NirAmaya

(UDP)

A PROJECT REPORT

Submitted by

Madhav Jariwala	160090107020
Ayush Master	160090107024
Priya Patel	160090107037
Viren Patel	160090107040

Guided by

PROF. YOGESH M. KAPURIYA

Assistant Professor

In partial fulfillment for the award of the degree of

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In

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C. K. Pithawalla College of Engineering and Technology, Surat

Gujarat Technological University, Ahmadabad

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The findings of this report do not necessarily reflect the views of any representative of any organization or government department that was interviewed for the project. Any shortcomings or errors of fact or interpretation are the responsibility of the authors alone.

Certificate

C. K. Pithawalla College of Engineering and Technology, Surat

Department of Computer Engineering

Year – 2020

Date: 10/05/2020

This is to certify that the project entitled "NirAmaya" has been carried out by following students under my guidance in partial fulfillment of the degree of Bachelor of Engineering in Department of Computer Engineering (8^{th}Semester) of Gujarat Technological University, Ahmadabad during the academic year 2019-20. The work done by them is found satisfactory.

Name	Enrollment Number
Madhav Jariwala	160090107020
Ayush Master	160090107024
Priya Patel	160090107037
Viren Patel	160090107040

PROF. Yogesh M. Kapuriya

Prof. Neelam A Surti

Guide **Jury** **Head of Department**

Abstract

Viral and water-borne diseases rise seasonally and regionally. Hygiene is one of the reasons why some regions in India have a higher disease rate compared to others. NirAmaya is a health alert application that alerts about the Viral and water-borne diseases that are rising in certain regions which can be dangerous to one's life. It also implements the prediction of various Diseases through Time series forecasting with the help of past records, weather, topology which can be helpful to various NGOs and Government Departments to take necessary steps.

Seeing the recent pandemic that we are going through; it is obvious that the government alone cannot handle such epidemics or pandemics efficiently without the involvement of each and every citizen. Our aim with this project is to include citizens for their own healthiness. We have divided our website into two parts; One will be accessed through admin users in which forecasted values of certain diseases will be shown and they will be allowed to send alert notifications on mobile application of users living in concerning wards or areas. The second will be used by various Urban Health centers and SMC health and hospital organizations to report the cases. It will help the government to get the society name and exact location of patients which will later help the government to notify users living near infected patients' vicinity. Using our mobile application, citizens will be able to get notifications sent by authorities, and information about its prevention will be given as well.

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1 Introduction

1.1 Project Overview

NirAmaya is a health alert system that can use the available relevant information about the factors responsible for the spread of viral epidemics and use it to predict the occurrence of those epidemics within a geographical region. It provides the interface through which health organizations can report viral epidemics occurring at that time so that public health experts can prepare for, manage and control the epidemic.

1.2 Citizens

Before using our mobile application, citizens have to install the application and register through their phone numbers and verify through OTP. Citizens would also have to select their home's location using google places API to register. We require the home address to send the alert notification whenever there are possible viral outbreaks in their vicinity. These alert notifications will open our app to give you basic information about particular disease spreading in the region. Prevention, symptoms, home remedies, etc. of diseases will be shown.

The total number of cases reported can be seen in graphical structure and filters will be available as well to select certain areas, time duration, etc. On the dashboard, heat map will be shown where the list of diseases spreading at the user's location will be shown. By clicking on one of the listed diseases, basic information about those diseases will be shown.

1.3 Hospitals and Urban Health Centers

Health Organizations will report cases using our website by taking patient's basic information including their home address. This helps in creating accurate clusters for authorities. Whenever, the cases are reported to one particular society, users who have registered using the same address, will get automatic alert notifications.

1.4 SMC Health and Hospital Department

SMC will work as an admin for our project. Admin will be able to analyze forecasted results to take future actions. Admin will also be able to view reported cases in a graphical manner by filtering by area, time duration, and disease. Admin will be able to place alerts for particular areas which will notify users through push notifications on the mobile application.

1.5 Literature Review

1.5.1 Patents

Sr no.	Patent No.	Patent Name
1.	201941030238	EPIDEMIC ANALYSIS WITH TIMELINE LAYER INTERACTION IN MAPS USING NEIGHBOURHOOD ROUGH SET BASED APPROX
2.	TWI557679B	System and method for generating real-time alerts of health
3.	201921001917	Methods and Kits for the Prediction of Therapeutic Success, Recurrence Free and Overall Survival in Cancer Therapies
4.	JP2013508859A	Integrated health data acquisition and analysis system
5.	PMC6013221	The association between temperature, rainfall and humidity with common climate-sensitive infectious diseases in Bangladesh
6.	PMC6606307	Effect of climate on Enteric Fever incidence in Ahmadabad, India

Table 1. Patents

1.5.2 Comparison Table

No	Applications/Research (till date)	Advantages	Disadvantages	Reference
1	Surat Municipal Corporation App	• Can complaint about Mosquitoes and mosquito borne disease • Register complaint about disease	• Does not ask for location when asking for disease report	[30]
2	Medium - Prediction of epidemic disease dynamics using machine learning	• Prediction for Zika Virus	• Various factors play role for different viral diseases	[31]
3	BMC Infectious Diseases **volume 19**,Article numb	• Prediction of Dengue outbreaks	• Poor out-of-sample prediction result • Could explain only 73% percent of	

	er: 272(2018)		variation	[32]
4	Malaria Outbreak Prediction Model Using Machine Learning	• Prediction of Malaria using SVM and ANN	• Could only predict 10-15 days in advance • Required large datasets • Does not predict number of cases	[33]
5	NHP Health Directory Services	• User gets nearest Hospital / Blood bank information as per current geographical location • The application also works offline	• Does not provide the information about any diseases • Can’t report case	[34]
6	NHP Swasth Bharat	• reliable and relevant health information • provides detailed information regarding healthy lifestyle, disease conditions (A-Z), symptoms, treatment options	• Users cannot report their diseases case • Inadequate or poor health information can increase the risk of hospitalization	[35]
7	MeraAspataal (My Hospital)	• initiate to capture patient feedback on the services received from both public and empanelled private health facilities	• disseminated on a frequently updated dashboard so it should be consistent	[36]

Table 2. Comparison Table

1.6 Purpose

We aim to implement a system that can give alert about the current spread of the epidemic and the prediction about the spread of Epidemics in future.

- Analyze and determine the spread of epidemic diseases.
- Build a machine learning model that could predict the epidemic disease dynamics.
- Gathering information about the viral diseases of that present time.
- Give gathered information to plan interventions to decrease or prevent disease transmission.

1.7 Tools and Technology

- Python(Scikit-learn)
  - → Scikit Learn provides a bunch of genuinely useful utilities for splitting data, computing common statistics, and doing even not-so-common matrix operations. More specifically, it's a set of – as the authors say – simple and efficient tools for data mining and data analysis.
- Prophet
  - → Prophet is a procedure for forecasting time series data based on an additive model where non-linear trends are fit with yearly, weekly, and daily seasonality, plus holiday effects. It works best with time series that have strong seasonal effects and several seasons of historical data. Prophet is robust to missing data and shifts in the trend, and typically handles outliers well.
- Statmodels
  - → It is a Python module that provides classes and functions for the estimation of many different statistical models, as well as for conducting statistical tests, and statistical data exploration.
- Google Services
  - → Unlimited google analytics for mobile apps
  - → Cloud firestore provides synchronized data
  - → Web hosting fast and secured way
  - → Multi-platform authentication with firebase

- Android Studio
  - → Gradle Integration
  - → Advanced Code Completion
  - → User Interface
  - → System Stability
  - → Organization of project

- Php
  - → Compared to other languages and especially compared to web frameworks, PHP is lower level, less abstract, and more transparent.
  - → Advantages: Performance, Portability(Platform Independent),Ease of Use, Open Source, Third-Party Application Support, Community Support

- MPAndroidChart
  - → Android Graph Library for creating zoomable and scrollable line and bar graphs
  - → Open-source native Android graph/chart framework includes line chart, stick chart, candlestick chart, pie chart, spider-web chart etc.Mobile phones, tablets and other gadgets running Android will probably benefit of this charting library

2 Design

2.1 Design Analysis

- As a development of any software we need to design and map design to our final product in form of graphical representation.
- We made different diagrams to view the systemfrom a development point of view.

