Department of Information Technology

Vaccine Distribution Monitoring System

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Dissertation Approval Sheet

The dissertation entitled "Vaccine Distribution Monitoring System" submitted by Achal Athale, Apoorva Gupta and Ashutosh Halwai is approved as partial fulfillment for the award of Bachelor of Engineering in Information Technology Degree by Devi Ahilya Vishwavidyalaya, Indore.

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Recommendation

The dissertation entitled **Vaccine Delivery Monitoring System** submitted by Achal Athale, Apoorva Gupta, Ashutosh Halwai is a satisfactory account of the bonafide work done under my supervision is recommended towards the partial fulfilment for the award of Bachelor of Engineering in Information Technology by Devi Ahilya Vishwavidyalaya, Indore.

Date: 31/01/2021   **Dr. Pratosh Bansal**

                                                                            Project Guide

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Candidate Declaration

We hereby declare that the work which is being presented in this project entitled Vaccine Delivery Monitoring System in partial fulfillment of degree of Bachelor of Engineering in Information Technology is an authentic record of our own work carried out under the supervision and guidance of Dr. Pratosh Bansal, Name of the post of the project guide in Department of Information Technology, Institute of Engineering and Technology, Devi Ahilya Vishwavidyalaya, Indore

We are fully responsible for the matter embodied in this project in case of any discrepancy found in the project and the project has not been submitted for the award of any other degree.

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ABSTRACT

The purpose of this project is to understand various Vaccine Distribution Models employed in India, to evaluate their shortcomings and prepare a platform which solves as many issues as possible in the currently used Vaccine Distribution Models.

During research the team found out that the current Vaccine Distribution Monitoring Model employed in India is the Electronic Vaccine Intelligence Network platform. The platform uses a wide worker base to monitor the condition of the stored vaccine and update the stock information in a central database for effective monitoring via the mobile application. The platform however fails to track the vaccines while being transported which can lead to loss of vaccines due to multiple reasons.

This project aims to deploy a platform which can track the vaccines by updating their locations as the vaccine stock crosses any checkpoint (storage facilities, transportation agencies, etc) which will help to track the origin of the vaccine till the vaccination for whoever it may concern.

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1 Chapter-1 Introduction

1.1 Overview and
issues involved

In the currently available vaccine distribution models in the country there exist multiple problems which lead to inefficient, unmonitored and unsafe distribution of vaccines. In recent advancements in the vaccine distribution infrastructure, vaccines are monitored while stored but there is still lack of transparency in the whole process i.e. from production of the vaccine to the vaccination of citizens. The current system was only focused on child vaccination but pandemic has brought new challenges such as black-marketing of vaccines, counterfeit vials or even imperfect vaccination drives as has been witnessed in several countries in the current situation.

1.2 Problem Definition

To research current vaccine storage and distribution models in the country, examining them for all possible flaws and resolving the flaws with a robust set of solutions. Where the major findings include the possibility of black marketing of the vaccine, tampering the vial, etc.

1.3 Significance of problem

A Vaccine can save someone's life if and only if its efficacy is at its highest level and the efficacy of a vaccine is affected by the change in temperature. The regarded temperature is provided by the manufacturer. Efficacy of the vaccine must be maintained throughout the cold chain from the manufacturer to its beneficiaries. If the vaccine is exposed to temperatures higher than a predetermined level, the vaccine loses its effectiveness which means all the resources used to produce, transport and store the vaccine go to waste. This is why the vaccines must be monitored while stored or while being transported to avoid vaccine wasted as much as possible.

1.4 Proposed solution

To develop a platform which can accurately track production, transportation and storage of the monitored vaccine and identify possible cases of vial tampering.

Different user classes will be defined to categorize the potential users of the platform as: Admins, Producers, Distributors, Warriors, and Beneficiaries. Based on these user classes the platform will layout a User Interface with relevant features for the user's class. Every transaction of the vaccine will be tracked using these classes. From production till injection, as the vaccine crosses any check point the details will be updated on the blockchain for precise tracking. The system will later be trained to process the location data collected to catch any abnormalities in the transportation or storage of the vaccine.

The user classes will be as follows:

Beneficiaries: The Beneficiary class will consist of the general population which is to be vaccinated. This class will allow its users to Register on the platform, authenticate themselves with Aadhaar based authentication, view their vaccination history that has been stored on the platform's servers, and track the path of vaccine vial that the user was injected with.

Warriors: The warrior class will consist of medical frontline workers that are assigned to vaccinate the general public. This class will allow its users to register on the platform, add a new transaction to the servers when a person is vaccinated, and view the history of all the people vaccinated by the user.

Distributors: The Distributors class will consist of the Storage Facilities, transportation agencies and workers who are assigned the task of storing and/or transporting the vaccines from one facility to another. This class will allow its users to Register on the platform, add a new transaction when any consignment has been transported from one facility to another, and view the history of all the transportation tasks undertaken by the user.

Producers: The Producer class will consist of the manufacturers and/or importers of the vaccines in the country. This class will allow its users to update the stock of vaccines as and when produced with the essential details about the vaccine, and view the history of the production as updated on the platform's servers.

Admins: The Admin class will consist of the administrators including Central Government Officials, State Governments' Officials, District Officers, etc. This class will allow its users to monitor all the actions performed on the platform as per their clearance levels, and authenticate users of all classes except Beneficiaries.

2 Chapter-2 Literature Survey

2.1 Methodology

First phase of the project will focus on researching the pre-existing solutions in detail to understand their shortcomings. Once the problems are identified the team will then explore the optimal solutions for the identified shortcomings of the pre-existing solutions. The next step will be to look for the best tech stack that could be used to approach the solution in minimum time for the most effective deployment. After which the development of the platform will begin which will include designing and coding the User Interface for various classes of users, preparing the backend solutions to provide all the necessary functionalities to the application.

2.2 Existing Solutions

To understand the challenges faced by a government for mass Vaccination we have to study the current scenario of immunization and the processes of the past from which the current immunization process has evolved to what it seems to be today. The current research model is Universal immunization program which aims to vaccinate 0- to 6-year-old children. UIP launched in 1985 aims to eradicate the common diseases suffered by the children. It has evolved from conventional methods to E-VIN present current internet-based technology.

The healthcare sector is structured at the primary, secondary and tertiary levels. Sub-centres and primary health centers are at the primary level (PHCs). Community health centers (CHCs) and smaller sub-district centers are situated at the secondary level. Finally, the top level of public care offered by the Government is the tertiary level, comprising Medical Colleges and District/General Hospitals.

The current structure of our Vaccine Distribution system is hierarchical. There are 4 main vaccine stores across our country located in Kolkata, Chennai, Karnal and Mumbai which hold vaccines of different types for the long run and also hold incoming International vaccination.

The vaccine manufactured in batches is transferred to the state which has made the requirements through the GMSD or directly from the manufacturer to the state vaccine store. The vaccine reaches the SPS through the aeroplane or the Refrigerated vaccine van to the state vaccine

store. Each state majorly holds one state vaccine store where the inoculation shots are stored in large cooling apparatus.

