters,	string and filters. The hitsPerPage and
	hitsPerPage,	page parameters are used to do
	page	pagination. It returns the result list.
	}	

6.6 Web Application Implementation

This section will display each web application page and explain the business logic using section code.

6.6.1 User Account

The User Account module can be divided into login activity and logout activity.

6.6.1.1 Login Activity

When the user logs in, the Ant-Design UI library will check whether the value of the input box is legal, and if it is legal, the login button is disabled. When the user submits the login form, it will enter the onFinish function. In this function, it will go to the database to find the matching username and password and check the user's role. If no user is found or the user's role is empty, a warning box will pop up. If the username, password, and role are all valid, the user data will be stored in React Redux and browser's local storage, and the user will be directed to the home page.

I ALPR System				
	User I	Login		
	A Username)	
	Please input your username			
	🔒 Password	Ø		
	password must be entered			
	Log	in		

Figure 6.58:

Login Validation Page.

I ALPR System	8 User not found, ple	ase try again or contact admin	
	Use	er Login	
	오 dqad		
		Ø	
		Log in	

Figure 6.59: System Alerts User to Try Again.



Figure 6.60: Ant-Design Form Validation.



Figure 6.61: Login Logic.

6.6.1.2 Logout Activity

The user can click the Logout button on the homepage to log out, and a confirmation message box will pop up to confirm whether the user wants to log out. When the user the clicks ok button, the system deletes the user information in Redux and browser's local storage and this will cause all React components using the redux to re-render. The admin component monitors the user info of Redux. When the user info is deleted, it will automatically direct user to the login page. In addition, the system will automatically log out the user when the information or role of the user account is changed in the database.



Figure 6.62: Logout Modal.



Figure 6.63: Logout Action.



Figure 6.64: Admin Component Monitor User Info and Redirect to Login Page.



Figure 6.65: Automatically Log Out User When User Account or Role Changed.

6.6.2 Car Access Log

The Car Access Log Module can be divided into sections of viewing car access records, performing basic search, performing filter search, and viewing car owner information.

6.6.2.1 View Car Access Logs

When the user navigates to the homepage, it will fetch the first ten car access logs from the Firestore. At the same time, the system will detect whether there is a new car access record in real time, and if there is, it will append the new car access log to the current list. User can click the load more button to load ten more car access records.

🕑 ALPR	Home		Welcome admin Logout	Î
습 Home				
🖻 Management 💙	Search by Car Plate	✓ Please enter car plate to search Q Search	⊽ Filter	
A User		AHI8455		-
禺 Role	AHG 8385	UNAUTHORIZED		
		2023-04-07 14:55:52		
		AHI8455 UNAUTHORIZED		
	AHG 8385	enter 2023-04-07 14:52:06		
		AHG8385		
	AHG 8385	enter		
		2023-04-07 14:21:54		
	440	UNAUTHORIZED		
		enter 2023-04-07 14:21:47		
		AHI8455		
	AHG 8385	enter 2023-04-07 14:20:41		

Figure 6.66: Web Home Page.



Figure 6.67: Load First 10 Car Access Records.



Figure 6.68: Listen to Carpark's Collection in Real-time.





Figure 6.70: Load More Records.

6.6.2.2 Perform Basic Search

User can choose search by car plate, name, phone no, category or search by enter or exit. After the user enters the search keyword, user clicks the search button to search. Basic search functionality is done by using the Algolia search function.



Figure 6.71: Search for Car Access Record.



Figure 6.72: Function to Perform Basic Search.

6.6.2.3 Perform Filter Search

Users can provide a variety of search data to perform filter search. The date range is a required input field. After the user fills in the search data, click submit button to search the car access logs. The filter search function utilizes the Algolia search function to complete.

🕑 ALPR	Home	imes Filter Search		
යි Home		Car Plate		
🖻 Management 💙	Search by Car Plate			
A User		Name Please enter owner name		
品 Role	AHG 8385	Category		
		Please choose the category		
		Phone Number		
		Please enter owner phone number		
		Enter Or Exit		
		Please choose the car access type		
		* Date		
		2023-04-06	→ 2023-04-07	Ë
		Clear All Search		

Figure 6.73: Web Filter Search Page.

<pre>const onFinish = asymc (values) => { currentPageNumberRef.current = 0 cargarxSarxInter.current = " cargarxFilterRef.current = " personSarxInterRef.current = " pessonSilterRef.current = " pasiConAdvanceSearch.current = "advance" </pre>			
<pre>messageApi.open({ key, type: 'loading', content: 'Loading', loading', loadi</pre>			
<pre>[1] [let collectedFormData = { values, carPlate: values.carPlate ? values.carPlate.trim().replace(/\s/g, "") : "", name: values.name ? values.make.trim() : "", phoneNumber: values.nonNumber ? values.phoneNumber.trim().replace(/\s/g, "") : "", startDate: values.date[0].5d, endDate: values.date[1].5d, ;;</pre>	Process Form Data		
<pre>carparkSearchRef.current = collectedFormData.carPlate ** carparkSearchRef.current = collectedFormData.carPlate ** carparkFilterRef.current = createAtt_S[(collectedFormData.date[0].startOf("day").unix() + 28800) * 1000) TO \${(collectedFormData.date[1].endOf("day").unix() + 28800) * 1000)' if (collectedFormData.dateFined) { carparkFilterRef.current = carparkFilterRef.current.concat(" AND enterOrExit:s[collectedFormData.aterOrExit)") }</pre>			
<pre>if (collectedformData.phoneNumber != "" collectedformData.name != "") { // let algoli. let personArr = [].concat(collectedformData.phoneNumber, collectedformData.name); personSearchReformData.category != undefined) @ personFileFrefF.current = 'category'S' </pre>	Prepare Algolia Search Keyword		
<pre>if (collectedformData.shoneNumber != "" collectedformData.name != "" collectedformD</pre>	Nata.category != undefined) {		
<pre>// console.log("onfilter personIDList,", personIDList) // console.log("onfilter personSearchRef:", personSarchRef.current) // console.log("onfilter carparKiterRef:", carparKiterRef.current) // console.log("onfilter carparKiterRef:", carparKiterRef.current) // console.log("onfilter carparKiterRef:", carparKiterRef.current)</pre>			
<pre>let personData = await registrationIndex.search(personSearchRef.current.trim(), { filters: personDiterRef.current.trim() "", hitsPerrage: 00)) let (hits) = personData if (hits.length == 0) { // no person list found, return show empty at homescreen messageApi.open((key, type: 'success'. }) </pre>	Search Car owner		

Figure 6.74: Perform Filter Search on Car Owners.



Figure 6.75: Perform Filter Search on Car Access Log.

6.6.2.4 View Car Owner's Information

If the car plate number is registered, a more button will appear on the right side of the car access record, and after clicking, user can view the personal information of the car owner.

🗭 ALPR	Home	A Welcome admin Logout
ᢙ Home➢ Management ▲	Search by Car Plate V qqq	Q Search
Category Person	QQQ7777 VISITOR	
久 User 聶 Role	2023-04-06 17:36:38	more
	QQQ 77777 VISITOR enter 2023-04-06 17:36:37	more
	QQQ7777 VISITOR enter 2023-04-06 17:36:35	more
	QQQ7777 VISITOR enter 2023-04-06 17:36:34	more

Figure 6.76:

View Car Owner's Information.



Figure 6.77:

Show Car Owner's Information.



Figure 6.78: Load Car Owner Data When Loading Car Access Logs.

6.6.3 Category Module

Category Module can be divided into view category list, add a category, edit category, and remove category section.

6.6.3.1 View Category List

When the user navigates to the category page, the system will load all categories and monitor whether there is any change in the category collection of Firebase. If there is a new change, the changes will be updated to the page.

🧭 ALPR	Category	A Welcome admin Logout
☆ Home ✑ Management ▲	Category Management	+ Add
Category Person	Category Name	Operation
A User	RWER	Edit Remove
器 Role	HRHTR	Edit Remove
	OWNER	Edit Remove
	VISITOR	Edit Remove
		< 1 >

Figure 6.79:





Figure 6.80: Load Category List.

6.6.3.2 Add a Category

When the user clicks add button, the add category modal will pop up. After the user enters the category name, the data in the input box will be verified, and then check whether there are duplicate category names. If all the verifications are passed, add the new category to Firestore.

ALPR	Category	Welcome admin Logout
	Cate Add Category X Please enter category name	+ Add
Person	Ca Cancel OK RWER	Operation Edit Remove
品 Role	HRHTR	Edit Remove
	OWNER	Edit Remove
	VISITOR	Edit Remove

Figure 6.81: Add Category Modal.



Figure 6.82: Perform Add Category

6.6.3.3 Update Category

The user can click the edit button of the category, and the update category modal box will pop up. After the user enters the category name in the input field, Ant-Design will verify the data, and the toUpdate function will also checks whether the new category name is duplicated. If all verifications are passed, the update category operation will be performed.

I ALPR	Category		Welcome admin Logout
 ↔ Home ↔ Management ▲ ▲	Cate Update Category RWER Ca	Cancel OK	+ Add Operation
A User 吊 Role	RWER		Edit Remove
	OWNER		Edit Remove
	VISITOR		Edit Remove

Figure 6.83: Update Category Modal.



Figure 6.84: Perform Update Category.

6.6.3.4 Remove Category

The user can click the remove button of the category, and the confirmation modal will pop up. After the user clicks OK, the category will be deleted.

ALPR	Category	A Welcome admin Logout
습 Home	Category M () Confirm	+ Add
☐ Category	Are you sure to remove RWER?	nfirm
In Person 尺 User	RWER	Edit Remove
篇 Role	HRHTR	Edit Remove
	OWNER	Edit Remove
	VISITOR	Edit Remove
		< 1 >

Figure 6.85: Remove Category Confirmation.



Figure 6.86: Perform Delete Category.

6.6.4 Person Module

The person module is divided into sections of viewing the car owner's personal information, registering the car owner, editing the car owner, deleting the car owner, and searching for the car owner.

6.6.4.1 View Car Owner' Personal Information

The user navigates to the person page to view list of car owners, after that, the system uses Algolia to search for the first 5 records of data and loads them on the page. At the same time, the system will detect whether there is any change in the car owner list in real time, and if so, it will present the updated data on
the user interface. User can click the view button to navigate to the person detail page and find the detailed information of the car owner from Firestore such as name, phone number, license plate, category, registration time, and more personal information.

☑ ALPR	Person				A Welcom	ne admin Logout
습 Home E> Management 🔺	Please enter n	ame, car plate	Q Search			+ Register
E Category	Name	Car Plate	Phone No	Category	Registered At	Operation
久 User 聶 Role	TEST	3213	3123	VISITOR	2023-04- 20 14:22:40	View Edit Remove
	TINTIN	KKK8888	0168886969	OWNER	2023-04- 06 17:27:16	View Edit Remove
	ONGLIPWEI	QQQ7777	0109636698	VISITOR	2023-04- 06 17:22:08	View Edit Remove
						< 1 >

Figure 6.87: Person Page Shows List of Car Owners.