2.1.1 Use-case Diagram

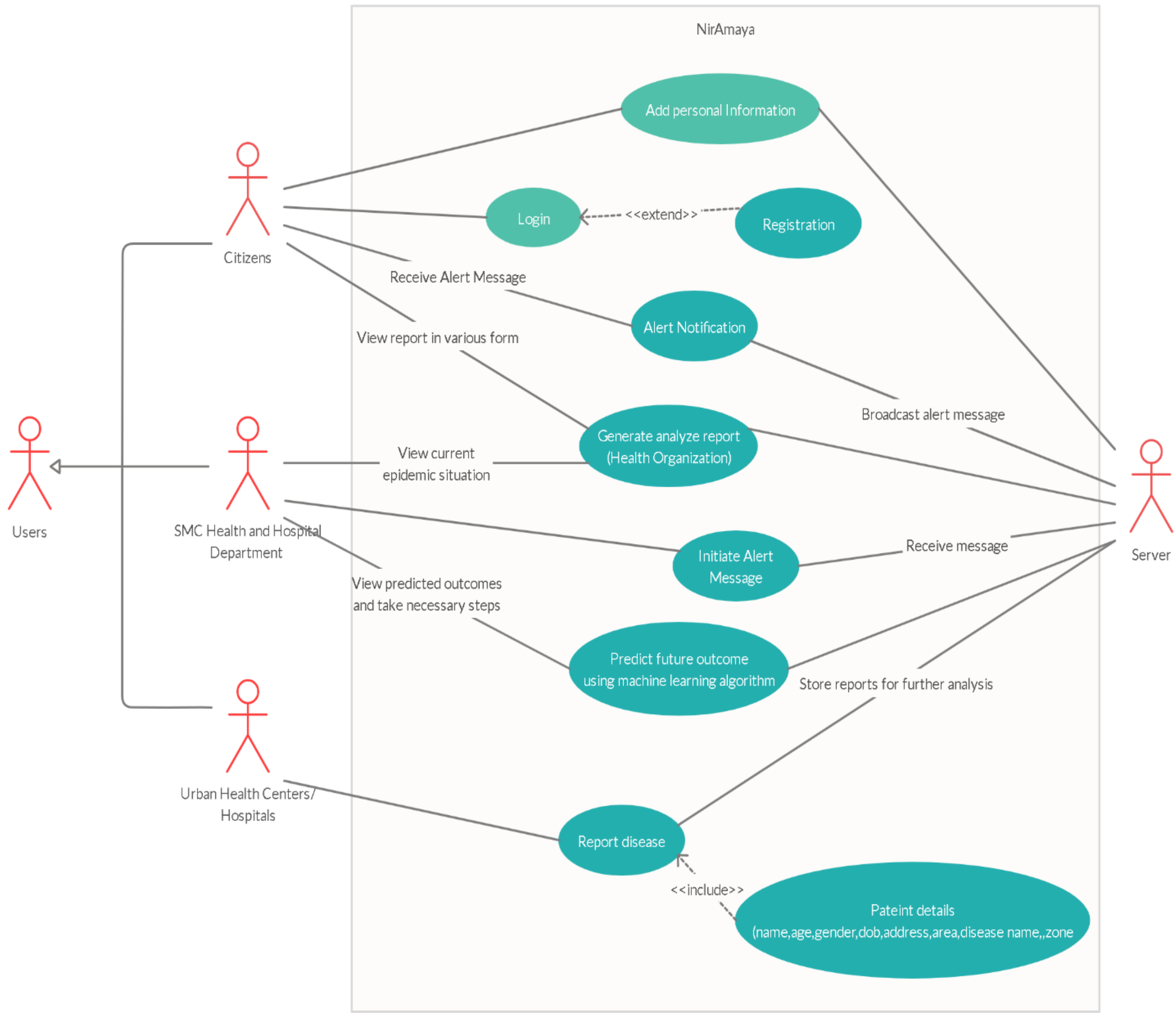

Figure 2.1 Use-case Diagram

2.1.2Data Flow Diagram

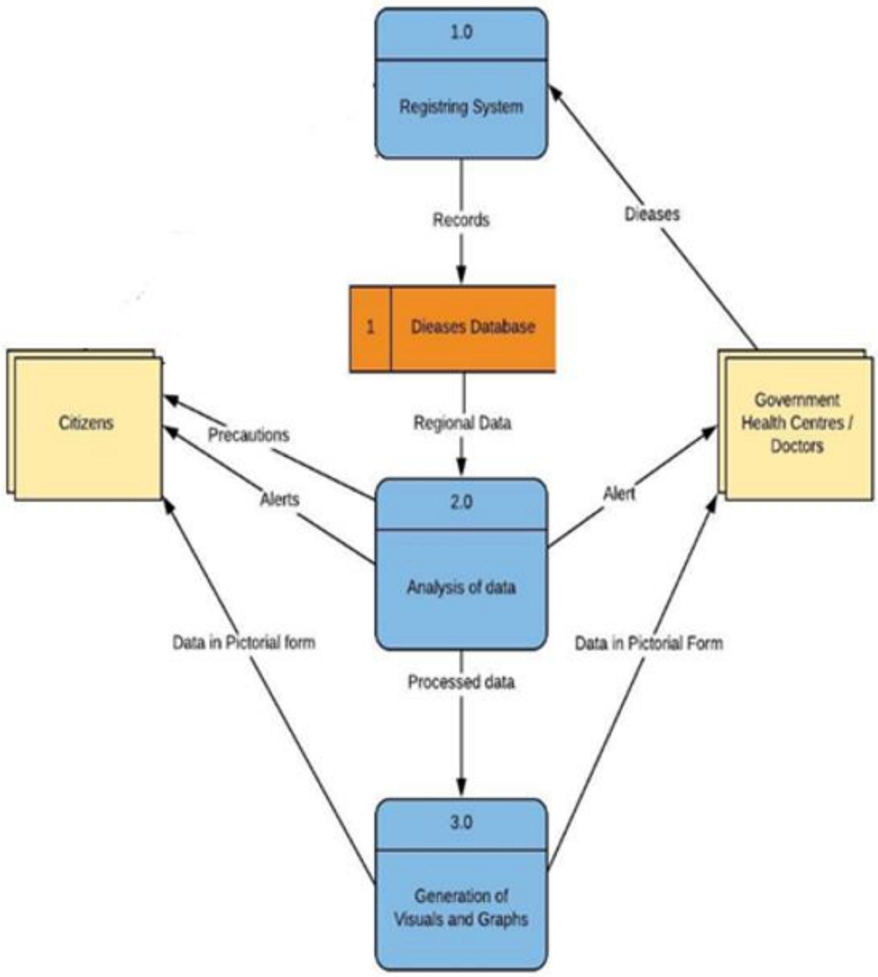

Figure 2.2 Data Flow Diagram

2.2 Canvases

2.2.1 AEIOU Canvas

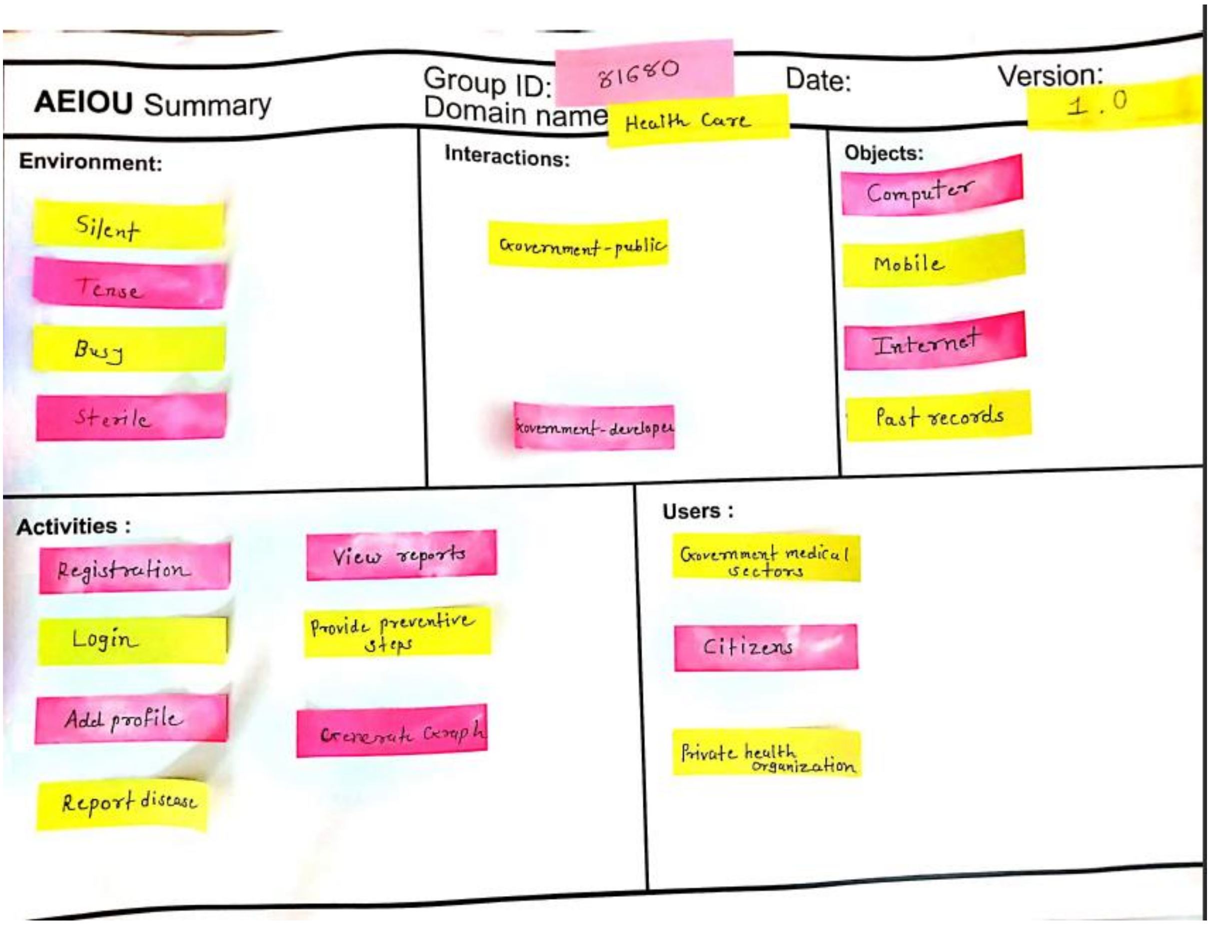

Figure 2.3 AEIOU sheet

- **Activities:**
  → Registration
  → Login
  → Add Profile
  → Report Disease
  → View Reports
  → Generate Graph
  → Provide Preventative Steps

- **Environment**
  → Silent
  → Busy
  → Tense
  → Sterile

- **Interaction**
  → Government-Public
  → Government-Developer

- **Objects:**
  → Computer
  → Past Records
  → Mobile
  → Internet

- **User:**
  → Government Health Sectors
  → Citizens
  → Private Health Organizations