According to their storage time they are either stored in a walk-in freezer or walk-in coolers. The Walk in Freezers' temperature range is 0 to -25 with which it is capable of holding inoculation shots of Polio for up to 2 years in lower temperature ranges. Walk-in Freezers are used for moving inoculations, with a range of 2 to 8 degree Celsius. The state has several reserve vaccine stores to uphold with the State Vaccine Store. They are called regional vaccine stores, which administer the dispatch of vaccines to district vaccine stores .

Each state is divided into districts and then further blocks and each block holds several subdivisions. Madhya Pradesh has 52 districts and accompanies 4 regional vaccine stores or RVS in Indore, Bhopal, Gwalior, and Jabalpur. The vaccine is provided to each district or the blocks or sub health centers depending on the requirements generated by them.

Regional vaccine stores facilitate the distribution of vaccine from State Vaccine Store to Divisional or District Vaccine stores. Each district has its own District Vaccine Store, which immobilizes the inoculation shots for their corresponding blocks as per demand. The district which is divided into further blocks, which houses their own Vaccine store and same for the corresponding sub centre, contemplating the amount of inoculation shots in their respective Health centers region as demand.

Health centers are the main focus point for holding inoculations shots. There are Community health centers in each block, depending upon the area population, rural or urban the Community Health Centers(CHCs) are established. The urban Community Health Centers(CHCs) are established with a population of around 300,000 to 500,000 and rural Community Health Centers(CHCs) are established with populations covering from 80000 to 150000. The establishment of Health centers can vary depending upon the population.

The District Vaccine Store is located in a District with a health center in District Hospital, which will disperse the need of the vaccine and rest resources for the blocks and their corresponding.

Under CHC there are Primary Health centers. There are generally 4 to 7 Primary Health Centers(PHCs) under a CHC and will vary under population. Under PHC we proceed to more rural areas that have Sub health centers under PHC according to the population. Primary Health Centers(PHCs) are established under CHC with a population of 20000 to 30000. And SHCs under Primary Health Centers(PHCs) for a population around 3000 to 5000. Generally, 4 to 7 SHCs are under a PHC. And Each SHC incorporates 4 to 7 villages.

The Sub-Center is planned to represent highly rural areas with spending's entirely funded by the national government. It requires at least two health employees (male and female) to serve a population of 5000. Sub centers also function to teach rural residents about important healthier practices.

Primary Health Centers serve as broader health facilities staffed with physicians and paramedics. Patients can be sent to Primary Health Centers(PHCs) from local sub-centres for complex situations. Distinction from Sub-Centers is that state governments finance Primary Health Centers(PHCs), not the central government. Primary Health Centers(PHCs) seek to enhance health education, with a strong focus on prevention steps.

The Community Health Center is financed by state governments and receives patients from the Primary Health Centres. Patients from these agencies can be moved to District Hospital for additional care. Thus, CHC's are also first referral units, or FRUs, which are expected to provide obstetric care, new born/child care, and blood storage capability at all times of the week.

The vaccine is stored at district hospital with a future hold of 2 months for all health centers under it. It can have WIC(walk-in-coolers) and ILR(ice lined refrigerators) and deep freezers according to the demand of the following centers. The Rural CHC holds at least 4 ILR and 4 deep freezers (vary depending upon population). The Primary Health Centers(PHCs) under the Community Health Centers(CHCs) are supplied with their demand store in at least 2 ILR and 2 Deep freezers through refrigerated or insulated vans.

The SHCs may or may not have ILR and DF, if they seem to occupy, they may have 1 ILR and 1 deep freezer. Further for vaccination of infant's vaccine carriers or the cold boxes are used.

The cold boxes and the vaccine carrier have ice packs for vaccines. These ice packs are conditioned before use as they are placed in deep freezers.

For immunisation sessions the ANM, ASHA and AWW work together to gather information about infants and AWW brings them to Anganwadi centers under ASHA workers. In these sessions' infants are inoculated by ANM.

Anganwadi is a type of rural child care centre in India. They were started by the Indian government in 1975 as part of the Integrated Child Development Services program to combat child hunger and malnutrition. *Anganwadi* means "courtyard shelter" in Hindi.

The primary field staff that provides outreach services, is called "ASHA (Accredited Social Health Activist)" or a village health nurse, depending upon the Indian state where the PHC is located. The village health nurse provides service at the point of care, often in the patient's home. If additional diagnostic testing or clinical intervention is required, the patient is transported to the PHC to be evaluated by the Medical Officer.

Auxiliary nurse midwife, generally referred to as ANM Auxiliary nurse midwife, is a village-level female health worker in India who is regarded as the first contact person between the population and health services. ANMs Auxiliary nurse midwife are perceived to be grassroots workers in the health agency pyramid. Their services are deemed to be vital for providing village communities with healthy and successful care.

Government is using Electronic Vaccine Intelligence Network - Electronic Vaccine Intelligence Network in connection with the United Nations Development Program (UNDP) to identify primary beneficiaries and vaccine distribution networks.

Electronic Vaccine Intelligence Network gives real-time information by the process of digitising the vaccine stocks and keeps a check on the temperature of the cold chain through a smartphone application. The Electronic Vaccine Intelligence Network technology was initially launched in 2015 across 12 states of India in order to provide support for better vaccine logistics management at cold chain points.

Electronic Vaccine Intelligence Network is an indigenously developed technology that aims to support the Government of India's Universal Immunization Programme by providing real-time information on vaccine stocks. The technological innovation is implemented by the United Nations Development Programme (UNDP) Electronic Vaccine Intelligence Network aims to strengthen the evidence base for improved policy-making in vaccine delivery, procurement and planning.

The aim is to ensure equality in the simple and timely provision of vaccinations to all children. Electronic Vaccine Intelligence Network digitizes vaccine stocks in all 27,000 vaccine storage centers in all districts of 29 states and 7 union territories of India; enables real-time tracking of storage temperatures by building nearly 50,000 temperature loggers; builds the capability of nearly 37,000 government staff for vaccines and cold chain logistic management on Electronic Vaccine Intelligence Network; deploys vaccine and cold chain management on Electronic Vaccine Intelligence Network; deploying vaccine and cold chain managers in every district for constant supportive supervision.

Cold chain handlers are provided smartphones having the Electronic Vaccine Intelligence Network application which allows for the digitization of vaccine inventories. As a part of the Routine, every cold chain handler enters the net utilization for each vaccine in registers and the Electronic Vaccine Intelligence Network application and uploads on a cloud server which can then be viewed by programme managers at district, state and national level . The system also helps to track storage temperature of vaccines. SIM-enabled temperature loggers attached into the cold chain equipment capture temperature data through a digital sensor placed in the refrigerator. Data is recorded every ten minutes and updated at an interval of sixty minutes on the server through GPRS/SIM. In case of

temperature breach, the logger alarms and sends email and SMS alerts to responsible cold chain technicians and managers and District immunization officers.

The conventional method involved paperwork, home to home collection of data documentation, letters and registers to maintain records, and requests for vaccines which is largely inefficient method. It has been replaced by Electronic Vaccine Intelligence Network Technology.