Figure 6.88: View Car Owner's Detail Information.



Figure 6.89: Load Car Owner List.



Figure 6.90: Detect New Data in Registration Collection.



Figure 6.91: Detect Update on Registration Collection.



Figure 6.92: Detect Deletion on Registration Collection.



Figure 6.93: Navigate to Detail Page.



Figure 6.94: Person Detail Page Load Car Owner Information.



Figure 6.95: Person Detail Page Load Car Owner's Category.

6.6.4.2 Register Car Owner

The user navigates to the person page, clicks the register button to enter the registration page. User can enter the car owner's name, license plate number, phone number, category, and more personal information. When the user submits the form, the system will validate the data in the form and check for duplicate license plate numbers. If all the validation passes, it will add this car owner to Firestore, display the message of successfully registering the car owner, and return to the previous page.

😥 ALPR	Person
ය Home	
🖻 Management 🔺	< Registration Form
Category	* Name: Insert your name
📧 Person	
유 User	* Car Plate: Insert your car plate
聶 Role	* Phone No: eg 0109858785
	* Category: Please choose the category V
	Person Detail B I U S [] x ² X ₂ Normal T
	14▼ Font ▼ ☷ ☲ ☲
	Submit

Figure 6.96: Register Car Owner Page.



Figure 6.97: Click Registration Button Navigate to Registration Page.



Figure 6.98: Registration Form Validation.



Figure 6.99: Register Car Owner Function.

6.6.4.3 Edit Car Owner

The user navigates to the person page and clicks the edit button to enter the edit person page. The system will first load the car owner's data into the form, and then the user can edit the car owner's name, license plate number, phone number, category, and person detail. When the user clicks submit, the system will validate the data in the form and check for duplicate license plate numbers. If all the validations pass, it will update the data in Firestore, display the message of successfully updating the car owner, and return to the previous page.

🕑 ALPR	Person A Welcome admin Logout
☆ Home ✑ Management ▲	< Edit Person
E Category	* Name: TEST
A User	* Car Plate: 3213
品 Role	• Phone No: 3123 • Category: VISITOR Person Detail B / U \$ {} x ² x ₂ Normal • If the font • if if i i i i i i i i i i
	Google Chrome is recommended for the best user experience

Figure 6.100: Edit Car Owner Page.



Figure 6.101: Load Car Owner Information.



Figure 6.102: Validate Input Fields.



Figure 6.103: Perform Update Car Owner Action.

6.6.4.4 Remove Car Owner

After the user navigates to the person page and clicks the delete button, a confirmation modal box will pop up. After the user confirms the deletion, this record will be removed from Firestore, and the system will check whether the change has been updated to the Algolia Database. If there is, system prompts the deletion success message and close the modal box.

♂ ALPR	Person			(A Welcom	ne admin Logout
습 Home ☞ Management ▲	Remove Person Are you sure to re	move TEST?			×	+ Register
Category Person				Cancel	OK ered	Operation
옷 User 륣 Role	TEST	3213	3123	VISITOR	2023-04- 20 14:22:40	View Edit Remove
	TINTIN	KKK8888	0168886969	OWNER	2023-04- 06 17:27:16	View Edit Remove
	ONGLIPWEI	QQQ7777	0109636698	VISITOR	2023-04- 06 17:22:08	View Edit Remove
						< 1 >

Figure 6.104: Remove Car Owner Modal.



Figure 6.105: Perform Delete Car Owner Action.

6.6.4.5 Search for Car Owner

User navigates to the person page, enters the license plate, name, or mobile phone number in the search field to search for the car owner, and the user can click the search button to search. System will use Algolia function to perform search operation, the returned result will be presented to user.

🛛 ALPR	Person				A Welco	me admin Logout
습 Home 터 Management A	ONGLIPWEI		Search			+ Register
Category Person	Name	Car Plate	Phone No	Category	Registered At	Operation
오 User 퓲 Role	ONGLIPWEI	QQQ7777	0109636698	VISITOR	2023-04-06 17:22:08	View Edit Remove
						< 1 >

Figure 6.106: Search Car Owner Page.

<pre>const getPersonList = async () => { try { setIsLoading(true); //when user press search, page is loading</pre>	
<pre>let registrationData = await registrationIndex.search(personSearchRef.current.trim(), { hitsPerPage: 5, page: currentPageNumber.current - 1 })</pre>	
<pre>const { hits, nbPages, nbHits } = registrationData if (hits.length == 0) { // totalDataCount.current = 0 setPersonList([]); return } totalDataCount.current = nbHits</pre>	
<pre>const resultList = hits.map(async (doc) => ({ key: doc.objectID, name: doc.name, carPlate: doc.carPlate, phoneNumber: doc.phoneNumber, category: doc.category, categoryName: await getCategoryById(doc.category), detail: doc.detail, registeredAt: dayjs(dayjs.unix(doc.createdAt / 1000)).format("YYYY-MM-DD HH:mm:ss"), }); </pre>	
<pre>let localPersonList = []; for (var i = 0; i < resultList.length; i++) { let person = await resultList[i]; localPersonList.push(person); } Return Searched Data to UI }</pre>	
<pre>personListRef.current = [localPersonList] setPersonList([personListRef.current]);</pre>	
<pre>//set pagination items } catch (error) { message.error("Connection error, please check your internet access") } finally { setIsLoading(false) }</pre>	
<pre>//Save the item array to redux // props.savePerson(localPersonList); };</pre>	

Figure 6.107: Perform Algolia Search on Car Owner.

6.6.5 User Module

The user module is divided into sections of viewing user account list, creating a user account, editing the user account and deleting the user account.

6.6.5.1 View User Accounts

User navigates to the user page to view all user accounts. The system will monitor the user collection of Firestore and return all user account information to the user page.

🧭 ALPR	User					A V	Velcome admin Logout
 ☐ Home ▷ Management ▲ 	User Manage	ment					+ Add
E Category	Username	Password	Email	Phone No	Created At	Role	Operation
久 User 聶 Role	gerg	31231	gyre		2023-04- 20 14:23:48	person management	Edit Remove
	tham	tham			2023-04- 06 17:38:56	role manager	Edit Remove
	hahaong	hahaong2			2023-04- 06 17:28:07	person management	Edit Remove
							< 1 >

Figure 6.108: User Page.



Figure 6.109: Load User Data to User Page.

6.6.5.2 Create User Account

User navigates to the user page and click the add button, the system will pop up the add user modal box. After the user enters the username, password, email address, mobile phone number and role, the system will verify the data in the input fields and check if there are duplicate usernames. After all validations pass, the system inserts a new piece of data into Firestore and closes the modal.

I ALPR	User		A Welcome	e admin Logout
	Add User		×	+ Add
	* Username :	Please enter your username		Operation
	* Password : Email :	Please enter your password Please select your email		Edit
	Phone No:	Please select your phone No	nent	Remove
	* Role:	Please select your role V		Edit Remove
		Cancel	OK	Edit
	hahaong	hahaong2 04-06 17:28:07	management	Remove
				< 1 >

Figure 6.110:

Add User Modal.



Figure 6.111: Add User Form Validation.



Figure 6.112: Add User Account.

6.6.5.3 Edit User Account

The user can click the edit button after navigating to the user page, and the system will pop up the update user modal box and initialize the data of all input fields. After the user changes the username, password, email, mobile phone number and role, the system will verify the data in the input fields and check for duplicate usernames. After all validations pass, the system updates the data in Firestore and closes the modal.

ALPR	User		A Welcom	e admin Logout
☆ Home ▷ Management ▲	Update User I	nformation	×	+ Add
Category	* Username :	hahaong 🚳		
📧 Person	* Password :	hahaong2		Operation
८ User	Email:	Please select your email)	Edit
品 Role	Phone No:	Please select your phone No	nent	Remove
	* Role:	person management V	ок	Edit Remove
	hahaong	hahaong2 04-06 17:28:07	person management	Edit Remove
				< 1 >

Figure 6.113: Update User Account Modal.



Figure 6.114: Initialize Input Field Data.



Figure 6.115: Perform Update User Account Action.

6.6.5.4 Remove User Account

The user can click the remove button after navigating to the user page, and the system will pop up a confirmation modal. After the user confirms to delete the user, the system will delete the user account from Firestore and close the modal box.

✓ ALPR	User					A Welcome	admin Logout
 ☆ Home > Management ▲ 	Us 🕛 Co	onfirm e you sure to re	move haha	iong?			+ Add
Category E Person				Cancel	Confirm	Role	Operation
옷 User 聶 Role	gerg	31231	gyre		2023- 04-20 14:23:48	person management	Edit Remove
	tham	tham			2023- 04-06 17:38:56	role manager	Edit Remove
	hahaong	hahaong2			2023- 04-06 17:28:07	person management	Edit Remove
							< 1 >

Figure 6.116: Remove User Account Confirmation Modal.



Figure 6.117: Perform Delete User Account Action.

6.6.6 Role Module

The role module has 4 sections, namely view roles, create role, assign pages to role and remove role.

6.6.6.1 View Roles

The user navigates to the role page to view the role list. The system will monitor the role collection of Firestore and update the latest role list to user.

🕑 ALPR		Role			A We	elcome admin Logout
습 Home 卍 Management	^	Role Management				+ Add
Category Person		Role Name	Created At	Authorization At	Authorizer	Operation
A User		role manager	2023-04-06 17:40:04	2023-04-20 15:17:12	admin	Edit Remove
a Kole		person management	2023-04-06 17:27:47	2023-04-07 09:53:59	admin	Edit Remove
						< 1 >

Figure 6.118: Role Page.



Figure 6.119: Load Role List from Firestore.

6.6.6.2 Create Role

The user can click the add button after navigating to the role page, and the system will pop up the add role model. After the user enters the role name, the

system will verify the data in the input box and check that there are duplicate role names. After all validations pass, the system inserts a new role into Firestore and closes the modal.

✓ ALPR	Role			AW	elcome admin Logout
 ☆ Home ➢ Management ▲ ☐ Category 	Add Role * Role Name:			×	+ Add Operation
전 Person 오 User	role manager	17:40:04	Cance 15:17:12	admin	Edit Remove
篇 Role	person management	2023-04-06 17:27:47	2023-04-07 09:53:59	admin	Edit Remove
					< 1 >

Figure 6.120: Add Role Modal.



Figure 6.121: Add Role to Firestore.

6.6.6.3 Assign Pages to Role

After navigating to the role page, the user can click the edit button, and the system will pop up the edit role modal. The user can decide which interface

the role can see, the system will update the role in Firestore after user clicks the ok button and close the modal box afterward.