2.2.2 Ideation Canvas

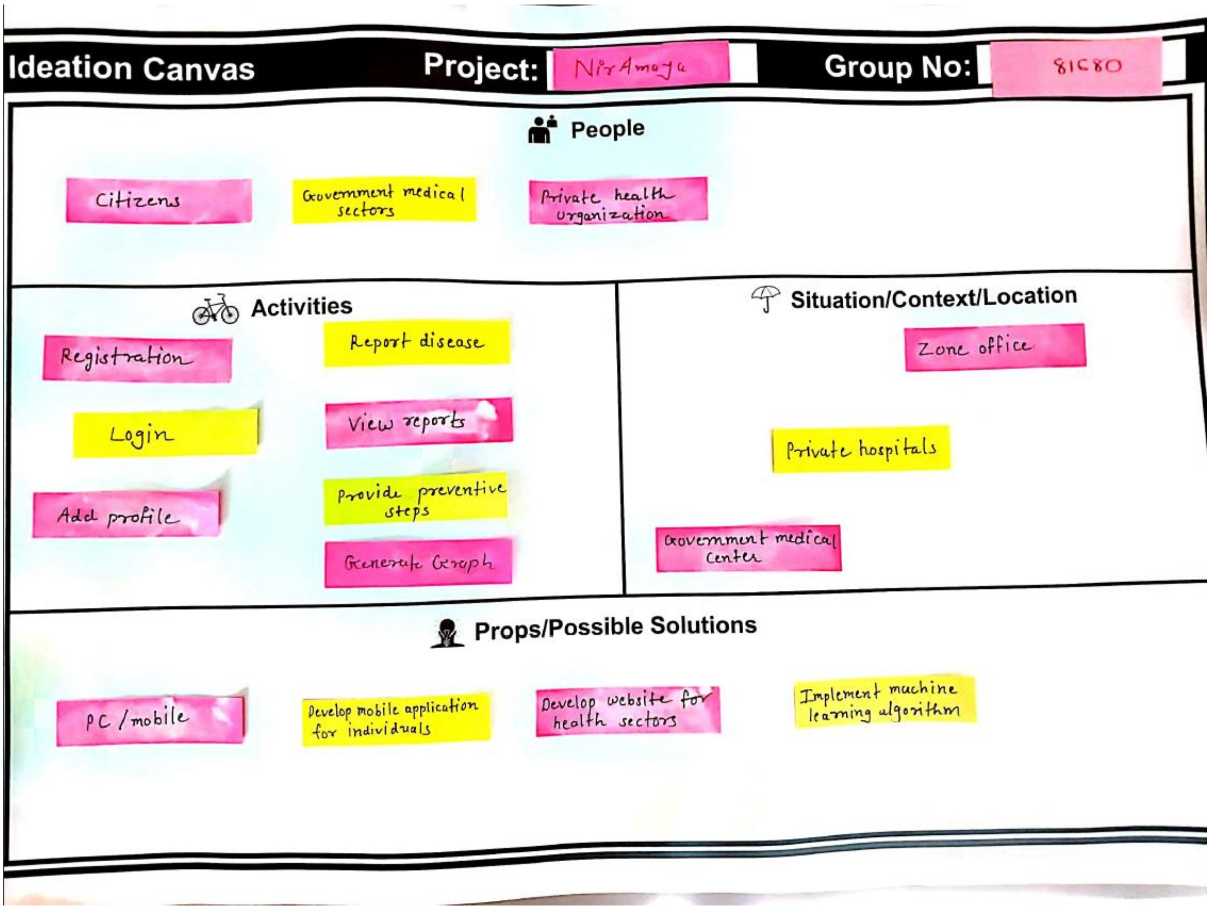

Figure 2.4 Ideation Canvas

- **People:**
  → Citizen
  → Government Health Sectors
  → Private Health Organization

- **Activities:**
  → Registration
  → Login
  → Add Profile
  → Report Disease
  → View Reports
  → Generate Graph
  → Provide Preventative Steps

- **Situation/Context/Location:**
  → Private Hospitals
  → Zone Office
  → Government Medical Centers

- **Props/Possible Solution:**
  → Computer
  → Develop Mobile Application for Individuals
  → Mobile
  → Develop Website for Health Sectors

2.2.3 Product Development Canvas

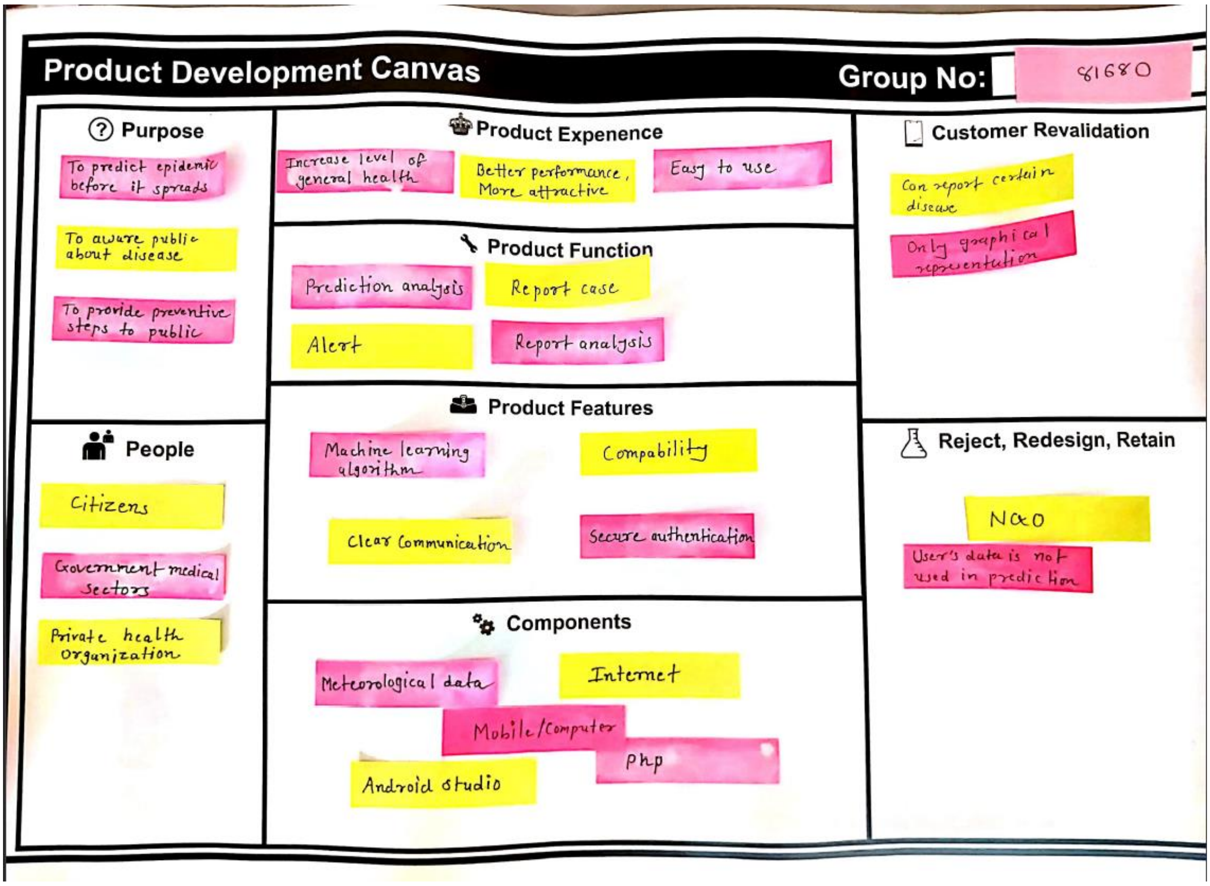

Figure 2.5 Product Development Canvas

- **Purpose:**
  → To alert the public about the disease
  → To predict the epidemic before it spreads
  → To provide preventative steps to public

- **People:**
  → Citizen
  → Government Health Sectors
  → Private Health Organization

- **Product Experience:**
  - → Increase level of general health
  - → Better Performance
  - → More attractive
  - → Easy to use

- **Product Function:**
  - → Prediction Analysis
  - → Report Case
  - → Report Analysis
  - → Alert

- **Product Features:**
  - → Machine Learning Algorithm
  - → Compatibility
  - → Clear Communication
  - → Secure Authentication

- **Component:**
  - → Meteorological
  - → Mobile
  - → Computer
  - → Android Studio
  - → Php
  - → Internet

- **Customer Revalidation:**
  - → Report for more disease required
  - → Graphical Representation is to be more User Friendly

2.2.4 Empathy Canvas

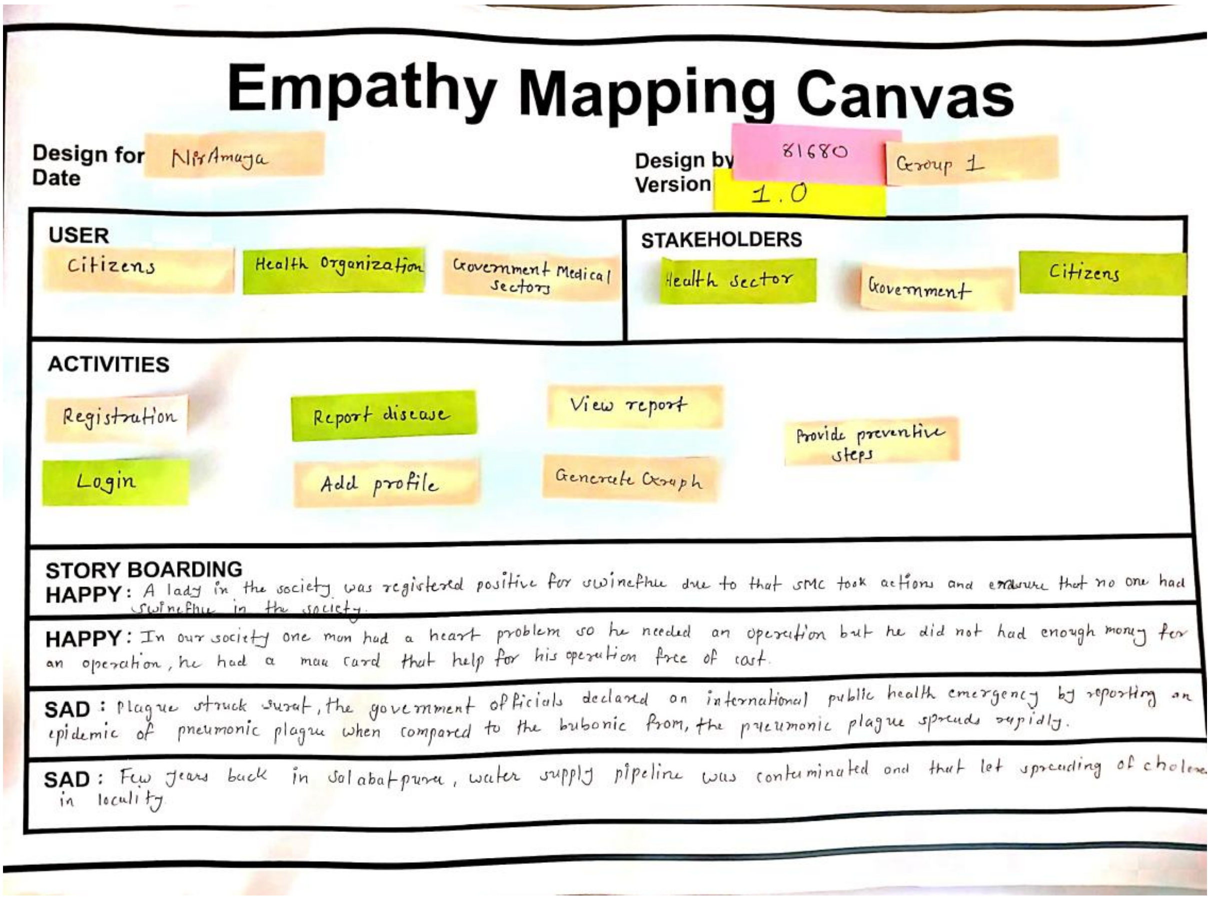

Figure 2.6 Empathy Mapping Canvas

- **User:**
  → Citizen
  → Government Health Sectors
  → Private Health Organization

- **Stakeholder:**
  → Health Sector
  → Government
  → Citizen

- **Activities:**
  → Registration
  → Login
  → Add Profile
  → Report Disease
  → View Reports
  → Generate Graph
  → Provide Preventative Steps

- **Happy Story:**
  - → A lady in the society was registered positive for the Swine Flu due took that SMC took actions and ensure that no one had the swine flu in society.
  - → One Man in our society had a heart problem so he needed an operation but he did not have enough money for the operation, he had an MAU card that helped him for his operation for free.