2.3 Technologies and Tools

BlockChain: Blockchain is a data structure used to store data immutably and would require an impractically large amount of computational resources to manipulate the data. Blockchain was used in this project to manage and make accurate data available to the public.

Flutter: Flutter is a portable UI toolkit by Google for building natively compiled applications for Mobile, Web, and Desktop from a single codebase. Flutter has an edge over its competitors which is why it was used in the project.

Firebase: Firebase is Google's mobile platform to quickly develop high-quality mobile/web apps. It provides services like FireStore (NoSQL database), User Authentication, etc. which are precisely the requirements for the project.

3 Chapter-3 Analysis

3.1 Software Requirements

The current prototype targets Android SDK 29 and the minimum SDK version required for the app to function properly is 21 (Android 5.0). The app has not been debugged for Web or iOS yet.

3.2 Hardware Requirements

Mobile device with enough resources to run Android OS along with a functional camera and GPS module.
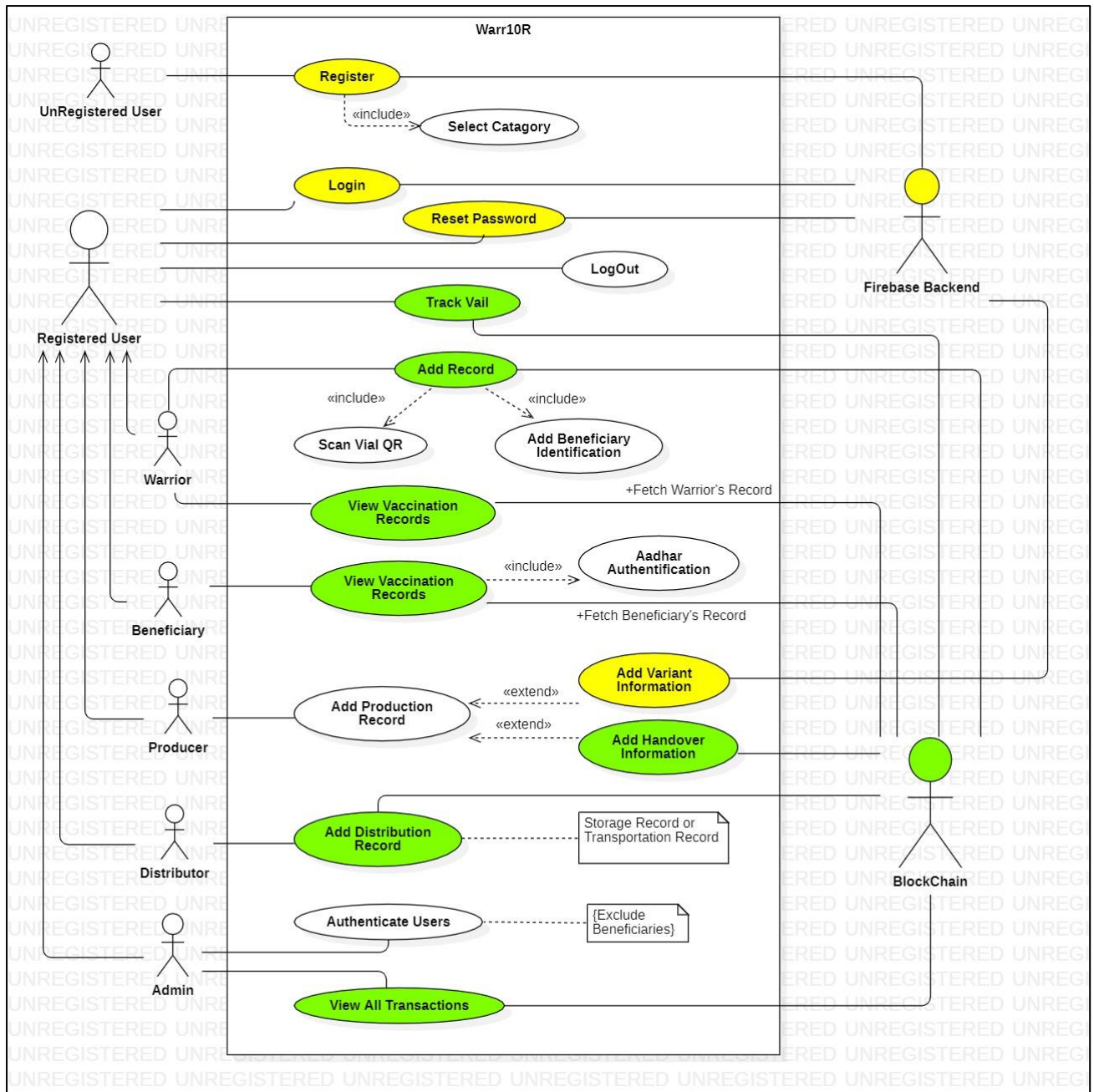
3.3 Use Case Model

Figure 3.1

3.4 Use Case Description

Table 3-1

Use Case Name	Login
Actors Involved	Registered User, Firebase
Basic Flow	• Users enter the username and password. • Username and Password are checked. • If correct, the user's dashboard is shown. • Else error message is shown
Special Requirements	Users need to be registered.
Pre-conditions	Existing user (Already have an account)
Post-conditions	Dashboard with all the information regarding the user and account is shown by the system

Table 3-2

Use Case Name	Register
Actors Involved	Unregistered User, Firebase
Basic Flow	• Enter the email and password. • Select appropriate category applicable. • Submit the details, the user is successfully registered to the system.
Special Requirements	-
Pre-conditions	-
Post-conditions	Now user can login to the system.

Table 3-3

Use Case Name	Reset Password
Actors Involved	Registered User, Firebase
Basic Flow	• Enter the Login Id. • An OTP is sent to the user for verification. • If successfully verified, the user will be asked for a new password.

	• Else registration failed.
Special Requirements	-
Pre-conditions	Registered user
Post-conditions	New Password is successfully set.

Table 3-4

Use Case Name	Logout
Actors Involved	Registered User
Basic Flow	Select Logout Option from the dashboard
Special Requirements	-
Pre-conditions	Already logged in to the system.
Post-conditions	Successfully logged out of the system.

Table 3-5

Use Case Name	Track Vial
Actors Involved	Registered User, BlockChain
Basic Flow	• Enter unique Shipment ID of the vial batch. • All the transactions related to shipment will be fetched from the block chain and displayed.
Special Requirements	Unique Shipment ID
Pre-conditions	Registered user
Post-conditions	Shipment Details are fetched.

Table 3-6

Use Case Name	View Vaccination Record
Actors Involved	Warrior, Beneficiary, BlockChain
Basic Flow	- Beneficiaries need to authenticate first. - Past records tab and select corresponding record. - Details of the particular record is displayed.
Special Requirements	-
Pre-conditions	User must be logged in to the system.
Post-conditions	Desired information is retrieved

Table 3-7

Use Case Name	Add Record
Actors Involved	Warrior, BlockChain
Basic Flow	- Warrior selects 'add record' option. - Scans QR code on the vial. - Enters the Identification details of beneficiary - Submits the details.
Special Requirements	- Identification Proof should be available with the beneficiary. - Vial with valid unique ID.
Pre-conditions	Warrior must be logged in to the system.
Post-conditions	Vaccination record is added to the system.