I ALPR	Role	A Welcome admin Logout
습 Home ☞ Management ▲	Edit Role	× + Add
E Category	 All Home Management 	Operation
A User	User Role	Edit Remove
番 Role	management 17:27:47	09:53:59 Edit Remove
		< 1 >

Figure 6.122: Edit Role Modal.



Figure 6.123: Assign Pages to Role.

6.6.6.4 Remove Role

The user can click the remove button after navigating to the role page, and the system will pop up a confirmation modal. When the user confirms to delete the role, the system will delete the role in Firestore and close the modal box.



Figure 6.124: Remove Role Modal.



Figure 6.125: Remove Role from Firestore.

6.7 Mobile Application Implementation

This section will display each mobile application page and explain the business logic using section code.

6.7.1 User Account

The User Account module can be divided into login activity and logout activity.

6.7.1.1 Login Activity

User can login by providing valid username and password. When the user submits the login form, system will verify the user credential. It will go to the Firestore to find the matching username and password and check the user's role. If no user is found or the user's role is empty, an error message will pop up. If the username, password, and role are all valid, the user data will be stored in React Redux and the Async Storage, and the user will be directed to the home page.

Welcome, Let's Sign In	Welcome, Let's Sign In		
Username ALPR	Username		
Enter your Username	dwqdwq		
Password	Password		
Enter your Password	Ø		
Sign In	Sign In		
Figure 6.126: Login Page.	User account doesn't exist.		





Figure 6.128: Login Action.

6.7.1.2 Logout Activity

The user can click the logout button from the navigation panel and a confirmation message box will pop up to confirm whether the user wants to log out. When the user the clicks ok button, the system deletes the user information in Redux and async storage direct the user to sign in page. In addition, the system will automatically log out the user when the information or role of the user account is changed in the database.



Figure 6.129: Logout Alert Modal.



Figure 6.130: User Press Logout Button to Logout.



Figure 6.131: User Logout Automatically When User Account Being .Modified or Removed

6.7.2 Car Access Log

The Car Access Log Module can be divided into sections of viewing car access logs, performing basic search, performing filter search, and viewing car owner information.

6.7.2.1 View Car Access Logs

When the user navigates to the home page, system will fetch the first ten car access records from the Firestore. At the same time, the system will detect whether there is a new car access record in real-time, and if there is, it will append the new car access record to the current list. User can scroll to the bottom to load more data.

	Home	E Home
Q Search car plo	ate, name, phone 🚅	Q Search car plate, name, phone 🖻
AHG 8385	AHG8385 UNAUTHORIZED enter 2023-04-07 14:52:06	AHG8385 UNAUTHORIZED enter 2023-04-0714:52:06
AHG 8385	AHG8385 UNAUTHORIZED enter 2023-04-07 14:21:54	AHG 8385 UNAUTHORIZED enter 2023-04-0714:21:54
AHE EBHS	ALIEAAS UNAUTHORIZED enter 2023-04-07 14:21:47	ALIEAAS UNAUTHORIZED enter 2023-04-0714:21:47
AHG 8385	AHG8385 UNAUTHORIZED enter 2023-04-07 14:52:06	AHG8385 UNAUTHORIZED enter 2023-04-07 14:52:06
AHG 8385	AHG8385 UNAUTHORIZED enter 2023-04-07 14:21:54	С
^ ::		▲ II ▷ ⊥ △
Figure 6.132	2: Home Page.	Figure 6.133: Load More Function

in Home Page.



Figure 6.134: Load First 10 Car Access Logs.



Figure 6.135: Listen for New Car Access Log in Real-time.



Figure 6.136: On Load More Function.

6.7.2.2 Perform Basic Search

User can search car access log by car plate number. After the user enters the search keywords, user pressed enter on the keyboard and the system will return the result. Basic search functionality is done using the Algolia search function.



Figure 6.137: Searching by Car Plate Number.



Figure 6.138: Perform Basic Search.

Users can provide a variety of search data to perform filter search. The date range is a required input field. After the user fills in the search data, clicks the submit button to search the car access logs. The filter search function utilizes the Algolia search function to complete.



Figure 6.139: Filter Search Drawer.



Figure 6.140: Perform Filter Search.

If the car plate number is registered, a more button will appear on the right side of the car access record, and after clicking, user can view the personal information of the car owner.

i i i i i i i i i i i i i i i i i i i	Home		Ξ	Home
Q qqq		Itt	Q qqq	II.
QQQ 7777	QQQ77777 VISITOR enter 2023-04-06 17:36:38	more	000 77 Name:	77 VISITOR more
000 7777	QQQ7777 VISITOR		Phone No:	0109636698
QQQ 7777	enter 2023-04-06 17:36:37	more	CarPlate:	QQQ77777
QQQ 7777	QQQ7777 VISITOR enter 2023-04-06 17:36:35	more	Category: Register At:	VISITOR 2023-04-06 17:22:08
QQQ 7777	QQQ7777 VISITOR enter 2023-04-06 17:36:34	more	Detail:	
QQQ 7777	QQQ77777 VISITOR enter 2023-04-06 17:36:33	more		
	6 •	123		
Figure 6.141:	View Car O	wner	Figure 6.142	Drawer Containing
Information.			Ĺ	ar Owner's information.


Figure 6.143: Load Car Owner Data When Loading Car Access Records.

6.7.3 Category Module

Category Module can be divided into view category list, add a category, edit category, and remove category section.

6.7.3.1 View Category List

When the user navigates to the category page, the system will load all the categories and monitor whether there is any change in the category collection of Firebase. If there is a new change, the changes will be updated to the page.



Figure 6.144: Category Page.

=>

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R

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A

When the user clicks add button, the add category modal will pop up. After the user enters the category name, the data in the input box will be verified, and then check whether there are duplicate category names. If all the verifications are passed, add the new category to Firestore.





Figure 6.147: Perform Add Category.

6.7.3.3 Update Category

The user can click the edit button of the category, and the update category modal box will pop up. After the user enters the category name in the input field, system will verify the input field, and the toUpdate function will also checks whether the new category name is duplicated or not. If all verifications are passed, the update category operation will be performed.

	≡	Category			≡		Cate	egory		
	Ш		Edit Remove		II					
	DWQD				DWG	ΙD				
	RWER				RWE	R				
	HRHTR				HRH	TR				
	OWNER			• • •	ov	Ed	it Cateç	gory Na	me	
	VISITOR			• • •	VIS	II				
Fi	gure 6.148:	Edit	Button	of		Cano	cel		Ok	
	Cate	egory.								ŧ
					*	:		Ð,	•	盘
					Figure	6.149:	Ec	lit	Ca	tegory
						Μ	odal.			



Figure 6.150: Perform Edit Category.

6.7.3.4 Remove Category

The user can click the remove button of the category, and the confirmation modal will pop up. After the user clicks OK, the category will be deleted from Firestore.

	≡	Category				Cat	egory
			Edit		н		
	П		Remove				
	DWQD			•••	DWQD		
	RWER				RWER		
	HRHTR				HRHTR	ł	
	OWNER				ov	Remove	e Category
					VIS	Are you sur	e to remove II?
	VISITOR			•••		Cancel	Ok
Fi	gure 6.151:	Remove	Buttor	n of			
	Cate	egory.					

Figure 6.152: Remove Category Confirmation.



Figure 6.153: Delete Category.

6.7.4 Person Module

The person module is divided into sections of viewing the car owner's personal information, registering the car owner, editing the car owner, deleting the car owner, and searching for the car owner.

6.7.4.1 View Car Owner' Personal Information

The user navigates to the person page to view list of car owners, after that, the system uses Firebase to search for the first 10 records of data and loads them on the page. At the same time, the system will detect whether there is any change in the car owner list in real time, and if so, it will present the updated data on the user interface. User can click one of the person cards to navigate to the person edit page, the detailed information of the car owner from Firestore such as name, phone number, license plate, category, registration time, and more personal information will be loaded to the edit page.





Figure 6.156: Load Car Owner List.



Figure 6.157: Detect New Data in Registration Collection.



Figure 6.158: Detect Update on Registration Collection.



Figure 6.159: Detect Deletion on Registration Collection.

6.7.4.2 Register Car Owner

The user navigates to the person page, clicks the add button to enter the registration page. User can enter the car owner's name, license plate number, phone number, category, and more personal information. When the user submits the form, the system will validate the data in the form and check for duplicate license plate numbers. If all the validation passes, it will add this car owner to Firestore, display the message of successfully registering the car owner, and return to the previous page.



Figure 6.160: Register Car Owner Page.



Figure 6.162: Register Car Owner Function.

6.7.4.3 Edit Car Owner

The user navigates to the person page and click one of the person cards to enter the edit person page. The system will first load the car owner's data into the form, and then the user can edit the car owner's name, license plate number, phone number, category, and person detail. When the user clicks submit, the system will validate the data in the form and check for duplicate license plate numbers. If all the validations pass, it will update the data in Firestore, display the message of successfully updating the car owner, and return to the previous page.



Owner page.



Figure 6.165: Perform Update Car Owner Action.

After the user navigates to the person page and clicks the remove button, a confirmation modal box will pop up. After the user confirms the deletion, this record will be removed from Firestore.

E Person	E Person
Q Search name, car plate, phone no	Q Search name, car plate, phone no
TEST 3213 3123 VISITOR 2023-04-20 14:22:40 Remove • • •	TEST (3213) (3123) (VISITOR) (2023-04-20 14-22:40)
TINTIN (KKK8888) (0168886969) (OWNER) (2023-04-06 17:27:16)	TINTIN (KKK8888) (01668886969) (OWNER) (2023-04-06 17:27:16)
ONGLIPWEI QQQ7777 (0109636698) (VISITOR) (2023-04-06 17:22:08)	ONGLIPWEI CC Remove Person Are you sure to remove TEST?
Figure 6.166: Remove Car Owner	Cancel Ok
Button.	
	+
	A II 👂 ± 🖄

Figure 6.167: Remove Car Owner Modal.



Figure 6.168: Perform Delete Car Owner Action.

6.7.4.5 Search for Car Owner

User navigates to the person page, enters the license plate, name, or mobile phone number in the search field to search for the car owner. System will use Algolia function to perform search operation, the returned result will be presented to user.



Figure 6.169: Search Car Owner Page.



Figure 6.170: Perform Algolia Search on Car Owner.

6.7.5 User Module

The user module is divided into sections of viewing user account list, creating a user account, editing the user account, and deleting the user account.

6.7.5.1 View user accounts

User navigates to the user page to view all user accounts. The system will monitor the user collection of Firestore and return all user account information to the user page.



Figure 6.171:

=)

R

User Page.