- **Sad Story:**
  - → The plague struck Surat, the government officials declared an international emergency by reporting the epidemic of pneumonic plague when compared to the bubonic form, the pneumonic spreads rapidly.
  - → A few years back in Salabatpura, the water supply pipeline was contaminated and that let the spreading of cholera in the locality.

2.2.5 Business Model Canvas

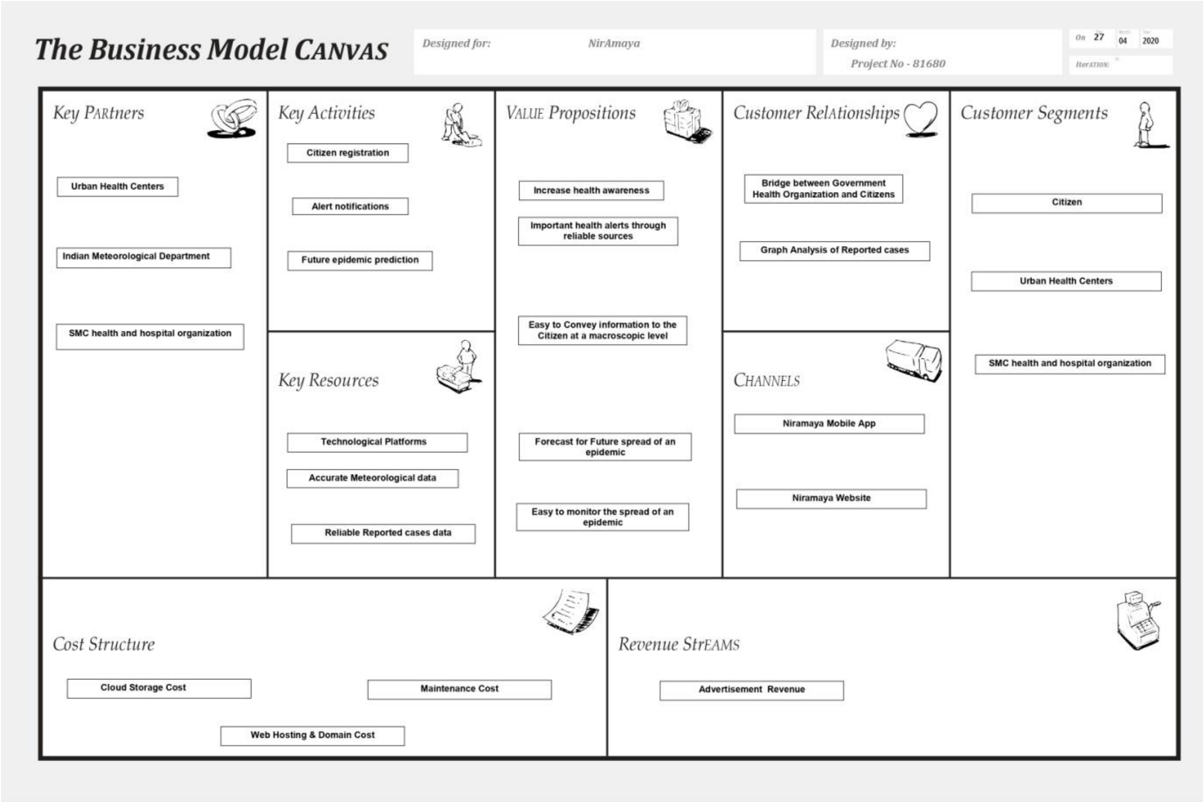

Figure 2.7 Business Model Canvas

- **Key Partners:**
  - → Urban Health Centres
  - → Indian Meteorological Department
  - → SMC health and hospital organization

- **Key Activities:**
  - → Citizen registration
  - → Alert notifications
  - → Future epidemic prediction

- **Value Propositions:**
  - → Increase health awareness
  - → Important health alerts through reliable sources
  - → Easy to Convey information to the Citizen at a macroscopic level
  - → Forecast for Future spread of an epidemic
  - → Easy to monitor the spread of an epidemic

- **Key Resources:**
  - → Technological Platforms
  - → Accurate Meteorological data
  - → Reliable Reported cases data

- **Customer Relationships:**
  → Bridge between Government Health Organization and Citizens
  → Graph Analysis of Reported cases

- **Customer Segments:**
  → Citizen
  → Urban Health Centres
  → SMC health and hospital organization

- **Channels:**
  → NirAmaya Mobile App
  → NirAmaya Website

- **Cost Structure:**
  → Cloud Storage Cost
  → Maintenance Cost
  → Web Hosting & Domain Cost

- **Revenue Streams:**
  → Advertisement Revenue

3 Implementation

3.1 Website

There are 2 different login modules for the different users i.e. for SMC and Urban Health centers/Hospitals. Each module has its dedicated passwords to protect their system. SMC can analyze the predicted data, see the current state of the city through heat maps and bar charts and send alerts to the concerned area if there is a disease spreading in that area. Urban Health centers and hospitals will only be allowed to enter records of diseases.

- **Login System**
  - → This module is used to login into the system so the users can use different modules that are in the system.

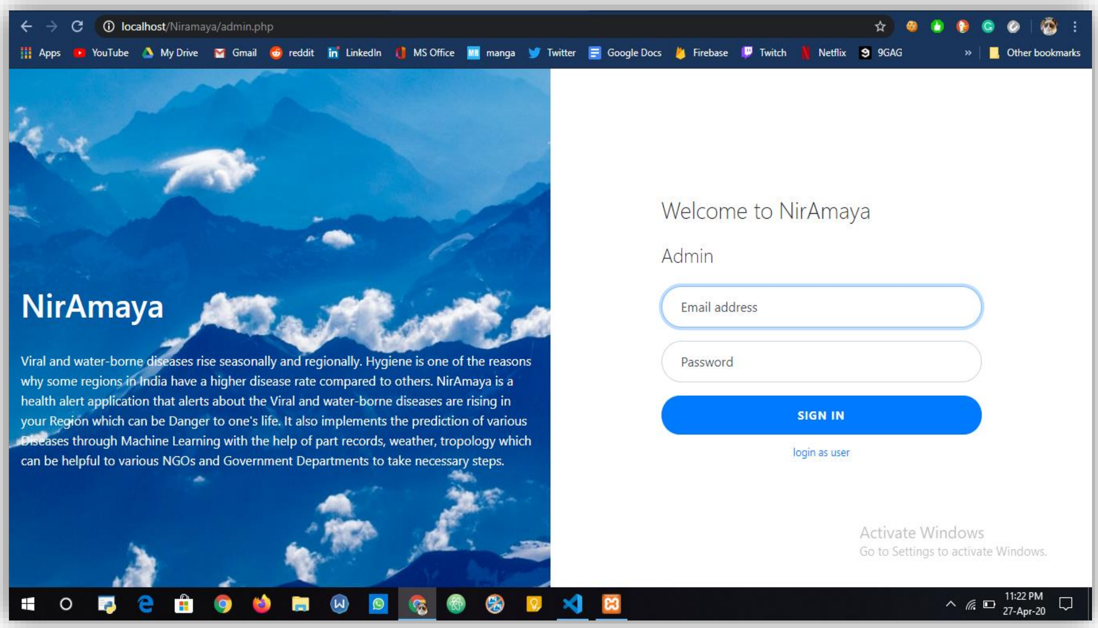

Figure 3.1 Web - Login

- **Reporting Cases**
  - → This module is used to report cases of different patients. This module will only be used by Urban Health Centers.
  - → For address, we are using google places API [38] for reporting the patient's home address which we will use later in generating heat map using google maps.

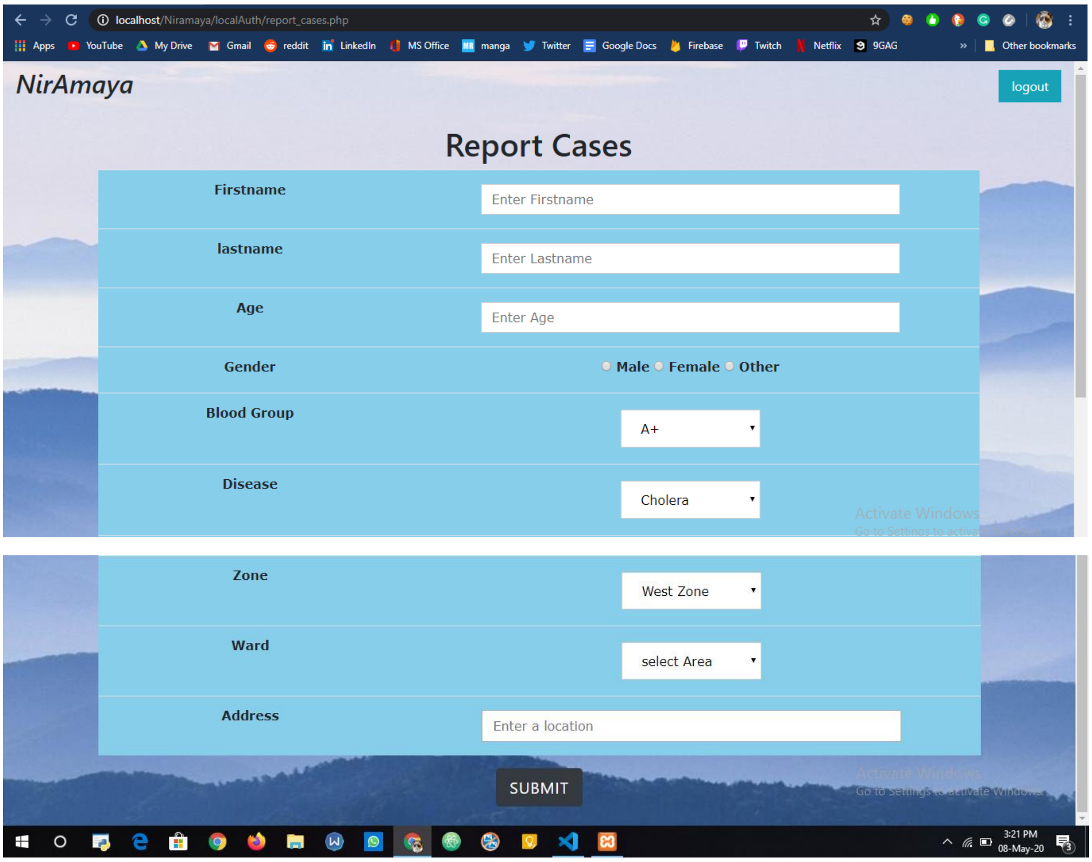

Figure 3.2 Report Cases

- **Send Alert**
  - → In this module zone then ward and then the disease is selected to send an alert to that specific ward about the disease that is spreading. Once the alert is sent it is added to the Show Alert list and from there one can remove the alert when necessary.
  - → Whenever we create a new alert, a cloud function will be triggered on google cloud functions which will send a push notification to users.
  - → This module will only be used by Admin which in our case would be SMC.