Table 3-8

Use Case Name	Add Production Record
Actors Involved	Producer, Blockchain, Firebase
Basic Flow	- Producer select add record option. - Enters details about the hand-over to government facilities. - Enters details about the vaccine variant. - Submit the details
Special Requirements	Vial Batch is examined by Government Officials before hand-over.
Pre-conditions	Producer must be logged in to the system.

Post-conditions	Vial batch is added to the system.

Table 3-9

Use Case Name	Add Distribution Record
Actors Involved	Distributor
Basic Flow	• Distributor select add record option. • Enter details about the arrival or dispatch of vial shipment • Submit the details
Special Requirements	Shipment received is verified by the distributor.
Pre-conditions	Distributor must be logged in to the system.
Post-conditions	Shipment information is added to the system.

Table 3-10

Use Case Name	Authenticate Users
Actors Involved	Admin
Basic Flow	• Monitors all the users from the dashboard. • Authenticate or revoke their actions.
Special Requirements	-
Pre-conditions	Admin must be logged in to the system.
Post-conditions	Take relevant actions.

Table 3-11

Use Case Name	View all transactions.
Actors Involved	Admin
Basic Flow	• Monitors all the transactions from the dashboard.
Special Requirements	-
Pre-conditions	Admin must be logged in to the system.
Post-conditions	Take relevant actions.

4 Chapter-4 Design

4.1 Technology Selection

BlockChain: Blockchain is a growing list of records called blocks which are linked using cryptography. Each block contains a unique cryptographic hash of the previous block, a timeStamp and the transaction data. By design, a blockchain is resistant to data modification. This design feature of blockchain makes it the best available technology to make close to real time data securely and accurately available to all the users of this platform. In this project BlockChain was implemented using "PythonAnywhere" which is an online integrated development environment and web hosting service based on the Python programming language. The platform was used to generate on Application Programming Interface which will be in-turn used by the application to update and retrieve the data stored on the blockchain.

Flutter: Flutter is a portable UI toolkit by Google for building natively compiled applications for Mobile, Web, and Desktop from a single codebase. After reviewing technologies like Java/Kotlin, Swift, JavaScript, etc. the team concluded that Flutter can provide uniform experience across several widely popular platforms (like Android, iOS, and Web), is fast to develop natively compiled apps with, and can use a single code base for multiple operating systems reducing the developmental time.

Firebase: Firebase is Google's mobile platform to quickly develop high-quality mobile/web apps. It provides services like FireStore (NoSQL database), User Authentication, etc. which are precisely the requirements for the project demonstration. User Authentication would be used to authenticate the user and classify the user's category. Firestore, on the other hand, would be used to store vaccine variants' information, users' details, etc. which would not be stored on the blockchain for security purposes as the blockchain's data would be publicly available.
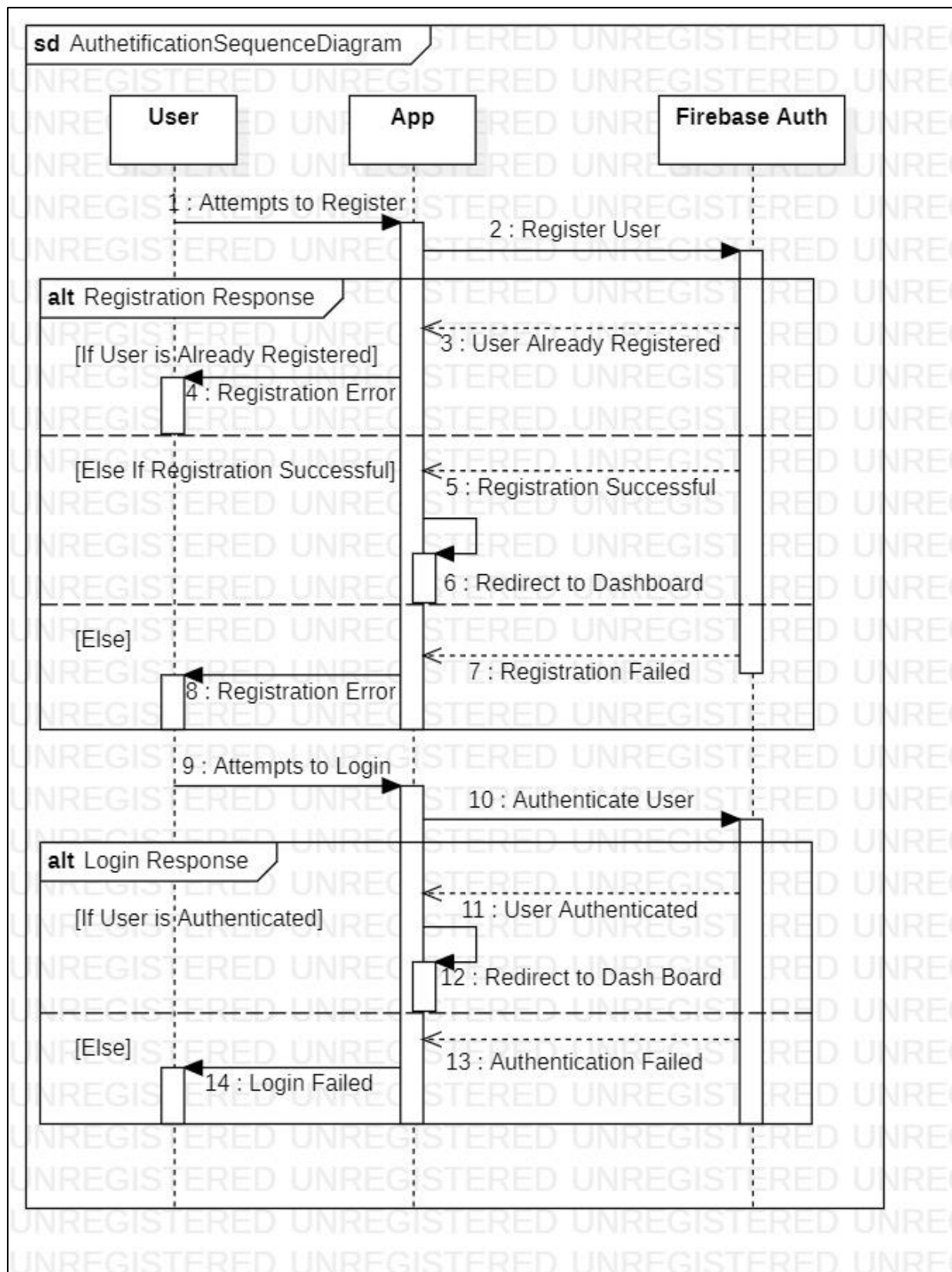
4.2   Sequence and Activity Diagrams