A

6.7.5.2 Create user account

User navigates to the user page and click the add button, the system will pop up the add user modal box. After the user enters the username, password, email address, mobile phone number and role, the system will verify the data in the input fields and check if there are duplicate usernames. After all validations pass, the system inserts a new piece of data into Firestore and closes the modal.



Modal.



Figure 6.175: Add User Account.

6.7.5.3 Edit user account

The user can click the edit button after navigating to the user page, and the system will pop up the update user modal box and initialize the data of all input fields. After the user changes the username, password, email, mobile phone number and role, the system will verify the data in the input fields and check for duplicate usernames. After all validations pass, the system updates the data in Firestore and closes the modal.

≡	User	_		≡
gerg (31231) <mark>дуге</mark> р	erson management	Edit Remove	•••	gerg 31231
tham (tham) (role mana	ager		•••	tham
hahaong hahaong2 pers	on management)		•••	* User ger

Figure 6.176: Edit User Button.

	Jser
gerg (31231) gyre (person manage	ment
tham	
Update Use	er Information
* Username:	
gerg	
* Password:	
31231	
Email:	
gyre	
Phone No:	
eg 0109587584	
* Role	
person manage	ement
Cancel	Ok
	÷
★ :: ₿	· ·
Figure 6.177:	Update User
Accou	nt Modal.



Figure 6.178: Initialize Form Data.

<pre>if (initialUsername.current == username && in setModalVisible(false) return }</pre>	itialPassword.cur ose Moc	rent == password && initialEm lal If same data	ail.current == C	= email &&
Toast loading ' 0)				
<pre>if (initialUsername.current != username) { let checkDuplicationResult = await reqChe if (checkDuplicationResult.msg && checkDu Toast.removeAll() Toast.fail("Same username exist", 1) return } }</pre>	ckDuplicationUser plicationResult.m Check fo	List(username); sg == "Same data exists") { or duplicate us	ernam	es
<pre>await reqUpdateUser(userId, { username, password, role: roleId, email: email ? email.trim() : "", phoneNumber: phoneNumber ? phoneNumber.tr</pre>	Upda ^{im()} : "",	ate the user ac	count	
<u>1</u>).				
<pre>\ Toast.removeAll() Toast.success("Successfully updated " + usern resetInputField() setModalVisible(false) catch (argenp) /</pre>	ame.trim(), 1)	close modal		
<pre>\ Toast.removeAll() Toast.success("Successfully updated " + usern resetInputField() setModalVisible(false) catch (error) { Toast.removeAll()</pre>	ame.trim(), 1)	close modal		
<pre>\}. Toast.removeAll() Toast.success("Successfully updated " + usern resetInputField() setModalVisible(false) catch (error) { Toast.removeAll() Toast.offline("Connection failed, please chec</pre>	ame.trim(), 1) k your internet a	close modal		

Figure 6.179: Perform Update User Account Action.

6.7.5.4 Remove user account

The user can click the remove button after navigating to the user page, and the system will pop up a confirmation modal. After the user confirms to delete the user, the system will delete the user account from Firestore and close the modal box.

User		⊟ User
Edit gerg 31231 gyre person management Remove		gerg 31231) gyre person management
tham (tham) (role manager)		tham (tham) (role manager)
hahaong [hahaong2] (person management)		hahaong hahaong2) (person management)
Figure 6.180: Remove	User	Remove User
Button.		Are you sure to remove gerg?
		Cancel Ok
		+
		Figure 6.181: Remove User
		Account Confirmation
		Modal.



Figure 6.182: Perform Delete User Account Action.

6.7.6 Role Module

The role module has 4 sections, namely view roles, create role, assign pages to role, and remove role.

6.7.6.1 View Roles

The user navigates to the role page to view the role list. The system will monitor the role collection of Firestore and update the latest role list to user.



Figure 6.183: Role Page.



Figure 6.184: Load Role List from Firestore.

6.7.6.2 Create Role

The user can click the add button after navigating to the role page, and the system will pop up the add role model. After the user enters the role name, the system will verify the data in the input box and check that there are duplicate role names. After all validations pass, the system inserts a new role into Firestore and closes the modal.

≡	Role			<pre>const validateRoleName = (value = roleName) => { if (value == "") { setRoleNameError("Role name cannot be empty" roleNameErrorRef.current = "Role name cannot </pre>		ty") not be empty"		
role ma	1nager 36 17:40:04) admin		•••	<pre>} else { setRoleNameError("") roleNameErrorRef.current = "" } </pre>				
person 2023-04-0	management 06 17:27:47 admin			Figure 6.186:	Validation	on	Role	
				Inpu	it Field.			
F								
	Add Role							
	Enter a role name							
	Cancel	Ok						
		9						
A	:: B ±							

Figure 6.185: Add Role Modal.

i	<pre>t checkDuplicationResult = await reqCheckDuplicationRoleList(roleName); f (checkDuplicationResult.msg == "Same data exists") { Toast.removeAll() Toast.fail("Same role name exist", 1) return:</pre>
} 1e /	et result = await reqAddRole({ role: roleName.trim() }); Add role to Firestore
To To re Se	<pre>wast.removeAll() past.success(`Add role \${roleName.trim()} successfully`, 1) esetInputField() close modal </pre>
cato To To	ch (error) { past.removeAll() past.offline("Connection failed, Please check you internet access", 1)
Fina	ally {

Figure 6.187: Add Role to Firestore.

After navigating to the role page, the user can click the edit button, and the system will pop up the edit role modal. The user can decide which interface the role can see, the system will update the role in Firestore after user clicks the ok button and close the modal box afterward.

Edit 2023-04-06 17:40:04 admin	role manager 2023-04-06 17:40:04 admin
person management 2023-04-06 17:27:47 admin	person management (2023-04-06.17:27:47) (admin)
	Edit Access Page
Figure 6.188: Edit Role Button.	✓ Home
	Category
	Person
	User
	Role
	Cancel Ok
	+
	★ II ▷ ⊥ ▲
	Figure 6.189: Assign Pages to
	Role.



Figure 6.190: Assign Pages to Role.

6.7.6.4 Remove Role

The user can click the remove button after navigating to the role page, and the system will pop up a confirmation modal. When the user confirms to delete the role, the system will delete the role in Firestore and close the modal box.

Role		Role
role manager (2023-04-06 17:40:04) (admin)	Edit Remove	role manager 2023-04-06 17:40:04) admin
person management 2023-04-06 17:27:47) (admin)		person management 2023-04-06 17:27:47 admin
Figure 6.191: Remove	Role Button.	

2222-04-06 1722747

Remove Role
Are you sure to remove role manager?
Al the users under this role will not be able to access the application.
Cancel
Ok
Image: Cancel
Ok
Figure 6.192: Remove The Role
Solution:



Figure 6.193: Remove Role from Firestore.

CHAPTER 7

SYSTEM TESTING

7.1 Introduction

This chapter mainly discusses the testing method of the project. The testing of this project includes the unit testing and using SUS to conduct system usability testing. Finally, this project also conducts on site testing to ensure that the applications can run well in a real working environment and meet the needs of user.

7.2 Unit Testing

This project uses unit testing to test every function of the web and mobile applications to ensure that the requirement specification is met. Unit testing is divided into web application unit testing and mobile application unit testing.

7.2.1 Web Application

Web application has a total of 49 test cases.

7.2.1.1 User Account

Login Account TC ID Test Case Test Case Steps Test Data **Expected Results** Result Summary TC001 Enter valid user Valid Username Redirected to home page Pass • Enter username 1. Valid Password account • 2. Enter password 3. Click login button TC002 Display validation error Provide empty Pass 1. Click login button input message TC003 Provide wrong Display account not found Wrong username Pass • 1. Enter wrong username Wrong password user account error message • 2. Enter wrong password 3. Click login button. TC004 User's role has Valid Username Display role has been Pass • 4. Remove the user role been removed Valid Password removed error message • 5. Enter valid username 6. Enter valid password 7. Click login button TC005 User's role has no Valid Username Display role has not been Pass • Remove the user's 1. pages assigned to Valid Password initialized message • role's menu list

Table 7.1:	Unit testing	of user account	(web application).
1 uoic 7.1.	Onit tosting	of user account	(web upplication).

	it	 Enter valid username Enter valid password Click login button 			
Logout A	Account				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC006	Logout from application	1. Click logout button	-	 Delete Redux's user info Delete local storage's user info Redirected to login page. 	Pass

7.2.1.2 Car Access Log

Table 7.2: Unit testing of car access log module (web application).

View Ca	r Access Logs					
TC ID	Test Case Summary	Test Case S	Steps	Test Data	Expected Results	Result
TC007	Display first 10 car access logs	1.	Navigate to home page	-	Display first 10 car access logs	Pass
TC008	Display next 10 car access logs	1. 2.	Navigate to home page Click load more button at the end of the list	-	Display total of 20 car access logs	Pass
Perform	Basic Search on Car	Access Logs	S			
TC ID	Test Case Summary	Test Case Steps		Test Data	Expected Results	Result
ТС009	Search with car plate number	1. 2.	Navigate to home page Select search by car plate	• Car plate number	 Display list of search results Display success message 	Pass
		3.	Provide car plate number in search field			
		4.	Click search button			

TC010	Search with name	1. 2. 3. 4.	Navigate to home page Select search by name Provide name in search field Click search button	• Name	 Display list of search results Display success message 	Pass
TC011	Search with phone number	1. 2. 3. 4.	Navigate to home page Select search by phone no Provide phone number in search field Click search button	• Phone number	 Display list of search results Display success message 	Pass
TC012	Search with category	1. 2. 3. 4.	Navigate to home page Select search by category Select a category from the selections. Click search button	Category	 Display list of search results Display success message 	Pass
TC013	Search with car access type	1. 2.	Navigate to home page Select search by enter or exit	• Enter type	 Display list of search results Display success message 	Pass
TC014	Search with empty field	 3. Select enter from selections 4. Click search button 1. Navigate to home page 2. Click search button 	-	• Display validation error message	Pass	
---------	--	---	--	---	--------	
Perform	Filter Search on Car	Access Logs				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result	
TC015	Filter search with car plate number, name, category, phone number, car access type and date range	 Navigate to home page Click filter button Provide car plate number, name, category, phone number, car access type and date range Click search button 	 Car plate number Name Category Phone number Enter type Start date End date 	 Display list of search results Display success message 	Pass	
TC016	Filter search with empty search fields	 Navigate to home page Click filter button Click search button 	_	• Display error message to alert user to provide date range	Pass	
View Ca	r Owner's Personal I	Information				
TC ID	Test Case	Test Case Steps	Test Data	Expected Results	Result	

	Summary				
TC017	View car owner personal information from car access log.	1. 2.	Navigate to home page Click more button from car access log	• Display a drawer containing the car owner's information	Pass

7.2.1.3 Category Module

Table 7.3: Unit testing of category module (web application).