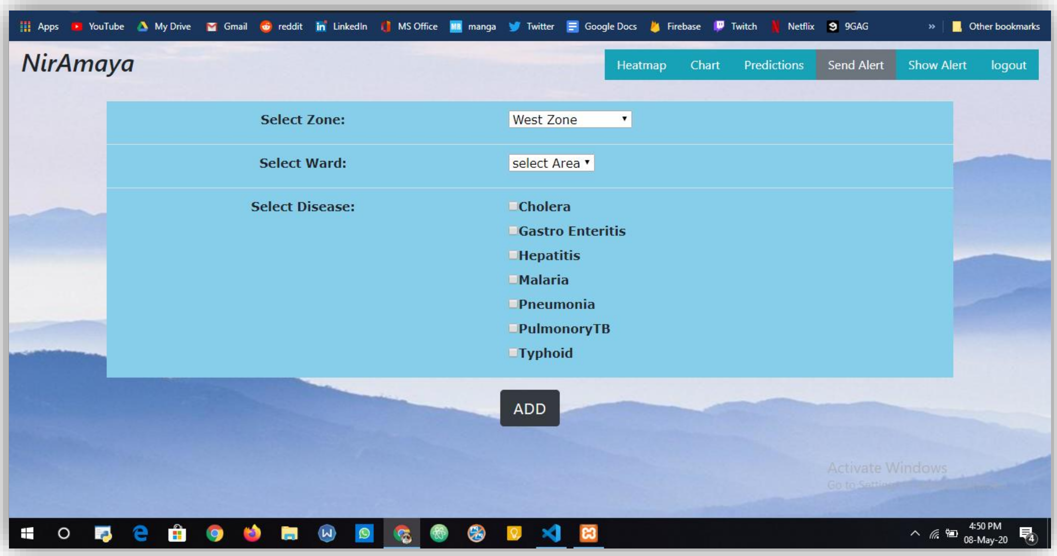

Figure 3.3 Send Alert

- **Show Report**
  - → Here, all the ongoing alerts will be shown and admin can remove the alert as well.

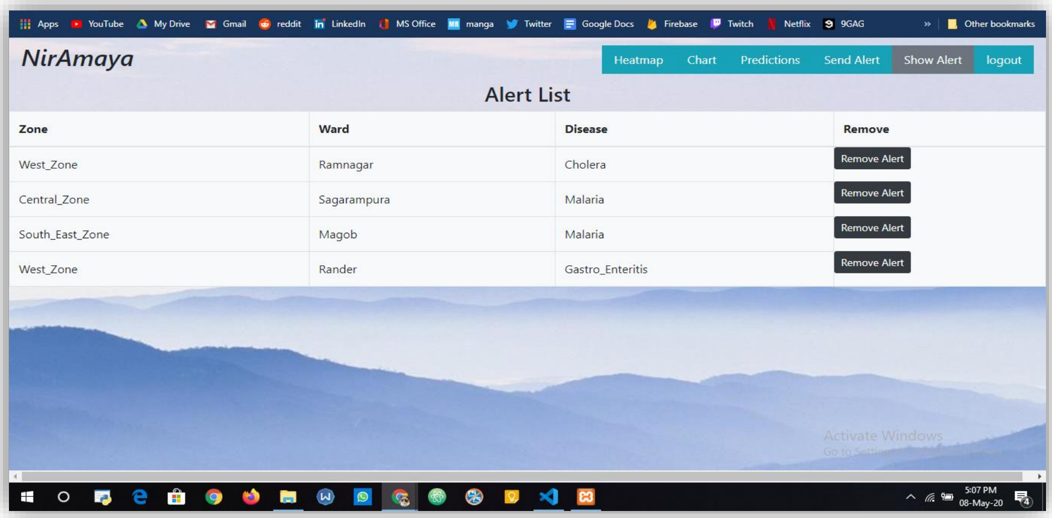

Figure 3.4 Show Alert

- **Analyzing Forecasted result**
  - → Here each blue bar shows the previous data that was used to predict the number of cases for the next month which is shown in the color red.

Figure 3.5 Prediction

- **Heatmap**
  - → This module gives a heatmap representation of affected areas where red represent the most affected area.

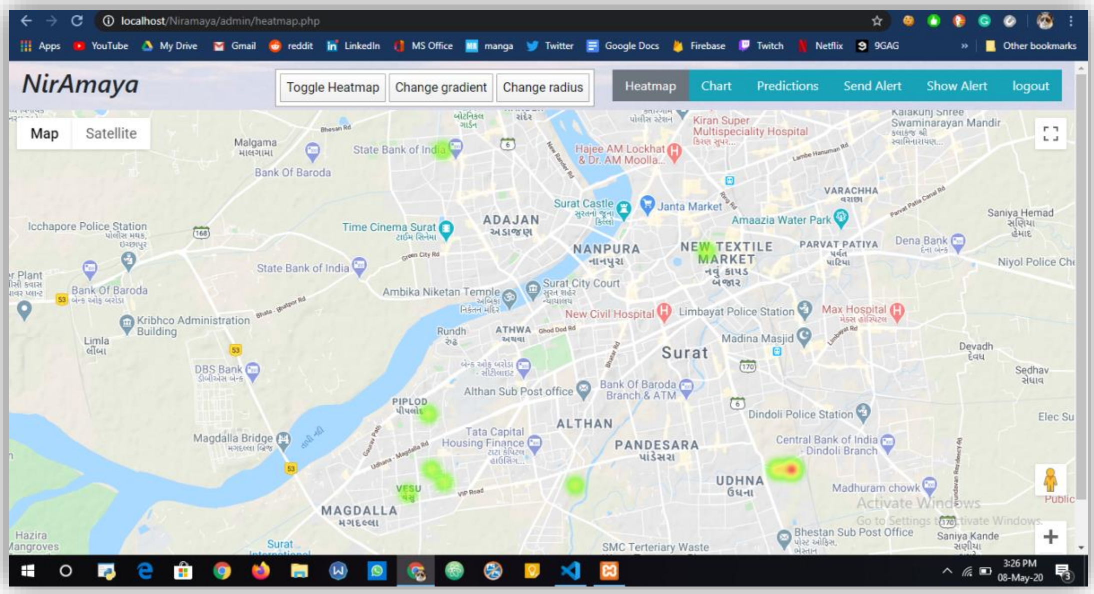

Figure 3.6 Web-Heatmap

- **View Reported Cases**
  → Using this module, admin will be able to analyze the reported cases using various filters like Disease and time duration.

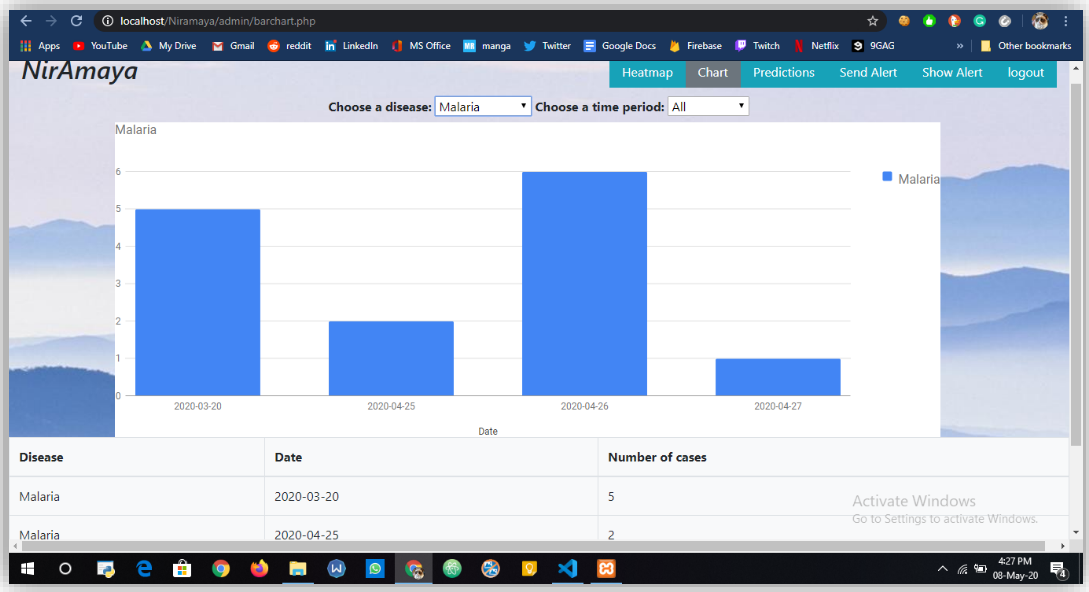

Figure 3.7 Web - View Reports

3.2 Android app

- **Splashscreen**
  - → As users will open our application, they can see the initial screen of our application on their mobile devices. It can be seen in Figure-3.8.

Figure 3.8 Splash screen

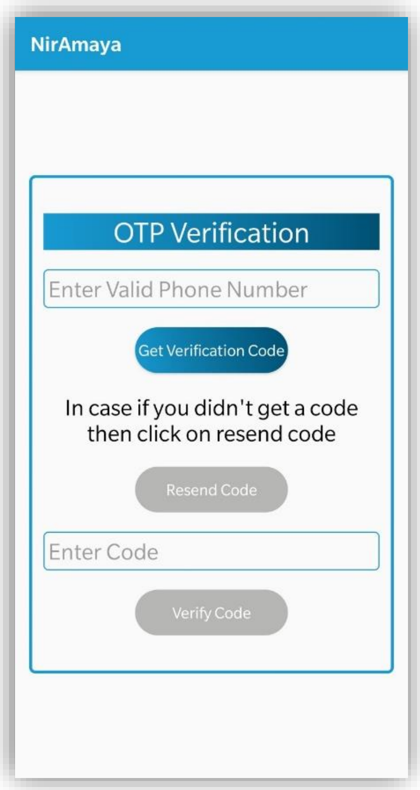

Figure 3.9 OTP

- **Mobile Number Verification**
  - → Before registration users have to verify their respective mobile number.
  - → On this screen users have to enter a 10-digit valid mobile number and then have to click on the “Get Verification Code” button.
  - → After few seconds they will receive a code on their mobile. They have to enter that code then click on the “Verify Code” button.
  - → In case if they didn't get a code then click on the “Resend Code” button in order to get another code. UI can be seen in Figure-3.9.

- **Registration**
  - → As we can see in Figure-3.11, on registration screen users have to enter full name, Email address, password, date of birth, residential address, area and gender, then have to click on the "Register" button.
  - → After Clicking on the "Register" button user will come on login screen where they have to enter email and password to login in the application.