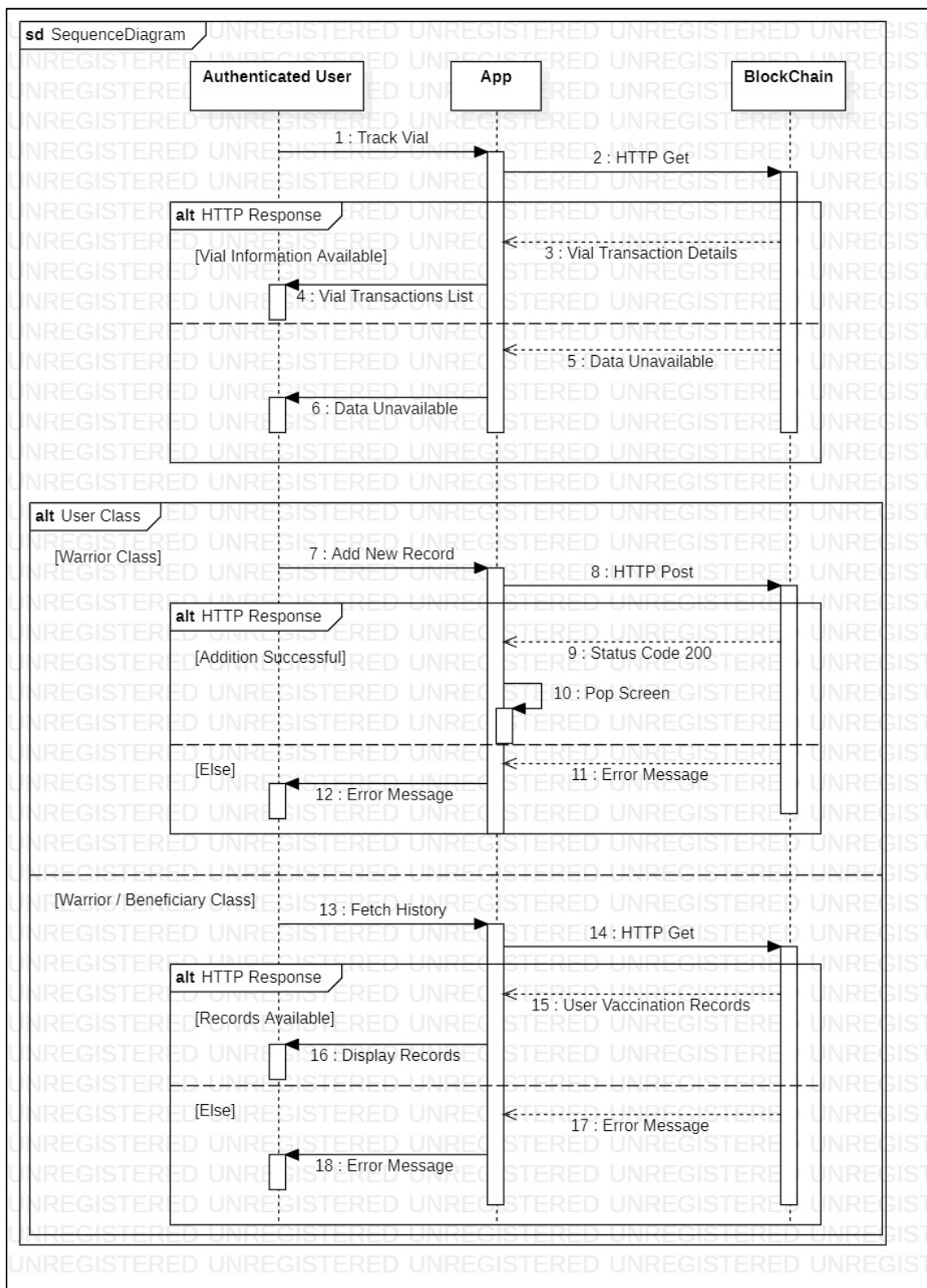*Figure 4.1   Authentication Sequence Diagram*
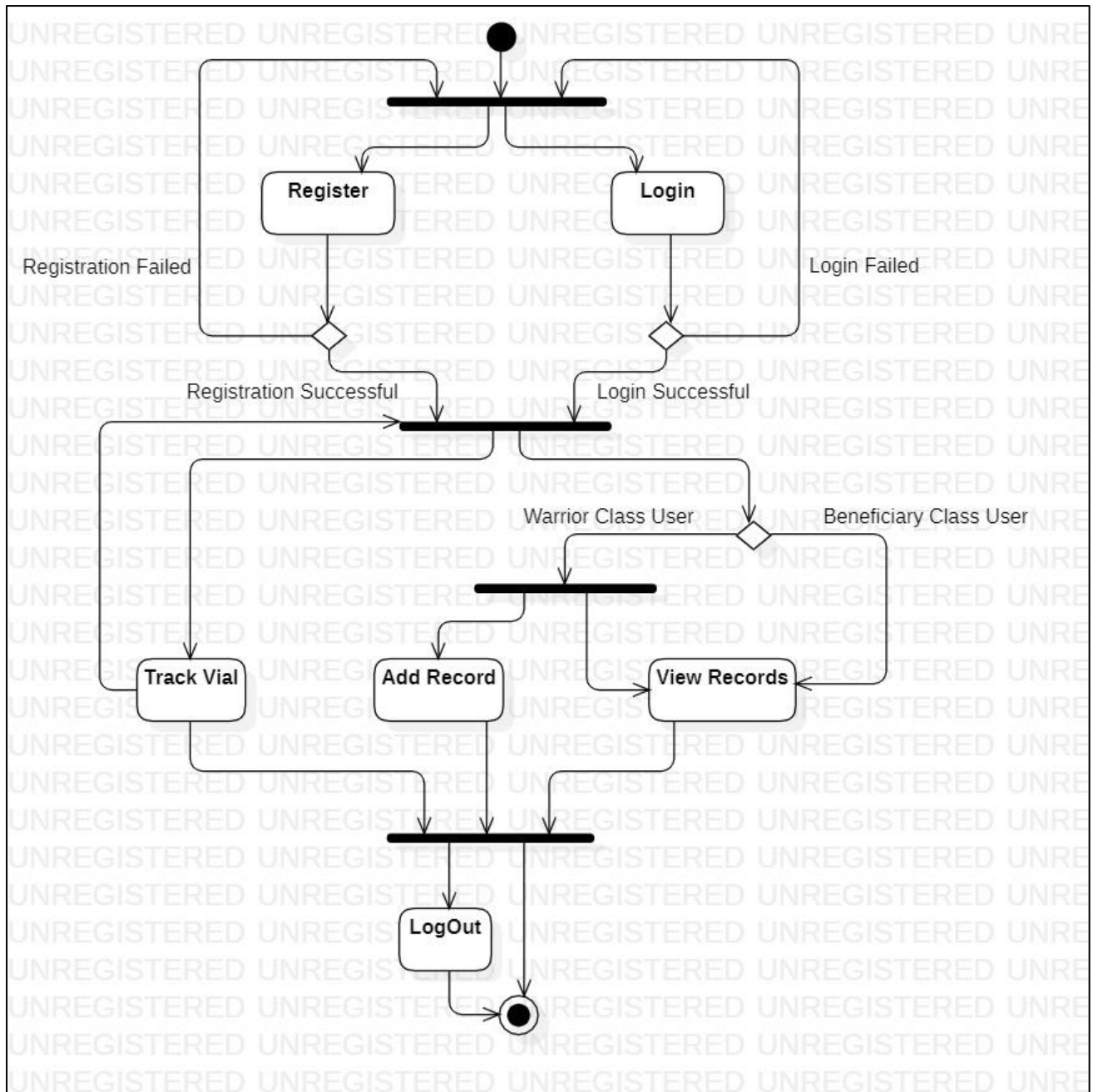
Figure 4.2   Sequence Diagram