View Ca	itegories					
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC018	Display list of categories	1.	Navigate to category page	_	Display a table listing the categories	Pass
Add a C	ategory					
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC019	Provide valid input	1. 2. 3. 4.	Navigate to category page Click add button Provide a category name Click ok button	Category name	 Show success message Close modal New category is appended to the list 	Pass
TC020	Provide empty input	1.	Navigate to category page	-	Display validation error message	Pass
		2.	Click add button			

		3.	Click ok button			
Edit Cate	egory					1
TC ID	Test Case Summary	Test Case S	Steps	Test Data	Expected Results	Result
TC021	Provide valid input	1. 2. 3.	Navigate to category page Click edit button Provide a category name	Category name	 Show success message Close modal Updated category name is shown in the list 	Pass
TC022	Provide empty input	1. 2. 3. 4.	Navigate to category page Click edit button Remove the data in the input field Click ok button	-	Display validation error message	Pass

TC023	Provide same input data	1. 2. 3.	Navigate to category page Click edit button Click ok button	Same category name	Close the modal	Pass
Remove	Category				-	
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC024	Remove category	1. 2. 3.	Navigate to category page Click remove button Click confirm button	-	 Show success message Close modal Remove the category from the list 	Pass

7.2.1.4 Person Module

View Ca	r Owners				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC025	Display list of car owners	1. Navigate to person page	, - , -	Display a table listing the car owners	Pass
TC026	View a specific car owner	 Navigate to person page Click view button 	-	Display the car owner's personal information	Pass
Register	Car Owner				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC027	Provide valid input	 Navigate to person page Click register button Provide valid name, car plate number, phone number, category, person detail Click submit button 	 Name Car plate number Phone number Category Person detail 	 Show success message Navigate to person page New person is appended to the list 	Pass

Table 7.4:Unit testing of person module (web application).

TC028	Provide empty input Provide invalid input	 Navigate to person page Click register button Click submit button Navigate to person page Click register button Navigate to person page Click register button Provide valid name, car plate number, category, person detail Provide invalid phone number Click submit button 	 Name Car plate number Invalid Phone number Category Person Detail 	 Display validation error message Display validation error message 	Pass
Edit Car	Owner				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
ТС030	Provide valid input	 Navigate to person page Click edit button 	 Name Car plate number Phone number Category 	 Show success message Navigate to person page 	Pass

		3. 4.	Provide valid name, car plate number, category, person detail Click submit button	• Person detail	• Updated information shown in the list	
TC031	Provide empty input	1. 2. 3.	Navigate to category page Click edit button Remove the data in the input fields	-	• Display validation error message	Pass
		4.	Click submit button			
TC032	Provide invalid input	1. 2. 3. 4. 5.	Navigate to person page Click edit button Provide valid name, car plate number, category, person detail Provide invalid phone number Click submit button	 Name Car plate number Invalid Phone number Category Person detail 	• Display validation error message	Pass

Remove	Car Owner				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC033	Remove car owner	 Navigate to person page Click remove button Click ok button 		 Show success message Close modal Remove the car owner from the list 	Pass
Search C	Car Owner				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC034	Search by car plate number	 Navigate to person page Provide car plate number in search field Click search button 	Car plate number	Display list of search results	Pass
TC035	Search by car owner's name	 Navigate to person page Provide name in search field Click search button 	Name	Display list of search results	Pass

TC036	Search by car owner's phone number	1. 2.	Navigate to person page Provide phone number in search field	Phone number	 Display list of search results 	Pass
		3.	Click search button			

7.2.1.5 User Module

 Table 7.5:
 Unit testing of user module (web application).

View Us	ser Accounts				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC037	Display list of user accounts	1. Navigate to user page	-	Display a table listing the user accounts	Pass
Create a	User Account				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC038	Provide valid input	 Navigate to user page Click add button Provide valid username password, email, phone number and role Click ok button 	 Username Password Email Phone number Role 	 Show success message Close modal New user account is appended to the list 	Pass
TC039	Provide empty input	 Navigate to user page Click add button Click ok button 	-	Display validation error message	Pass

Edit Use	er Account				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC040	Provide valid input	 Navigate Click edit Provide v password number a Click ok 	 to user page Username Password Email Phone number Role 	 Show success message Close modal Updated information shown in the list 	Pass
TC041	Provide empty input	 Navigate Click edit Remove to the input Click sub 	to user page t button the data from fields omit button	Display validation error message	Pass
TC042	Provide same input data	 Navigate Click edit Click ok 	to user page t button b	Close modal	Pass

TC ID	Test Case Summary	Test Case Ste	eps	Test Data	Expected Results	Result
TC043	Remove user account	1. 1 2. 0 3. 0	Navigate to user page Click remove button Click confirm button	-	 Show success message Close modal Remove the user account from the list 	Pass

7.2.1.6 Role Module

Table 7.6:Unit testing of role module (web application).

View Ro	les				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC044	Display list of roles	1. Navigate to role page	_	Display a table listing the roles	Pass
Create a	role				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC045	Provide valid input	1.Navigate to role page2.Click add button3.Provide valid role nam4.Click ok button	Role name	 Show success message Close modal New role is appended to the list 	Pass
TC046	Provide empty input	 Navigate to role page Click add button Click ok button 	-	Display validation error message	Pass
Assign p	ages to role				<u> </u>
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result

TC047	Provide input	1. 2. 3. 4.	Navigate to role page Click edit button Check the checkbox Click ok button	Menu list	 Show success message Close modal Update the role 	Pass
TC048	Provide same input data Role	1. 2. 3.	Navigate to role page Click edit button Click ok button	Same Menu list	Close modal	Pass
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC049	Remove role	1. 2. 3.	Navigate to role page Click remove button Click confirm button	-	 Show success message Close modal Remove the role from the list 	Pass

7.2.2 Mobile Application

Mobile application has a total of 43 test cases.

7.2.2.1 User Account

Table 7.7:	Unit testing	of user	account	(mobile	application).
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Login A	ccount				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC050	Enter valid user account	 Enter username Enter password Click sign in button 	Valid UsernameValid Password	Directed to home page	Pass
TC051	Provide empty input	1. Click sign in button	-	Cannot click sign in button	Pass
TC052	Provide wrong user account	 Enter wrong username Enter wrong password Click login button. 	Wrong usernameWrong password	Display account not found error message	Pass
TC053	User's role has been removed	1.Remove the user role2.Enter valid username	Valid UsernameValid Password	Display role has been removed error message	Pass

		3. 4.	Enter valid password Click login button			
TC054	User's role has no pages assigned to it	1. 2.	Remove the user's role's menu list Enter valid username	Valid UsernameValid Password	Display role has not been initialized message	Pass
		3. 4.	Enter valid password Click login button			
Logout A	Account					
TC ID	Test Case Summary	Test Case S	Steps	Test Data	Expected Results	Result
TC055	Logout from application	1. 2.	Open navigation panel Click logout button	-	 Delete Redux's user info Delete Async Storage's user info Redirected to sign in page. 	Pass

7.2.2.2 Car Access Log

 Table 7.8:
 Unit testing of car access log (mobile application).

View Ca	r Access Logs				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC056	Display first 10 car access logs	1. Navigate to home page	-	Display first 10 car access logs	Pass
TC057	Display next 10 car access logs	 Navigate to home page Scroll to the bottom of the list 	-	Display total of 20 car access logs	Pass
Perform	Basic Search on Car	Access Logs			
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC058	Search with car plate number	 Navigate to home page Provide car plate number in search field Hits enter from the keyboard 	• Car plate number	 Display list of search results Display success message 	Pass
Perform	Filter Search on Car	Access Logs			
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result

TC059 TC060	Filter search with car plate number, name, category, phone number, car access type and date range Filter search with empty search fields	1. 2. 3. 4. 1. 2.	Navigate to home page Click filter button Provide car plate number, name, category, phone number, car access type and date range Click submit button Navigate to home page Click filter button	 Car plate number Name Category Phone number Enter type Start date End date 	 Display list of search results Display success message Display error message to alert user to provide start date and end date 	Pass Pass
		3.	Click submit button			
View Ca	r Owner's Personal I	nformation				
TC ID	Test Case Summary	Test Case S	Steps	Test Data	Expected Results	Result
TC061	View car owner personal information from car access log.	1. 2.	Navigate to home page Click more button from car access log		• Display a drawer containing the car owner's information	Pass

7.2.2.3 Category Module

 Table 7.9:
 Unit testing of category module (mobile application).

View Ca	itegories					
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC062	Display list of categories	1.	Navigate to category page	_	Display a list of categories	Pass
Add a C	ategory					
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC063	Provide valid input	1. 2. 3. 4.	Navigate to category page Click add button Provide a category name Click ok button	Category name	 Show success message Close modal New category is appended to the list 	Pass
TC064	Provide empty input	1.	Navigate to category page	-	Display validation error message	Pass
		2.	Click add button			

		3.	Click ok button			
Edit Cate	egory					•
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC065	Provide valid input	1. 2. 3.	Navigate to category page Click edit button Provide a category name	Category name	 Show success message Close modal Updated category name is shown in the list 	Pass
TC066	Provide empty input	1. 2. 3. 4.	Navigate to category page Click edit button Remove the data in the input field Click ok button	-	Display validation error message	Pass

TC067	Provide same input data	1. 2. 3. 4.	Navigate to category page Click more button Click edit button Click ok button	Same category name	Close the modal	Pass
Remove	Category				•	•
TC ID	Test Case Summary	Test Case	Steps	Test Data	Expected Results	Result
TC068	Remove category	1. 2. 3. 4.	Navigate to category page Click more button Click remove button Click confirm button	-	 Show success message Close modal Remove the category from the list 	Pass

7.2.2.4 Person Module

Table 7.10: Unit testing of person module (mobile application).

View Ca	r Owners				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC069	Display list of car owners	1. Navigate to person page	_	Display a list of car owners	Pass
TC070	View a specific car owner	 Navigate to person page Click the person card 	-	Display the car owner's personal information	Pass
Register	Car Owner				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC071	Provide valid input	 Navigate to person page Click add button Provide valid name, car plate number, phone number, category, person detail Click submit button 	 Name Car plate number Phone number Category Person detail 	 Show success message Navigate to person page New person is appended to the list 	Pass

TC072	Provide empty input	1. 2.	Navigate to person page Click register button	-	• Display validation error message	Pass
		3.	Click submit button			
TC ID	Test Case Summary	Test Case S	teps	Test Data	Expected Results	Result
TC073	Provide valid input	1. 2. 3. 4.	Navigate to person page Click the person card Provide valid name, car plate number, category, person detail Click submit button	 Name Car plate number Phone number Category Person detail 	 Show success message Navigate to person page Updated information shown in the list 	Pass
TC074	Provide empty input	1. 2. 3. 4.	Navigate to category page Click edit button Remove the data in the input fields Click submit button	-	• Display validation error message	Pass
Remove	Car Owner					
TC ID	Test Case	Test Case St	teps	Test Data	Expected Results	Result

	Summary					
TC075	Remove car owner	1. 2. 3. 4.	Navigate to person page Click more button Click remove button Click ok button	-	 Show success message Close modal Remove the car owner from the list 	Pass
Search C	Car Owner	L			L	I
TC ID	Test Case Summary	Test Case S	Steps	Test Data	Expected Results	Result
TC076	Search by car plate number	1. 2. 3.	Navigate to person page Provide car plate number in search field Hits enter from the keyboard	• Car plate number	 Display list of search results 	Pass
TC077	Search by car owner's name	1. 2. 3.	Navigate to person page Provide name in search field Hits enter from the keyboard	• Name	 Display list of search results 	Pass

TC078	Search by car owner's phone number	1. 2.	Navigate to person page Provide phone number in search field	Phone number	 Display list of search results 	Pass
		3.	Hits enter from the keyboard			

7.2.2.5 User Module

Table 7.11: Unit testing of user module (mobile application).