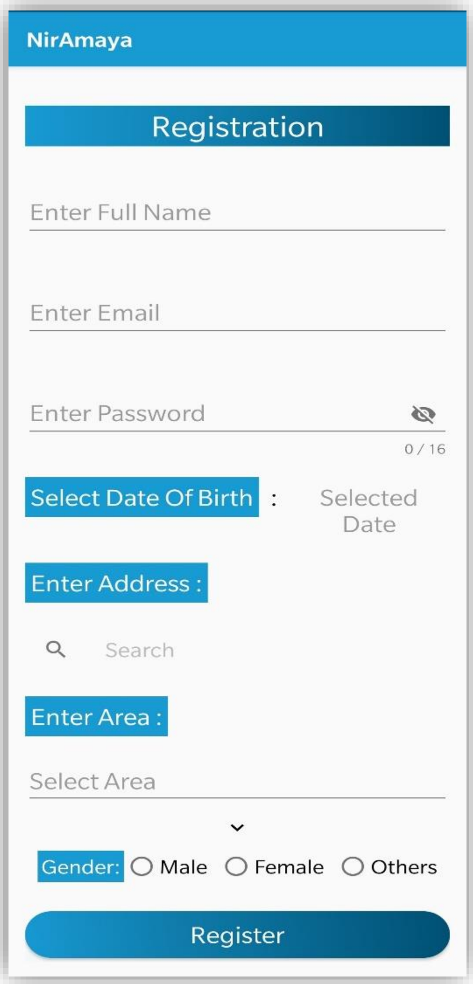

Figure 3.11 Android - Registration

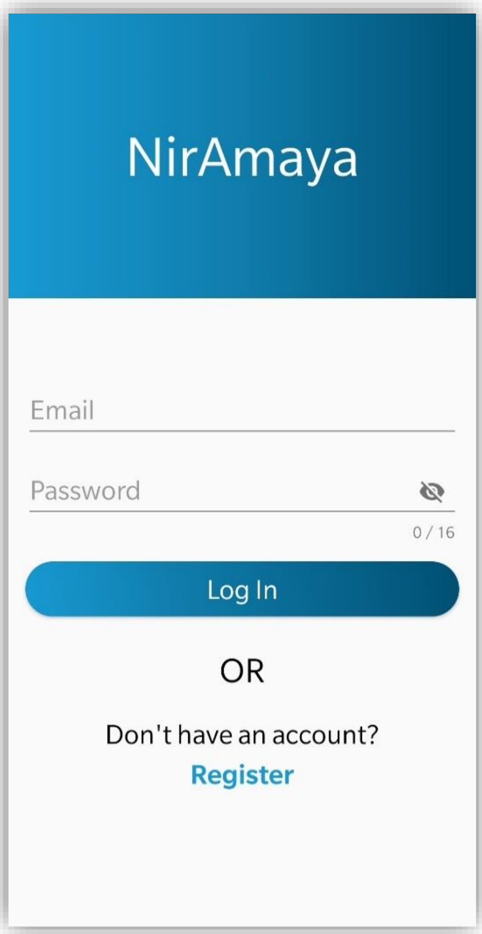

Figure 3.10 Android - Login

- **Login**
  - → As we can see in Figure-3.10, Users have to add valid email address and password in order to login in our application, then click on "Log In".
  - → If users are using our app for the first time then they have to register by clicking on "Register".
  - → After you successfully login, the dashboard will open.

- **Dashboard/Home**
  - → On the dashboard user can see heat map that shows the effect of total disease spreading in their vicinity.
  - → The coordinates to generate the heat map would be collected from a website used by urban health centers to register disease of each patient. The geo-location of their society will used to generate accurate heat map. Red mark will suggest the maximum number.
  - → User will able to see number of cases in their ward for a specific disease. Clicking on the listed diseases would direct to page where information about the particular disease will be shown such as symptoms, home remedies, etc.

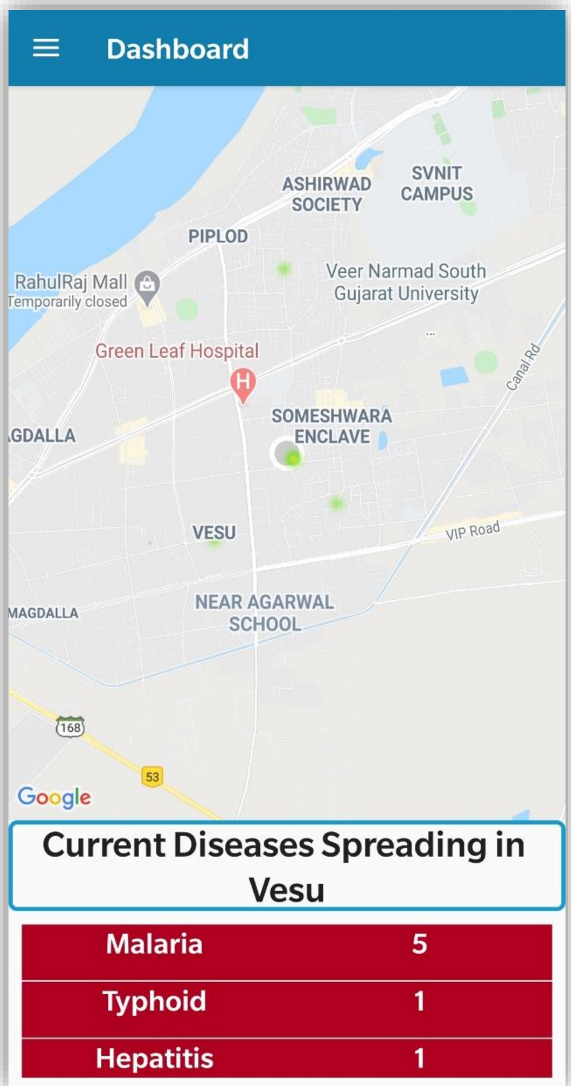

Figure 3.12 Android - Dashboard

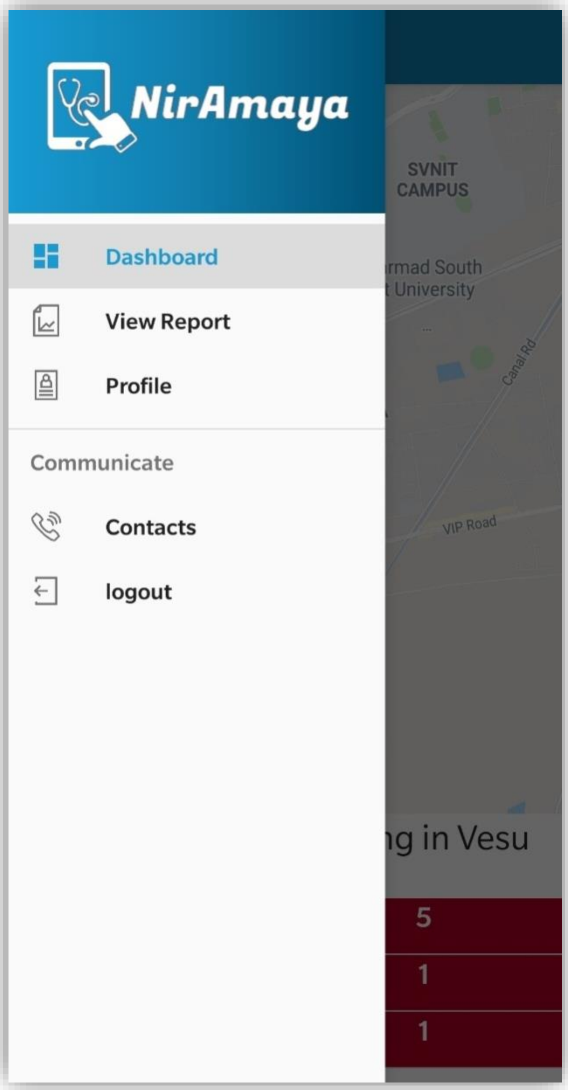

Figure 3.13 Android-Sidebar

View Report

- → In Figure-3.15, we can see the view report page where we can analyze the number of cases reported.
- → We have provided filters such as selecting disease, selecting the area/ward you want to analyze and finally, selecting the time duration.
- → After pressing the "View Graph" button, another page will be opened and bar chart showing the number of cases will open.

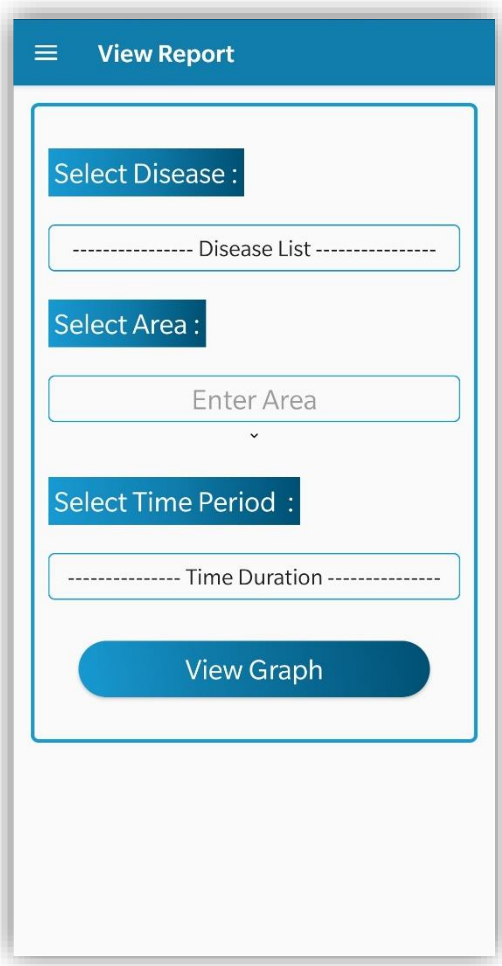

Figure 3.15 View Report

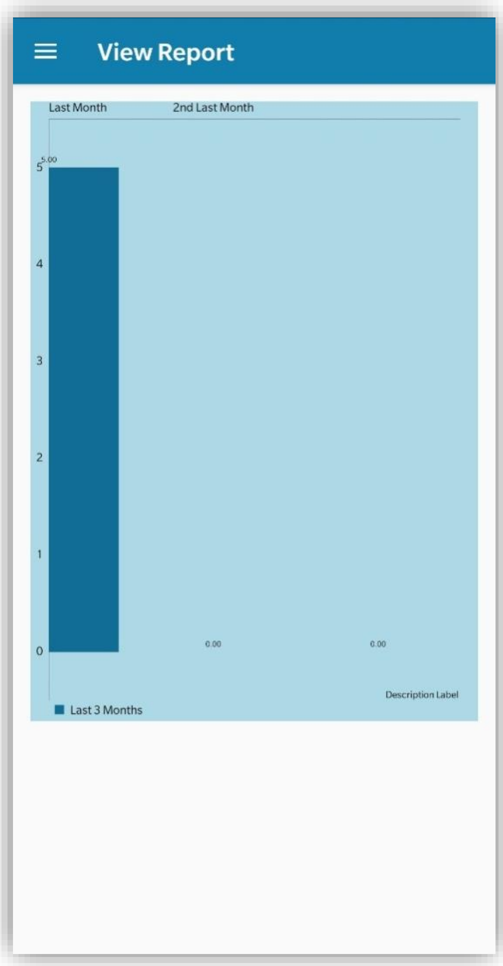

Figure 3.14 View Graph

- **Profile**
  - → On this screen shown in Figure-3.16 users can see their details such as name, date of birth, age, gender, email and area.
  - → If users want to change above mentioned details then they have to click on the "Update Profile" button, this will redirect them to update profile activity.