Figure 4.3 Activity Diagram
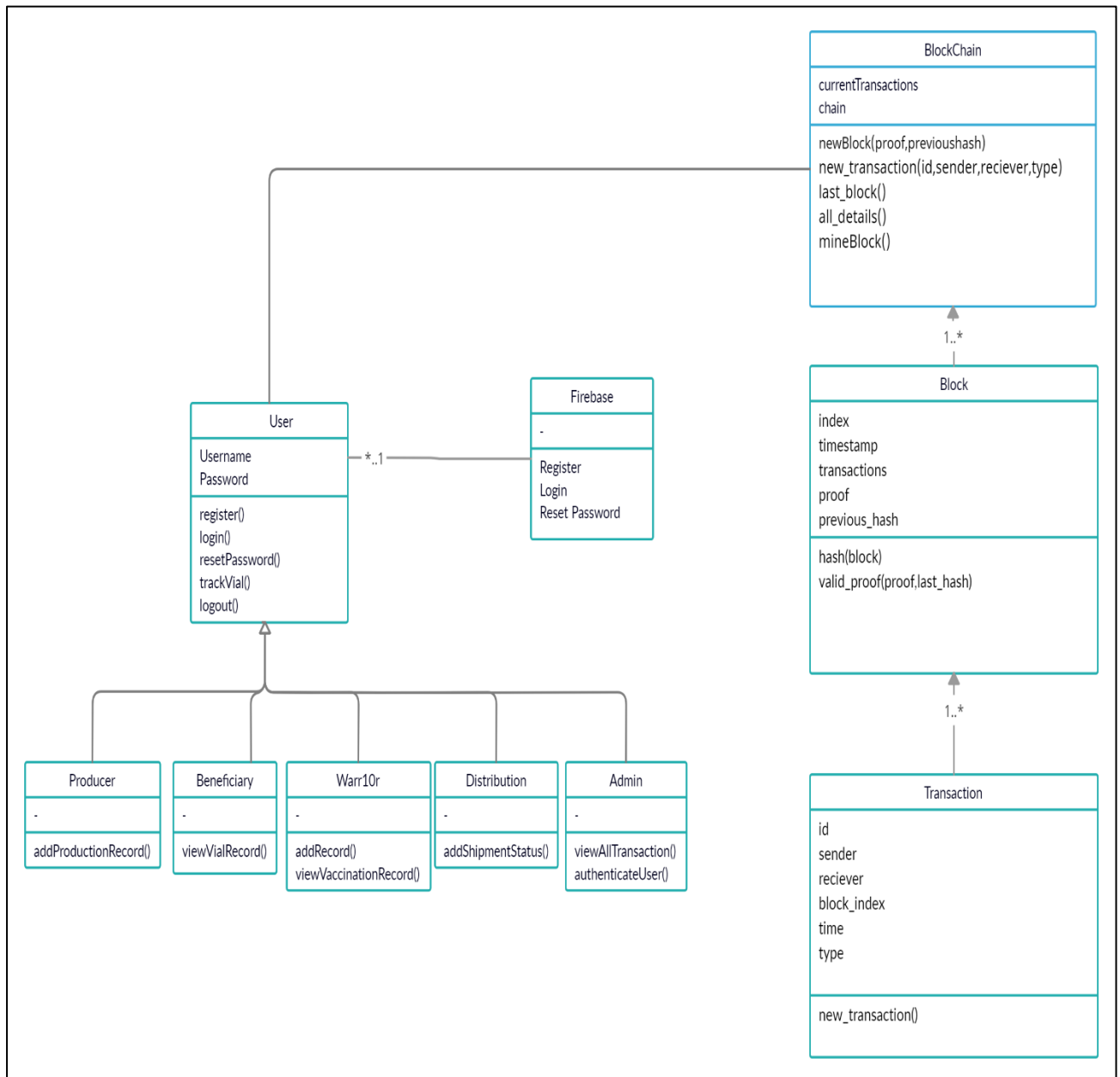
4.3 Class Diagram

Figure 4.4 Class Diagram

5 Chapter - 5 Testing

5.1 Test Cases:

Login Screen Test 01:
Test for invalid Email
Email: testmail.com
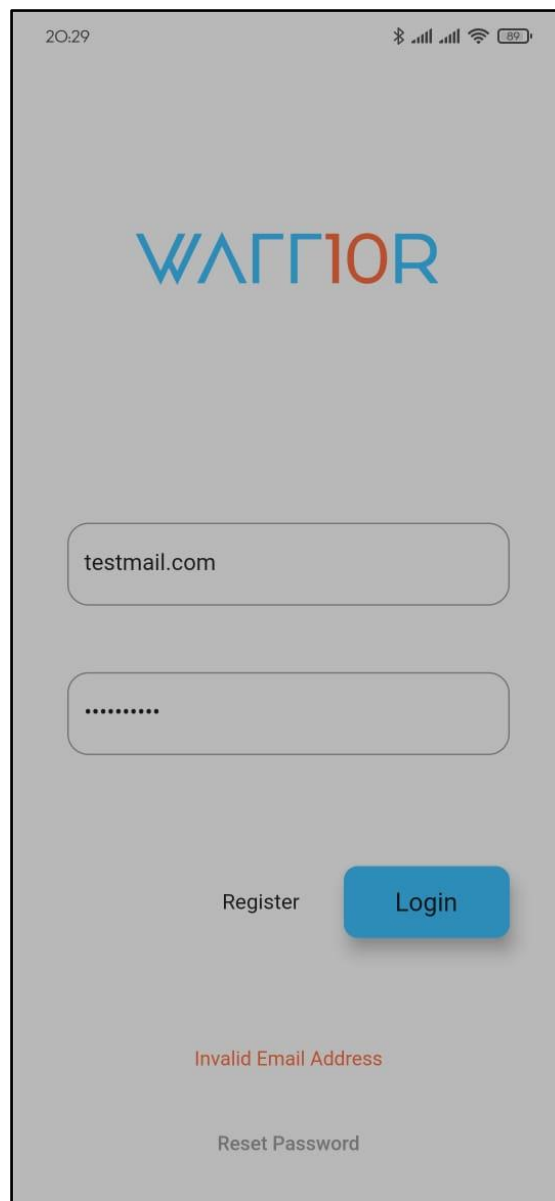password: qwert1234
Output: "Invalid Email Address" Error