View Us	View User Accounts					
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result	
TC079	Display list of user accounts	1. Navigate to user page	-	Display a list of user accounts	Pass	
TC080	View user account detail	 Navigate to user page Click a user card 	-	Display a drawer containing user account detial	Pass	
Create a	User Account					
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result	
TC081	Provide valid input	 Navigate to user page Click add button Provide valid username password, email, phone number and role Click ok button 	 Username Password Email Phone number Role 	 Show success message Close modal New user account is appended to the list 	Pass	

TC082 Edit Use	Provide empty input r Account	1. 2. 3.	Navigate to user page Click add button Click ok button	-	• Display validation error message	Pass
TC ID	Test Case Summary	Test Case S	Steps	Test Data	Expected Results	Result
TC083	Provide valid input	1. 2. 3. 4.	Navigate to user page Click edit button Provide valid username, password, email, phone number and role Click ok button	 Username Password Email Phone number Role 	 Show success message Close modal Updated information shown in the list 	Pass
TC084	Provide empty input	1. 2. 3. 4.	Navigate to user page Click edit button Remove the data from the input fields Click submit button	-	• Display validation error message	Pass
TC085	Provide same input data	1. 2. 3.	Navigate to user page Click edit button Click ok button	 Same username Same password Same email Same phone number 	Close modal	Pass

				• Same role		
Remove	User Account					
TC ID	Test Case Summary	Test Case Steps	,	Test Data	Expected Results	Result
TC086	Remove user account	 Navigate Click mod Click rem Click con 	to user page re button love button firm button		 Show success message Close modal Remove the user account from the list 	Pass

7.2.2.6 Role Module

Table 7.12: Unit testing of role module (mobile application).

View Ro	oles				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC087	Display list of roles	1. Navigate to role pag	ge -	Display a list of roles	Pass
TC088	View role detail	 Navigate to role page Click one of the role cards 	ge - e	Display a drawer containing the information of pages that this role can access.	Pass
Create a	role				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC089	Provide valid input	 Navigate to role page Click add button Provide valid role n Click ok button 	e Role name	 Show success message Close modal New role is appended to the list 	Pass
TC090	Provide empty input	 Navigate to role page Click add button Click ok button 	ge -	Display validation error message	Pass

Assign p	ages to role				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC091	Provide input	 Navigate to role page Click edit button Check the checkbox Click ok button 	• Menu list	 Show success message Close modal Update the role's menu list 	Pass
Remove	Role				
TC ID	Test Case Summary	Test Case Steps	Test Data	Expected Results	Result
TC092	Remove role	 Navigate to role page Click the more button Click remove button Click confirm button 	-	 Show success message Close modal Remove the role from the list 	Pass

7.3 System Usability Testing

This project uses SUS to evaluate the web and mobile applications. SUS is a standardized questionnaire that can help evaluate the usability of a system. It is a simple, reliable, and widely used tool that can be used to assess the effectiveness, efficiency, and satisfaction of a system.

Five participants were invited to conduct a system usability test. There are two main ways to conduct the usability testing, one is face-to-face testing with the participants, and the other is using zoom meeting for online testing. Figure 7.1 shows the developer conducting a system usability test with the user.

Before the test, the host will introduce the background of the system, and then read each test scenario to the participants, and the participants complete the corresponding tasks according to the test scenario. After the participants completed all the tasks, a google form link will be sent to them for them to fill out.



Figure 7.1: Conducting System Usability Test.

7.3.1 Test Scenario

Table 7.13 contains the test scenarios used to conduct the system usability test.

No	Test Scenario Title	Description
1	Login the account	 Scenario: You want to access the application. Task: Log in the admin account.
2	Logout from the application	 Scenario: You want to logout from the application. Task: Perform logout action.
3	View list of car access logs	 Scenario: You want to view the list of car access logs. Task:
		• View the car access logs.
4	Search for the car access log	 Scenario: You want to search for the car access logs from 1 April to 15 April. Task:
5	View car owner's personal information	 Search according to preference. Scenario: You want to check phone number of the car owner from the car access log. Task:
6	View list of	 View the car owner's personal information from home page. Scenario:
	categories	• You want to view all the categories that

Table 7.13: Usability Testing Scenario.

		can be assign to the car owner.
		Task:
		View category list
7	Create a category	Scenario:
		• You want to create a new category for the
		grab driver.
		Task:
		• Create a "Grab Driver" category.
8	Edit the category	Scenario:
		• You are not satisfied with the "Grab
		Driver" category name, you wish to
		change it to "Grab".
		Task:
		• Change the "Grab Driver" category name
		to "Grab".
9	Remove the	Scenario:
	category	• You do not want the "Grab" category to
		exist anymore, you wish to remove it.
		Task:
		• Remove the "Grab" category.
10	View list of	Scenario:
	registered car	• You want to view all the car owners'
	owners	information that has been registered to the
		system.
		Task:
		• View car owner list.
	Register a car	Scenario:
	owner	• You want to record a car owner's
		information in the system.

Task:	
• Register a car o	wner.
12Edit the car ownerScenario:	
• The car owner c	changed his phone number
yesterday, you v	want to update his new
phone number t	o the system.
Task:	
• Update the car of	owner's phone number.
13Remove the carScenario:	
• The car owner i	s no longer living in the
condominium, y	you want to remove his
record from the	system.
Task:	
• Remove the car	owner.
14 Search the car Scenario:	
owner • You want to sea	urch for the owner's phone
number of the c	ar that parks at
unauthorized ar	ea.
Task:	
Search for car o	wner's information.
15 View user Scenario:	
accounts • You want to vie	w all user accounts that
has access to this	is system.
Task:	
View user account	unts.
16 Create user Scenario:	
account You want to cre	ate a new account for the
security guard s	o that he can view car
access logs.	

		Task:
		• Create an account and assign the specific
		role to it.
17	Edit user account	Scenario:
		• The security guard wishes to have a simple
		password, you want to edit his account to
		change his password.
		Task:
		• Edit the security guard's account.
18	Remove user	Scenario:
	account	• The security guard quits his job, you want
		to remove his account.
		Task:
		• Remove the security guard's account.
19	View all the roles	Scenario:
		• You want to give a new role for the
		security guard, you want to browse and
		find the suitable role.
		Task:
		• Check role list.
20	Create a new role	Scenario:
	and assign page to	• You want to create a role that can only
	the role	access the home page, that is the user
		account with this role can only view car
		access logs.
		Task:
		• Create the role and assign home page to it.
21	Delete role	Scenario:
		• You found a role that is no longer used,
		you want to remove it.
--	-------	------------------------
	Task:	
	•	Delete the role.

7.3.2 System Usability Test Result

The SUS score can be calculated based on the results in **Appendix B**. Sauro (2011) listed the four main steps to calculate the SUS score. The four steps are:

- i. For questions with odd numbers, subtract 1 from the score.
- ii. For questions with even numbers, the score is subtracted by 5.
- iii. Add the final scores of all questions together, and then multiply by 2.5.
- iv. The calculated result is the SUS usability score of the product.

Bangor, Kortum and Miller (2009) mapped the SUS score with the adjective rating, as shown in Table 7.14. This project will apply the adjective rating in Table 7.15 and Table 7.16.

Table 7.14: SUS Score Interretation (Bangor, Kortum and Miller, 2009	Table 7.14:	SUS Score	Intepretation	(Bangor, Kortun	and Miller,	2009)
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Adjective Rating	SUS Score
Worst Imaginable	12.5
Awful	20.3
Poor	35.7
ОК	50.9
Good	71.4
Excellent	85.5
Best Imaginable	90.9

		U	sabil	lity S	Scor	e pe	r Q	uest	ions			
Participants	1	2	3	4	5	6	7	8	9	10	Total	Percentage
Cheah Sung Chai	4	4	3	1	3	4	3	3	4	4	33	82.5
Chang Hao Jie	4	4	3	4	3	3	4	4	4	4	37	92.5
Tong Kah Pau	3	4	4	3	4	4	4	3	4	4	37	92.5
Wong Tack Hwa	4	3	4	4	3	3	4	4	4	4	37	92.5
Ooi Yun Xiang	3	3	4	3	4	4	3	3	4	3	34	85
Average SUS Score									89			
Grade								Α				
Adjective Rating								Excellent				

Table 7.15: SUS Score of Web Application.

Table 7.16: SUS Score of Mobile Application.

		Usability Score per Questions							;	T	D	
Participants		2	3	4	5	6	7	8	9	10	lotai	Percentage
Cheah Sung Chai	4	3	3	1	3	3	4	3	4	4	32	80
Chang Hao Jie	4	4	4	4	3	3	4	4	3	3	36	90
Tong Kah Pau	4	4	3	3	4	4	4	4	3	3	36	90
Wong Tack Hwa	4	4	4	4	4	4	3	3	4	4	38	95
Ooi Yun Xiang	3	4	4	4	3	3	4	4	4	4	37	92.5
Average SUS Score										89.5		
Grade										Α		
Adjective Rating								Excellent				

7.4 On Site Testing

The project conducted onsite testing with the manager in Site A on April 7, 2023, this is to ensure that the applications run smoothly in a real working environment. The activities include installing the camera, running the license plate detection AI program on the Linux computer, and adjusting the boundary box of the frame in OpenCV to ensure that the vehicle's license plate falls in the blue boundary box for detection. The ability of web and mobile

applications to accept real time car access log updates was also tested. In addition, the offline upload function of the program is also tested, this is to ensure that the Python program can save the license plate information locally when the network is interrupted, and once the network connection is restored, it will be uploaded to the Firebase server immediately. Finally, the developer also performs system usability testing with the manager.



Figure 7.2: Installing Camera.



Figure 7.3:

Tuning Bounding Box.