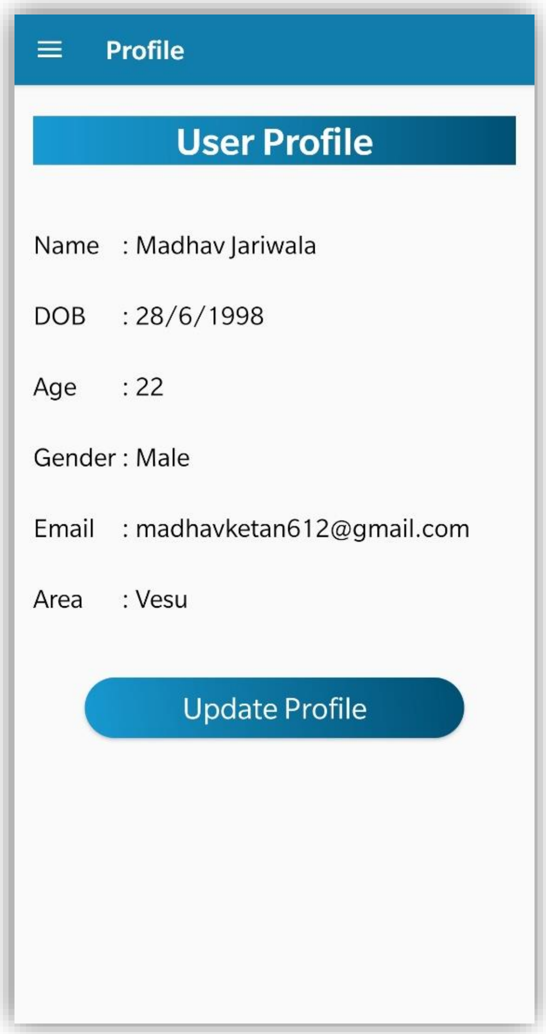

Figure 3.16 View Profile

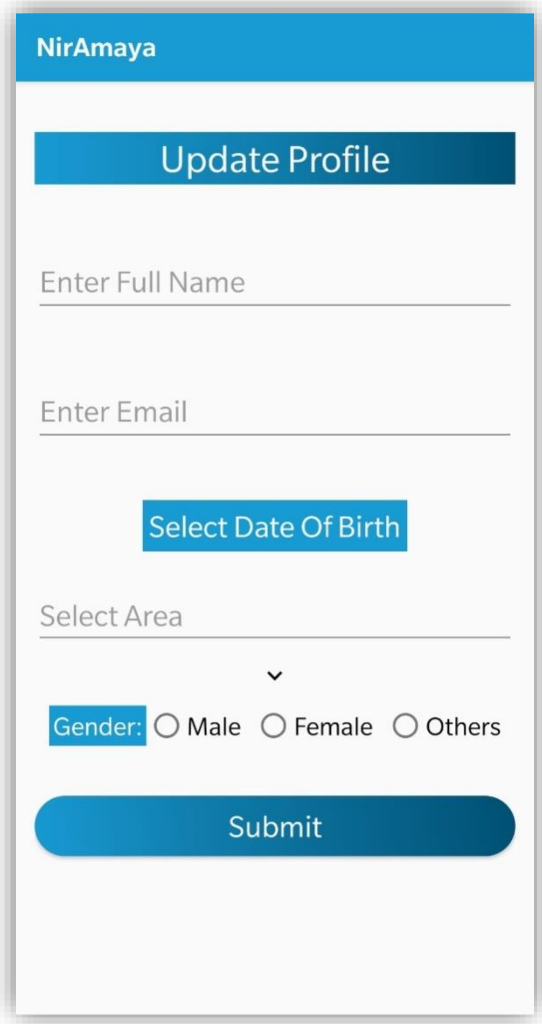

Figure 3.17 Update Profile

- **Update Profile**
  - → User can change details such as full name, email, date of birth, area and gender in order to update their profile and have to click on the "Submit" button shown in Figure-3.17.

- **Contact**
  - → If a user want to contact our development team then they have to simply click on our email address "ckpgroupb1@gmail.com", this will redirect them to Gmail mobile application where the compose mail window is already ready with our email address printed in "To (receiver email)" section. So, users have to simply enter a message they want to send us.
  - → By clicking on different hospital name mentioned on this page, the user can directly go to an official website of selected hospital where user can see several details about the hospital.
  - → If a user wants to call a hospital then they must click on the "Call" button which is placed in front of each and every hospital's name respectively.

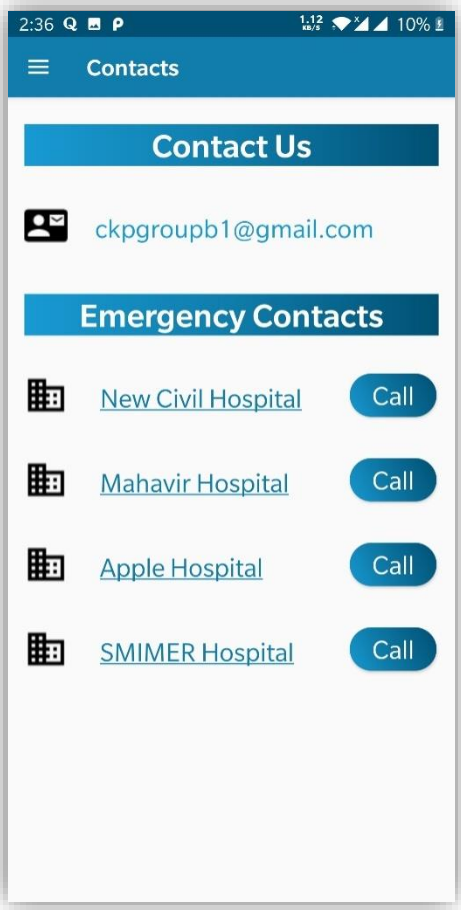

Figure 3.18 Android - Contact Us

- **Logout**
  - → In order to logout, the user has to open navigation drawer and has to click on "logout".

3.3 Prediction

3.3.1 Malaria Report

The rising burden of disease counts as one of the most prominent concerns of a warming climate. These risks are particularly severe in rapidly growing cities. Surat is located on the banks of River Tapi that has temperature and humidity patterns that can be described as ideal mosquito genetic conditions. Surat has a long history of river floods and usual water logging during the peak rainy season. It makes Surat prone to endemic vector-borne diseases and morbidity. In the past, most cases in Gujarat were reported in Surat but due to the preventive actions taken by SMC that number has started to deteriorate. This decline has been reported despite an increase in population over time.

Climate change causes a possible increase in relative humidity and rainfall would increase Malaria risk in the city. We tried to develop an urban climate impact assessment model with public health as our focal point. We are using past data of the number of Malaria cases registered and meteorological data (rainfall, relative humidity) to predict Malaria risk. This helps SMC health and hospital organizations to take preventive steps that can be beneficial from an economic point of view.

Disease Incidence and Climate Interactions

Since Mosquito breeding and their disease transmission efficiency is highly influenced by climate patterns like rainfall, temperature, and relative humidity, most vector-borne cases have a seasonal trend. Thus, predicting the future spread of disease provides an opportunity for health officials to be prepared for a possible outbreak. According to the annual report by SMC Vector-borne diseases control department [1] , relative humidity above 60%, mean temperature around 25-30° along with continuous and dense rainfall is an ideal climate for the rise in Malaria Cases.

We can see in Figure-3.19 that with the increase in Humidity, the significant increase in Malaria cases occurs. Rainfall follows almost the same seasonal pattern as relative humidity. We have taken all cases registered from 2010 to 2019 and added monthly cases together. For relative humidity data, we have taken the average. The highest increase is between July-October and humidity is greater than 60% in those months.

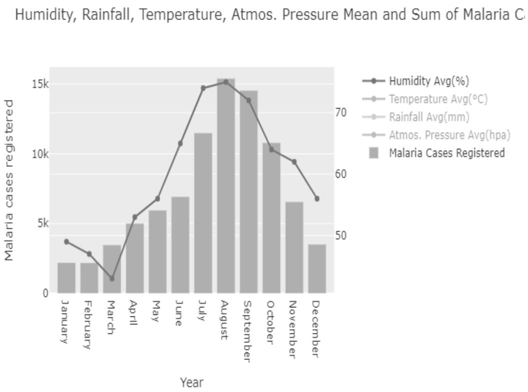

Figure 3.19 Avg Humidity and Monthly Malaria cases reported

Here, the decrease in air temperature plays a vital role in the increase in malaria cases. In summer, when the temperature is at the highest, there is not a significant increase in malaria cases which suggests that air temperature is in the negative correlation of malaria cases reported. Though, change in malaria cases is continuous throughout the year, the relative decrease in temperature suggests that it contributes to the increase in malaria cases. As you see in the Figure-3.20, the increase in malaria cases occurs during June-October and the temperature is between 25-30°.

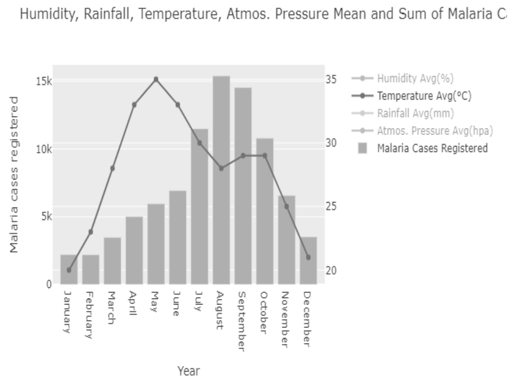

Figure 3.20 Avg Temperature and Monthly Malaria Cases

Here, the increase in rainfall correlates with the increase in malaria cases [17]. Though rainfall around non-monsoon months is around zero, when it rains, the cases are increased as there are potholes and spots with still water in which Anopheles mosquito lays eggs. Heavy rainfall can have a diverse range of effects on disease. In tropical and subtropical regions with crowding and poverty, heavy rainfall and flooding may trigger behavioral changes such as an increase in the morbidity of malaria.