Figure 5.1   Login Screen Test 01

Login Screen Test 02:
Test for invalid Password
Email: test@mail.com
password: 123
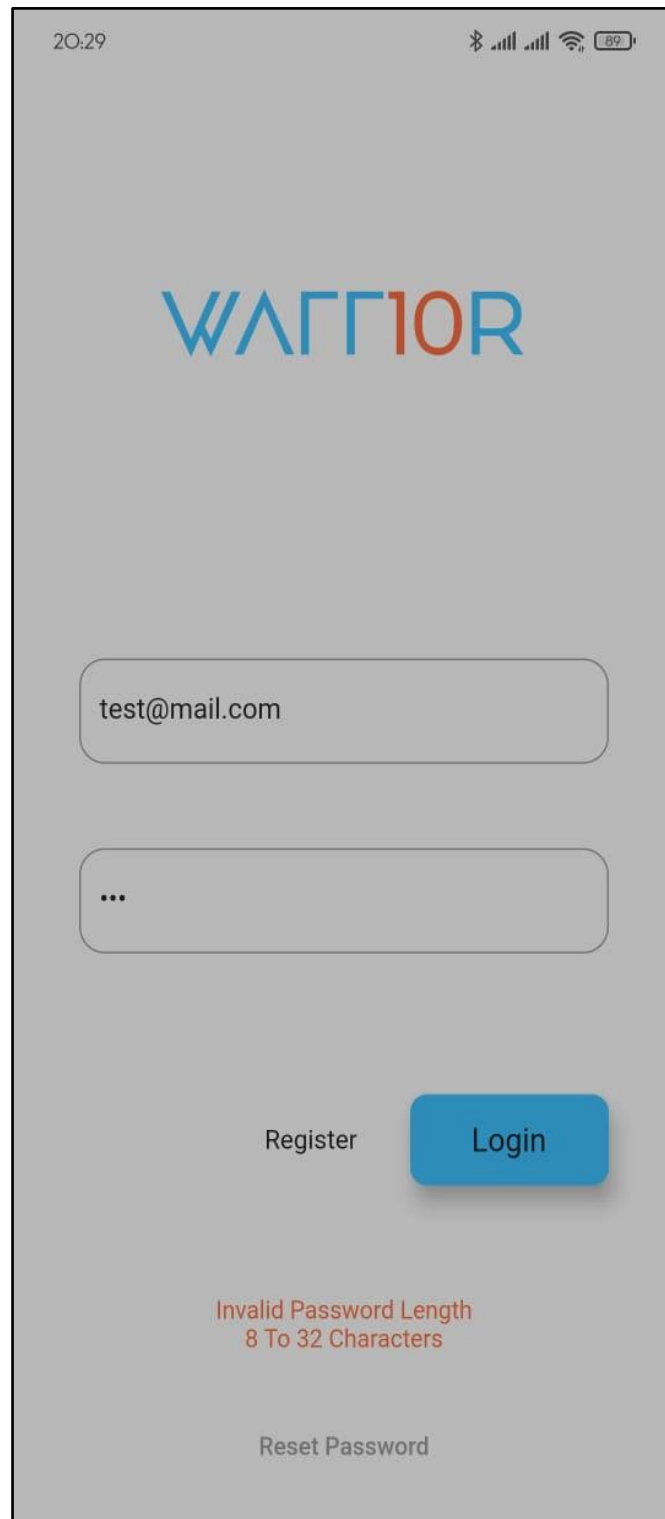Output: "Invalid Password Length (8 to 30 characters)" Error

Figure 5.2   Login Screen Test 02

Login Screen Test 03:
Test for Unregistered Email Login
Email: test@mail.com
Password: qwert1234
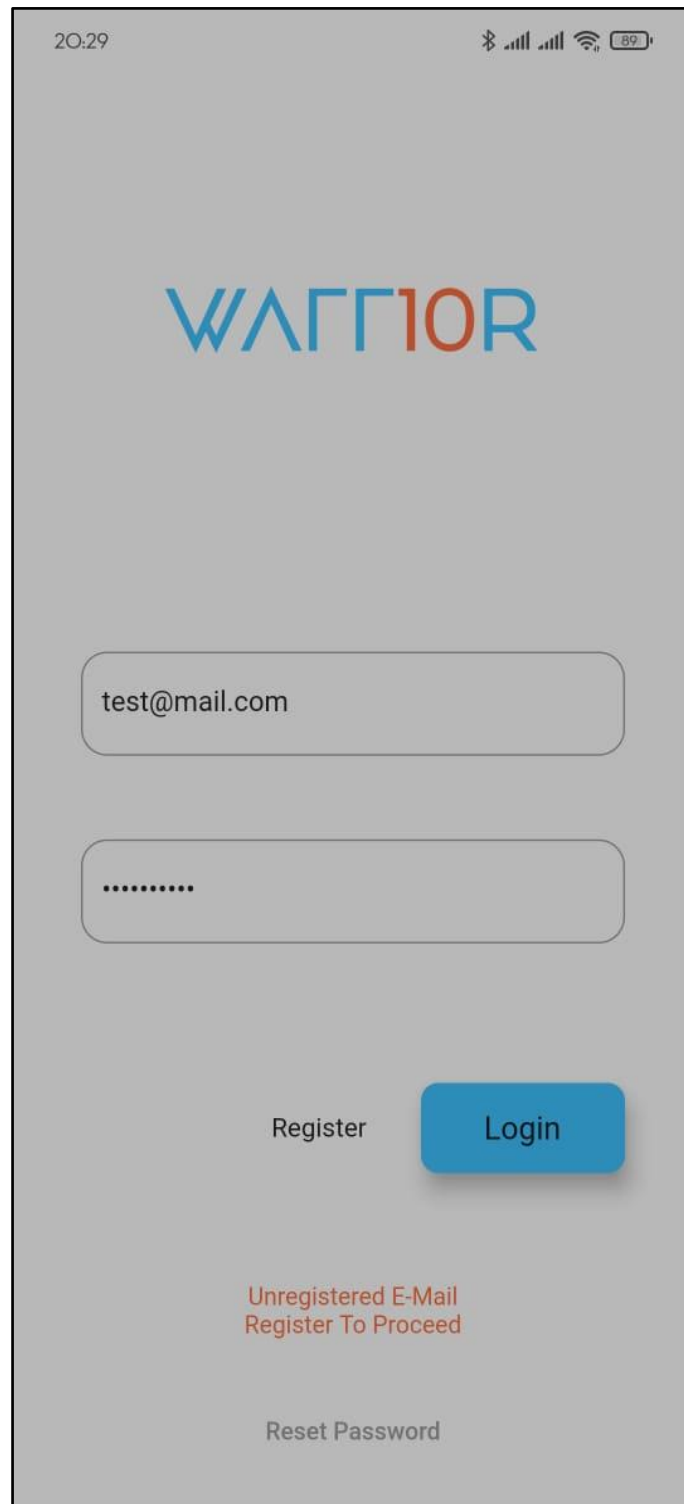Output: "Unregistered Email Register to proceed" Error