Figure 7.4: Perform System Usability Testing on Mobile Application

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

8.1 Conclusions

In conclusion, this project took a total of ten months to complete. The main purpose of the project is to use AI to replace the traditional monitor car access log and register car owner processes. In order to obtain accurate user requirements, on-site observation and questionnaire technique was used and the valuable data is then formulated to the project's objective and requirement specification. The system development starts after this. To ensure the portability, security, and stability of web applications, this project uses docker to run the web application and uses HTTPS to encrypt the website. In addition, AWS's load balancer and EC2 instances services are also used to ensure that the project runs on two servers. If one server fails to serve, the other server will take over the traffic. The project also uses the AWS Budgets service to monitor costs and ensure that costs are within the allowable range.

After the system is developed, unit testing, system usability testing, and most importantly onsite testing are carried out to ensure that the system can run stably in the working environment. The average SUS score for the web application was 89%, while the mobile application achieved 89.5%. Furthermore, the five objectives shown in the list below were successfully accomplished:

- 1. Develop real-time web and mobile ALPR application to monitor car access log and manage car owners. By using Firestore's real-update function in web and mobile applications, user can monitor car access in real time. In addition, both web and mobile applications use the Ant Design UI library to ensure the uniformity of the interface, so that users can manage car owners smoothly, thus abandoning the traditional process of using paper to record car owners.
- 2. Utilizing AWS cloud services to deploy web application. The AWS services used in this project include Route53, Load

Balancer, AWS Certificate Manager, EC2, Amazon CloudWatch and AWS Budgets. These services ensure that user can access the reliable project's web application online and keep the cost under budget.

- 3. Promote CI/CD flow by using Github Actions to automatically deploy web application on AWS servers. By using Github Actions, the traditional development process is optimized. Only one git push command is needed to deploy the latest web project on the two servers of AWS. The redeployment of the project only takes about 20 seconds, and the user can access the newly updated web application online.
- **4. Deploy ALPR system at the security guard station.** On April 7, 2023, the developer and mentor went to the security guard station in Site A for onsite testing to ensure that the entire system can operate smoothly and ensure that the system can record vehicle entry and exit information in offline environment.
- 5. Using system usability scale to evaluate web and mobile applications.

This project invited five people to conduct the system usability test, and the scores of most of the questions were between 4-3, which means that the system has a good usability and has been accepted by the target user during the onsite testing.

8.2 Limitations and Future Enhancement

The project still has some limitations and areas for improvement. Table 8.1 lists system limitations and improvement suggestions.

No		Limitatio	on	Recommendation					
1	Lack	of	data	a Use the E-chart library to make pi	ie				
	visua	lization		charts or histograms for vehicle entry					
	capab	oilities		and exit records					
2	The	current	YOLO	Use the transform function of OpenCV					

 Table 8.1:
 Limitations and Recommendations of the System.

	model has poor	to correct the tilted license plate to a					
	accuracy in recognizing	frontal perspective and it is necessary to					
	the license plate number	use the license plate photos at night to					
		train the neural network to have good					
		detection accuracy in the night					
		environment.					
3	When registering a new car owner in the person module, the system does not support the user to directly upload pictures	• Develop a function that allows users to upload pictures from the local machine to the database, but this will increase the operating cost of the database.					
	from the local photo						
	album.	• Use a chean photo album hosting					
		platform By uploading pictures					
		to the photo album hosting					
		platform it will return the photo					
		link and user can insert it to the					
		What You See Is What You Get					
		(WYSIWYG) component of					
		person's detail to achieve custom					
		picture insertion function.					
4	Applications only	Translate keywords into different					
	support English.	languages and package them into a					
		library, so that both web and mobile					
		applications use this language library to					
		provide different language such as Malay					
		or Chinese.					

REFERENCES

Hanna, K., 2007. Adsorption of aromatic carboxylate compounds on the surface of synthesized iron oxide-coated sands. *Applied Geochemistry*, 22, pp. 2045-2053.

Zhang, B., Cohen, J., Ferrence, R. and Rehm, J., 2006. The impact of tobacco tax cuts on smoking initiation among Canadian young adults. *American Journal of Preventive Medicine*, 30, pp. 474-479.

Affairs, A., 2022. *System Usability Scale (SUS) / Usability.gov. [online]* Usability.gov. Available at: https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html [Accessed 7 August 2022].

A complete guide to the waterfall methodology / indeed.com (2023). Available at: https://www.indeed.com/career-advice/career-development/waterfall-methodology (Accessed: April 26, 2023).

Agrawal, V., 2017. Improving Real-Time Object Detection with YOLO. Available through: California in United States, Cube Dev, Inc. Retrieved from: https://blog.statsbot.co/real-time-object-detection-yolo-cd348527b9b7 [Accessed 24 August 2021].

Alborzi, Y., Mehraban, T., Khoramdel, J. and Ardekany, A., 2019. Robust Real time Lightweight Automatic License plate Recognition System for Iranian License Plates. 2019 7th International Conference on Robotics and Mechatronics (ICRoM), [online] Available at: <https://ieeexplore.ieee.org/document/9071863> [Accessed 7 August 2022].

Bangor, A., Kortum, P. and Miller, J., 2009. *Determining What Individual* SUS Scores Mean: Adding an Adjective Rating Scale. Journal of Usability Studies, 4(3), pp. 114-123. [Accessed 20 April 2023]

Bentley.edu. 2022. *What Every Client Should Know about SUS Scores*. [online] Available at: https://www.bentley.edu/centers/user-experience-center/what-every-client-should-know-about-sus-scores [Accessed 24 August 2022].

Bochkovskiy, A., 2020. YOLOv4-tiny released: 40.2% AP50, 371 FPS (GTX 1080 Ti), 1770 FPS tkDNN/TensorRT. Available through: California in United States, GitHub. Retrieved from: https://github.com/AlexeyAB/darknet/issues/6067 [Accessed 18 August 2021].

DevOps implementation roadmap and advantages (2023) *TatvaSoft Blog.* Available at: https://www.tatvasoft.com/blog/devops-implementation/ (Accessed: April 26, 2023).

Dason, C., 2022. *Malls in Kuching use mobile app for parking payment | KuchingBorneo.* [online] KuchingBorneo. Available at: https://kuchingborneo.info/malls-in-kuching-use-mobile-app-for-parking-

payment/> [Accessed 7 August 2022].

Firasanti, A., Ramadhani, T., Bakri, M. and Zaki Hamidi, E., 2021. License Plate Detection Using OCR Method with Raspberry Pi. 2021 15th International Conference on Telecommunication Systems, Services, and Applications (TSSA), [online] Available at: https://ieeexplore.ieee.org/document/9768252>

Lee, Y., Yun, J., Hong, Y., Lee, J. and Jeon, M., 2018. Accurate License Plate Recognition and Super-Resolution Using a Generative Adversarial Networks on Traffic Surveillance Video. 2018 IEEE International Conference on Consumer Electronics - Asia (ICCE-Asia), [online] Available at: https://ieeexplore.ieee.org/document/8552121> [Accessed 7 August 2022].

Malaysia license plate recognition parking system with LPR camera ANPR camera (no date) Malaysia License Plate Recognition Parking System With Lpr Camera Anpr Camera - Buy License Plate Recognition Software,Lpr Camera,Anpr Camera Product on Alibaba.com. Available at: https://www.alibaba.com/product-detail/Malaysia-License-Plate-Recognition-Parking-system_60780988667.html (Accessed: April 28, 2023).

Martin, M., 2022. *Prototyping Model in Software Engineering: Methodology, Process, Approach.* [online] Guru99. Available at: <https://www.guru99.com/software-engineering-prototyping-model.html#5> [Accessed 26 August 2022].

Negassi, I., Goitom Araya, G., Awawdeh, M. and Faisal, T., 2018. Smart Car plate Recognition System. 2018 1st International Conference on Advanced Research in Engineering Sciences (ARES), [online] Available at: https://ieeexplore.ieee.org/document/8723276> [Accessed 7 August 2022].

Nooruddin, S., Sharna, F. and Ahsan, S., 2020. A Bangladeshi License Plate Detection System Based on Extracted Color Features. 2020 23rd International Conference on Computer and Information Technology (ICCIT), [online] Available at : https://ieeexplore.ieee.org/document/9392672> [Accessed 7 August 2022].

Petiwala, F., Shukla, V., Mishra, V. and Saini, S., 2021. Smart Parking System through Automation in License Plate Recognition. 2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), [online] Available at: https://ieeexplore.ieee.org/document/9596554> [Accessed 7 August 2022].

ReactJS - architecture (no date) Tutorials Point. Available at: https://www.tutorialspoint.com/reactjs/reactjs_architecture.htm (Accessed: April 27, 2023).

Rusakov, K., 2020. Automatic Modular License Plate Recognition System Using Fast Convolutional Neural Networks. 2020 13th International Conference "Management of large-scale system development" (MLSD), [online]

Available

https://ieeexplore.ieee.org/document/9247817/references#references [Accessed 7 August 2022].

Sauro, J., 2011. Measuring Usability with the System Usability Scale (SUS). [online] Available at: ">https://measuringu.com/sus/ [Accessed 21 April 2023]

Shkurti, L., Aliu, A. and Kabashi, F., 2021. ParkingKS: Parking Management System Using Open Automatic License Plate Recognition. 2021 International Conference on Electrical, Computer and Energy Technologies (ICECET), [online] Available at: https://ieeexplore.ieee.org/document/9698479 [Accessed 7 August 2022].

Sun, G., Li, G., Xu, L. and Wang, J., 2008. A new method of vehicle license plate location based on mathematical morphology and texture characteristics. 2008 3rd IEEE Conference on Industrial Electronics and Applications, [online] Available https://www.researchgate.net/publication/251855376_A_new_method_of_ve

hicle_license_plate_location_based_on_mathematical_morphology_and_textu re_characteristics> [Accessed 7 August 2022].

Suraj, S., Sridhar, N., Jijesh, J. and Shivashankar, 2018. Automatic Parking Gateway using Character Recognition. 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Computication Technology (RTEICT), [online] Available at: https://ieeexplore.ieee.org/document/9012222> [Accessed 7 August 2022].

Sgi (2023) Automated licence plate readers - SGI - SGI - liferay DXP PRD01, SGI. Available at: https://sgi.sk.ca/alpr (Accessed: April 28, 2023).

TAN, W., 2021. *IOT BASED CAR PLATE RECOGNITION SYSTEM*. Kajang: Universiti Tunku Abdul Rahman.

Tham, M. and Tan, W., 2021. IoT Based License Plate Recognition System Using Deep Learning and OpenVINO. 2021 4th International Conference on Sensors, Signal and Image Processing, [online] Available at: https://doi.org/10.1145/3502814.3502816> [Accessed 3 August 2022].

Tian, Q., Guo, T., Qiao, S., Wei, Y. and Fei, W., 2014. Design of Intelligent Parking Management System Based on License Plate Recognition. *Journal of Multimedia*, [online] 9(6). Available at: <https://www.researchgate.net/publication/306407821_Design_of_Intelligent_ Parking_Management_System_Based_on_License_Plate_Recognition> [Accessed 7 August 2022].

Wayleadr Blog. 2022. A Look at RFID Parking Systems and Alternative Options (Expert Guide). [online] Available at: https://wayleadr.com/blog/rfid-parking-system-alternatives/ [Accessed 3 August 2022].

at:

Wong, A., 2019. Sunway Pyramid Smart Parking accepts eWallet and card payments from Q1 2020 - SoyaCincau. [online] SoyaCincau. Available at: https://soyacincau.com/2019/10/29/sunway-pyramid-smart-parking-system-lpr-2020/> [Accessed 7 August 2022].

APPENDICES

Appendix A: Conduct Observation at Site A



Appendix B: System Usability Test Results

System Usability Result (Web Application)

Name: Cheah Sung Chai

4/24/23, 6.38 PM ALPR System Usability Scale Web Application	4/24/23, 8:39 PM ALPR System Usability Scale Web Application
	I thought the system was easy to use *
ALPR System Usability Scale Web Application	Strongly Disagree
	2 ()
I think that I would like to use this system frequently *	3 🔘
Strongly Disagree	4 ()
	5 🔿
2 0	Strongly Agree
3 ()	
4 ()	I think that I would need support of a technical person to be able to use this system *
5 Strongly Agree	
Groug) ngroe	2 ()
I found the system unnecessarily complex *	3 🔘
Strongly Disagree	4 ()
1 💿	5 🔿
2 ()	Strongly Agree
3 ()	
4 ()	
5 ()	
Strongly Agree	
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4/24/23, 8:39 PM	ALPR System Usability Scale Web Application	4/24/23, 8:39 PM	ALPR System Usability Scale Web Application
I found that various fu	unctions in this system were well integrated *	I would imagine that	t most people would learn to use this system very quickly *
Strongly Disagree		Strongly Disagree	
1 ()		1 ()	
2 ()		2 ()	
з ()		3 🔾	
4 💿		4 🔘	
5 🔿		5 🔘	
Strongly Agree		Strongly Agree	
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I thought there was to	so much inconsistency in this system *	Strangly Disagree	ery awkwalu to use
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2 🔘		2 🔘	
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Strongly Agree		Strongly Agree	
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4/24/23, 8:39 PM	ALPR System Usability Scale Web Application
I felt very confident using the system *	
Strongly Disagree	
1 🔘	
2 🔘	
3 🔘	
4 🔿	
5 🔘	
Strongly Agree	
I needed to learn a lot of things before I of	could get going with this system *
Strongly Disagree	

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3			
4			
5 🔿			
Strongly Agree			

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Name: Chang Hao Jie

4/24/23, 6-42 PM ALPR System Usability Scale Web Application	4/24/23, 8:42 PM	ALPR System Usability Scale Web Application
	I thought the system was e	easy to use *
	Strongly Disagree	
ALPR System Usability Scale Web Application	1 ()	
	2 ()	
I think that I would like to use this system frequently *		
	3	
Strongly Disagree	4 🔘	
. 0	5 ()	
2	Stronaly Agree	
3 🔘		
4 ()	I think that I would need su	upport of a technical person to be able to use this system *
5 🔘	Strongly Disagree	
Strongly Agree	1 💿	
	2 ()	
I found the system unnecessarily complex *	- 0	
Strongly Disagree	3	
1 💿	4 🔘	
2 ()	5 🔘	
3 ()	Strongly Agree	
4 ()		
5 🔿		
Strongly Agree		
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	https://docs.google.com/forms/d/1jmhwCujyB.	JjKMMo-O64k/HaaZG6opnsGoSew7LHDdos/edil#response=ACYDBNgSy8FTmsupR3i_bhNeFCXw



4/24/23, 8:42 PM	ALPR System Usability Scale Web Application
I felt very confident using the system *	
Strongly Disagree	
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Strongly Agree	

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Name: Tong Kah Pau

4/24/23, 8:47 PM	ALPR System Usability Scale Web Application	4/24/23, 8:47 PM	ALPR System Usability Scale Web Application
		I thought the system wa	s easy to use *
ALPR System	m Usability Scale Web Applicati	Strongly Disagree	
I think that I would like to Strongly Disagree 1 0	use this system frequently *	3 () 4 () 5 ()	
3 ()		Strongly Agree	
4 5 Strongly Agree		I think that I would need Strongly Disagree	support of a technical person to be able to use this system *
I found the system unner Strongly Disagree 1	essarily complex *	2 () 3 () 4 () 5 () Strongly Agree	
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4/24/23, 8:47	PM	ALPR System Usability Scale Web Application	4/24/23, 8:47 PM	ALPR System Usability Scale Web Application
I four	nd that various functions in	this system were well integrated *	I would imagine that m	nost people would learn to use this system very quickly \star
Stror	ngly Disagree		Strongly Disagree	
	1 ()		1 🔘	
:	2 ()		2	
:	3 🔘		3 🔘	
	4 🔘		4 🔘	
	5 🔘		5 🔘	
Stror	ngly Agree		Strongly Agree	
I thou	ught there was too much in	consistency in this system *	I found the system ver	ry awkward to use *
Stror	ngly Disagree		Strongly Disagree	
	1 💿		1 ()	
:	2 ()		2 💿	
:	3 🔿		3 🔘	
	4 🔘		4 🔘	
	5 🔿		5 🔘	
Stror	ngly Agree		Strongly Agree	
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4/24/23, 8:47 PM	ALPR System Usability Scale Web Application
I felt very confident using the system *	
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Name: Wong Tack Hwa

		I thought the system was easy to use *
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5		Strongly Disagree
Strongly Agree		1 💿
		2 ()
I found the system unneces	sarily complex *	3 ()
Strongly Disagree		4 ()
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4/24/23, 8:47 PM	ALPR System Usability Scale Web Application
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Name: Ooi Yun Xiang

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ALPR System Usability Scale web Application	1 ()
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I think that I would like to use this system frequently *	3 ()
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5 🔿	Strongly Disagree
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4/24/23, 8:45 PM	ALPR System Usability Scale Web Application
I felt very confident using the system *	
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System Usability Result (Mobile Application) Name: Cheah Sung Chai

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Name: Chang Hao Jie

4/24/23, 8:51 PM	ALPR System Usability Scale Mobile Application	4/24/23, 8.51 PM ALPR System Usability Scale Mobile Application
ALPR Syste	err Usability Scale Mobile Application	I thought the system was easy to use * Strongly Disagree 1 2 3 3
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4/24/23, 8:51 PM	ALPR System Usability Scale Mobile Application	4/24/23, 8:51 PM	ALPR System Usability Scale Mobile Application
I found that various fund	ctions in this system were well integrated *	I would imagine that	most people would learn to use this system very quickly \star
Strongly Disagree		Strongly Disagree	
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5 🔿		5 🔘	
Strongly Agree		Strongly Agree	
I thought there was too	much inconsistency in this system *	I found the system v	arv awkward to use *
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4/24/23, 8:51 PM	ALPR System Usability Scale Mobile Application
I felt very confident using the system *	
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Name: Tong Kah Pau

4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application	4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application
		I thought the system wa	is easy to use *
		Strongly Disagree	
ALPR Syste	m Usability Scale Mobile Application	1 ()	
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I think that I would like to) use this system frequently *	з ()	
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4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application
I felt very confident using the system *	
Strongly Disagree	
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Strongly Agree	

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Strongly Agree		

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Name: Wong Tack Hwa

4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application	4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application
		I thought the system	was easy to use *
		Strongly Disagree	
ALPR Syste	em Usability Scale Mobile Application	1 ()	
		2 ()	
I think that I would like	to use this system frequently *	3 ()	
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		https://docs.google.com/forms/d/1DDj/	eFX0fbbvwEg6nFxsx2M1dRq9LWzglog157JMIYMiedt#response=ACYDBNgCDcDxHMex(wpiZbPySAX)Sg5xY

4/24/23	8:50 PM	ALPR System Usability Scale Mobile Application	4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application
I	found that various function	ons in this system were well integrated *	I would imagine th	at most people would learn to use this system very quickly *
5	Strongly Disagree		Strongly Disagree	
	1 🔘		1 🔘	
	2 🔘		2 🔘	
	3 🔘		з ()	
	4 🔿		4 💿	
	5 🔘		5 🔘	
5	Strongly Agree		Strongly Agree	
-	thought there was too mu	uch inconsistency in this system *	I found the system	very awkward to use *
5	Strongly Disagree		Strongly Disagree	
	1 🔘		1 ()	
	2 🔘		2 🔘	
	3 🔘		з ()	
	4 🔘		4 🔿	
	5 🔘		5 🔘	
5	Strongly Agree		Strongly Agree	
https://d	iocs.google.com/lorms/d/1DDjeFX0ffb	bbvwEg6nFxsx2M1dRq6LWzglog157JMIYMiediWresponse=AGYDBNgCDcDXHMexjwpiZbl	https://docs.google.com/forms/d/	1DDjeFX0ffbbvwEg&nFxsx2M1dRq9LWzglog157JMIYMiedit/tresponse=ACYDBNgCDcDXHMex/wpiZ

4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application
I felt very confident using the system *	
Strongly Disagree	
1 🔿	
2	
3 🔘	
4 🔘	
5 🔘	
Strongly Agree	

Strongly Disagree			
1 🔘			
2 🔘			
3 🔘			
4			
5 🔘			
Strongly Agree			

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Name: Ooi Yun Xiang

4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application	4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application
		I thought the system w	vas easy to use *
		Strongly Disagree	
ALPR Syste	em Usability Scale Mobile Application	1 ()	
		2 🔿	
I think that I would like to	o use this system frequently *	з ()	
Strongly Disagree			
1 ()		- 0	
2 ()		5 🔘	
- 0		Strongly Agree	
3 ()			
4 🔘		I think that I would nee	ed support of a technical person to be able to use this system *
5 🔿		Strongly Disagree	
Strongly Agree		1 🔘	
		2 ()	
I found the system unne	ecessarily complex *		
Strongly Disagree		3 ()	
1 🔘		4 🔿	
2 ()		5 🔿	
- 0		Strongly Agree	
3 🔿			
4 🔿			
5 🔿			
Strongly Agree			
bites lite as sould comformability of the			
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4/24/23, 8:50 PM	ALPR System Usability Scale Mobile Application
I felt very confident using the system *	
Strongly Disagree	
1 🔿	
2	
3 🔘	
4 🔘	
5 🔘	
Strongly Agree	

Strong	y Disagree			
1	۲			
2	0			
3	0			
4	0			
5	0			
Strong	y Agree			

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