Figure 5.3   Login Screen Test 03

Registration Screen
Test 01: Test for Registered Email Registration
Email: test@test.com
Password: qwert1234
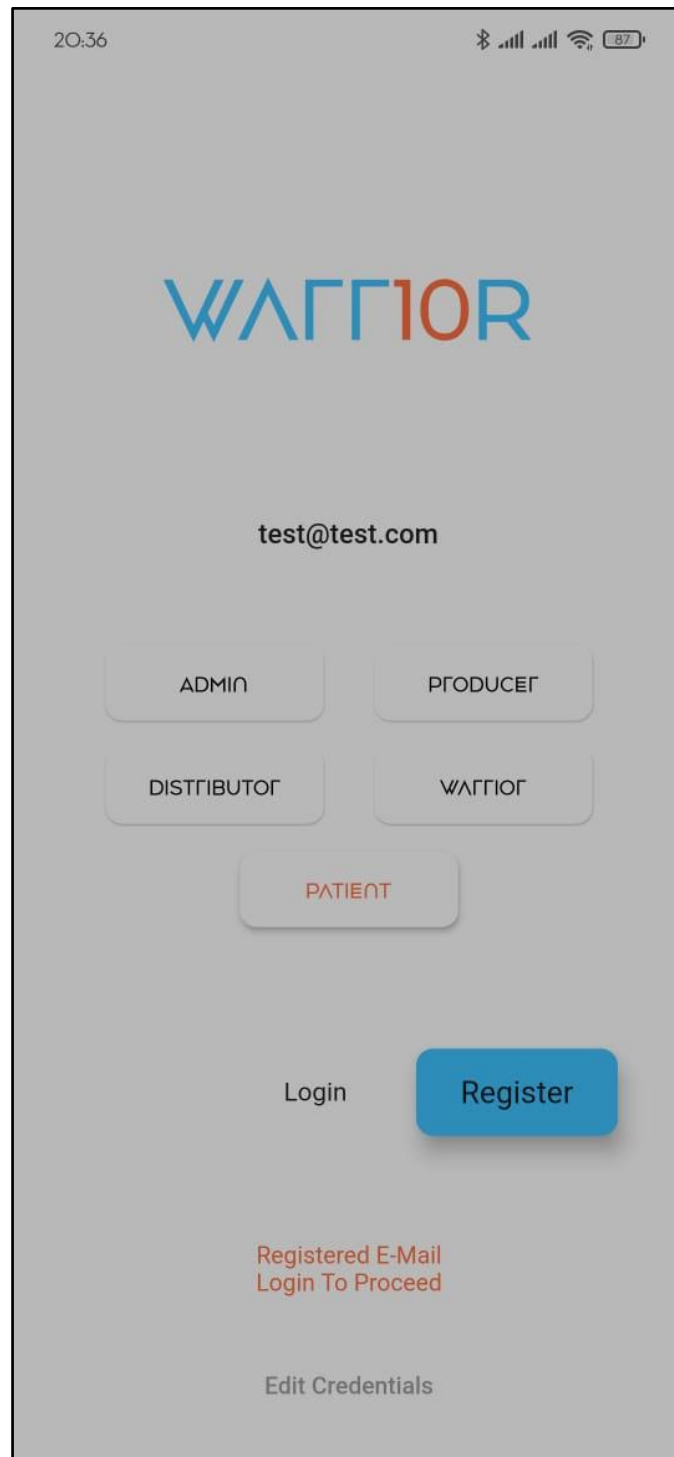Output: "Registered Email Login to proceed" Error

Figure 5.4   Registration Screen Test 01

Vial Search Screen Test 01:

Test for searching unregistered vial
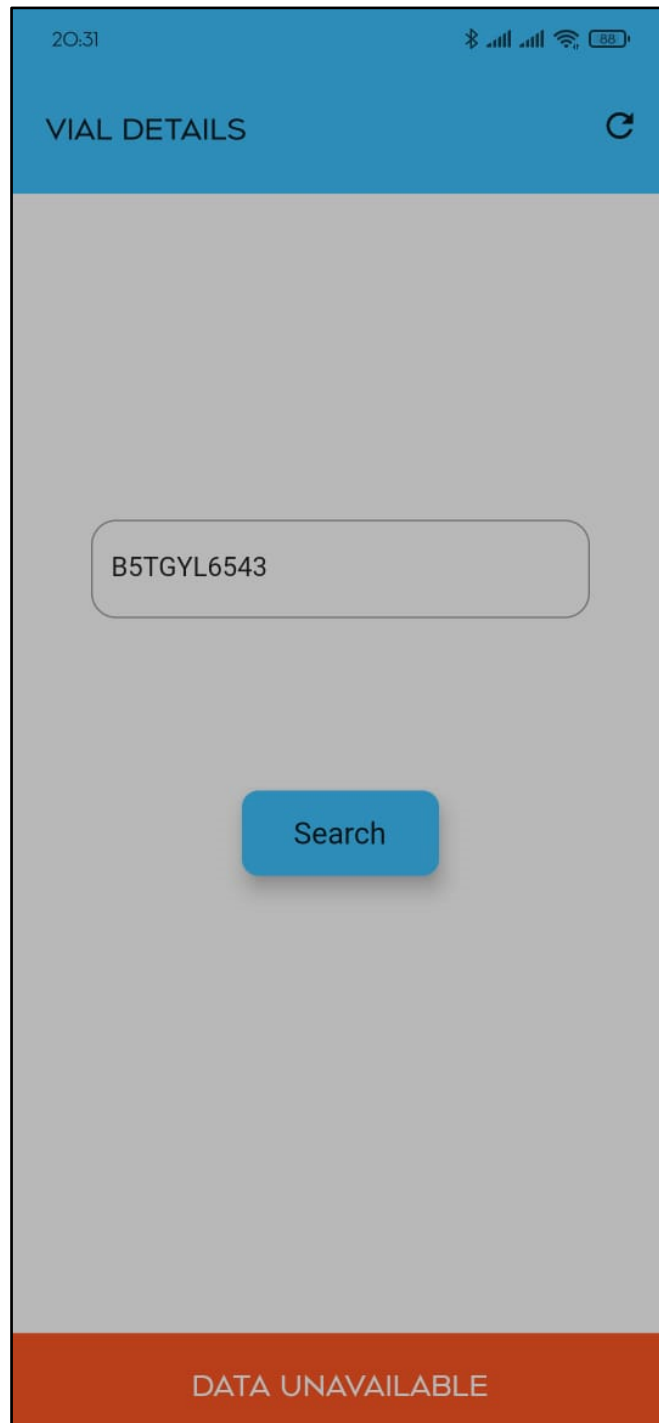 Vial Id: B5TGYL6543
Output: "Data Unavailable"

Figure 5.5   Test for Unregistered Vial

6 Chapter – 6 Conclusion

While researching for the project, the team got to understand the vaccine distribution infrastructure in the country as well as the shortcomings of the current system. Later during the project development, the team learnt how to select the appropriate technology stack for any project. The team also learnt about technologies like BlockChain and Flutter which are being predicted to be widely popular over the coming few years.

As an advancement to the project, IOT devices can be combined with the current system to track and monitor the vaccine status in real time. This would enable Administrators to reduce the damage caused by factors like Temperature Breach, Vaccine Black Marketing, etc.

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