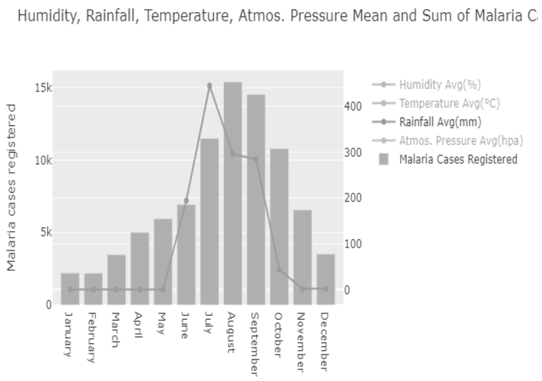

Figure 3.21 Avg Rainfall and montly reported cases

Table 3.Pearson Correlation between Meteorological elements and Malaria cases

Pearson Correlation between Meteorological elements and Malaria cases:				
	Relative Humidity(%)	Rainfall	Temperature	Atmospheric Pressure
Malaria Cases	0.23	0.5	0.62	-0.75

Correlations are calculated between [-1,1]. A correlation of -1 indicates that data points are negatively correlated which means that if one variable increases other decreases. A correlation of +1 indicates that data points are positively correlated which means that if one variable increases another increase as well. A correlation value 0 indicates that there is no correlation between two variables [2]. A Pearson correlation between two variables X and Y is calculated by

$$r_{XY} = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}}$$

$\overline{X}$ - mean of X
$\overline{Y}$ - mean of Y
n - number of variables

Figure 3.22 Pearson's correlation matrix equation

Prediction

We started predicting with conventional machine learning models and though the results were adequate, we were looking for models that could help us with the time series forecasting. Conventional machine learning models do not train models in a sequential manner. Thus, we needed models that could perform satisfactorily on sequential data. We decided to use the SARIMA model which is Seasonal Auto-regressive Integrated Moving Average [3].

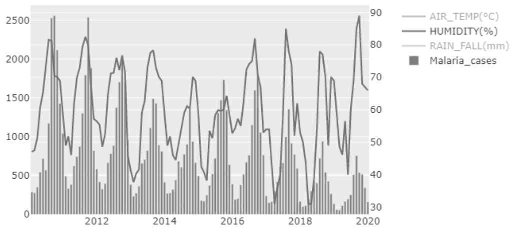

Figure 3.23 Humidity and Malaria cases of last 10 years

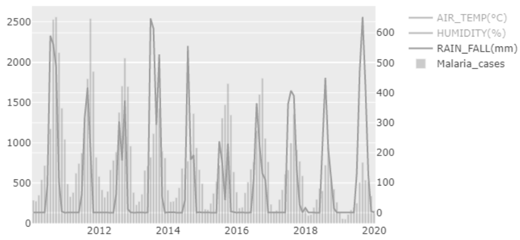

Figure 3.24 Rainfall and Malaria cases of last 10 years

From the Figure-3.23 and 3.24, we can depict that a recent drop in the number of malaria cases is not especially related to exogenous variables like Rainfall and Relative Humidity. There are no significant changes in either Humidity or Rainfall in the last few years that we can correlate with the recent changes in the trend of a number of cases registered. In Rainfall, the last year 2019 was an exceptional year but no changes in malaria cases occurred which was surprising considering the rainfall effect on malaria cases mentioned earlier in the report. Though Rainfall might affect malaria cases registered on a seasonal basis, it certainly is not helpful in predicting the trend of the graph. The same case can be made for Relative Humidity as well. The graph below can show you the decomposition of the time series which is malaria cases registered from 2010-2019.

Time series decomposition involves thinking of time series as a combination of Trend, Seasonality, and Residual which is known as noise as well. Decomposition provides a useful abstract model for thinking about time series generally and for better understanding problems during time series analysis and forecasting [4].

Here, our seasonal component is considerably high, which means that there are more similarities between the seasonal values of the time series. If we follow the trend graph, we can see that it is moving downward that infers that the number of malaria cases being recorded is decreasing due to the SMC’s initiative. Starting from 2016, the graph has been in a downward trend.

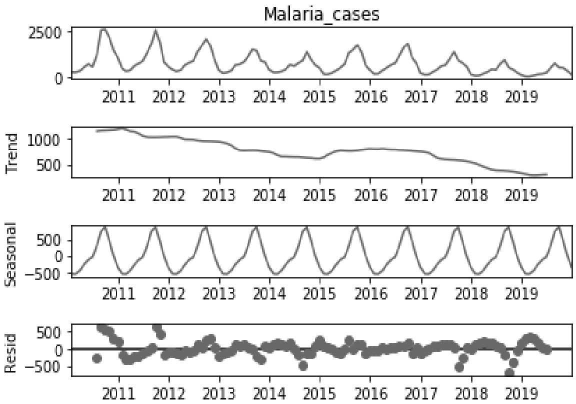

Figure 3.25 Decomposition of malaria cases time series

If we analyse the Figure-3.25, we can depict that graph is continuous through the start of the year to the end. Cases start to rise from January to September and start to decrease after September. Almost every line which represents a whole year suggests the same. Thus, we are using the SARIMA model without using any external variables. SARIMA is one of the most widely used forecasting methods for univariate time series data forecasting [5]. This method can handle the trend as well as the seasonality of the time series. Before we start training our model, we need to make sure that our data is stationary.

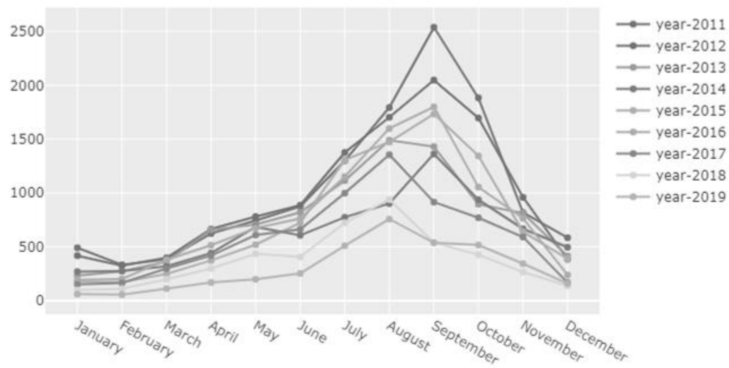

Figure 3.26 Malaria cases in last 9 years split year-wise

There are a myriad of ways to check for time series stationary but the easiest way is to check whether the mean and variance are constant over certain time periods. In our case, the time series we are dealing with does not have a constant mean over the years. One other way is through Unit test roots such as the Augmented Dickey-Fuller test [6]. There are numerous ways to make your time series stationary. We have achieved Stationary through Log Transformation [7] of the time series and then, taking a difference of the time series [8]. The change can be seen in the table-4.

Table 4. Results of Augmented Dickey-Fuller test

Results of Dickey-Fuller Test:		
	Before applying any changes	After applying log transformation and difference
Test Statistic	-0.830413	-3.556707
p-value	0.810025	0.006645
Number of Observations Used	106	106
Critical Value (1%)	-3.493602	-3.493602
Critical Value (5%)	-2.889217	-2.889217
Critical Value (10%)	-2.581533	-2.581533

From the Table-4, we can analyse that Test Statistic in the latter, is smaller than Critical Value(1%) and the p-value is smaller than the significance level of 0.05, which fundamentally means that we are rejecting the null hypothesis with the confidence level of 99%. Consequently, we can say that our time series is now stationary. The difference can be seen in the Figure 3.27.

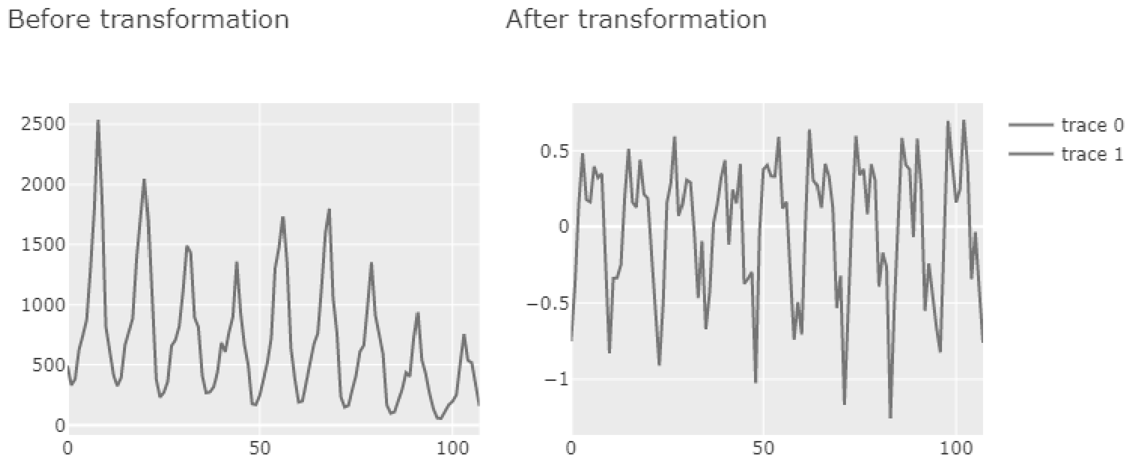

Figure 3.27 Malaria Cases time series

We can see in the figure above that the latter image has a constant mean and variance over different periods. Now, we can start predicting using the modified time series. Now, let us understand the SARIMA model letter by letter. SARIMA(p,d,q)(P,D,Q,s):

- AR(p) - Autoregression model i.e. regression of the time series onto itself. The basic assumption is that the current series values depend on its previous values with some lag. It can be determined from the PACF plot.
- MA(q) - Moving average model. Without going into detail, it helps the model to analyze the error of the time series. This can be determined using the ACF plot.
- I(d) - Order of Integration. This is a number of nonseasonal differences needed to make the time series stationary.
- S(s) - This is responsible for seasonality and it gives season period length of the given time series.
- P - Order of Autoregression for the seasonal component of the model. It can be determined from the PACF plot.
- Q - Same as P, but using ACF plot.
- D - Order of seasonal integration.

Configuring the SARIMA model requires selecting the above-mentioned hyperparameters for both trend and seasonal elements of the time series. These hyperparameters can be analyzed through ACF and PACF plots[9]. ACF stands for Autocorrelation function and PACF stands for Partial Autocorrelation function. These are plots that graphically summarize the strength of a relationship with an observation in a time series with observations at prior time steps.

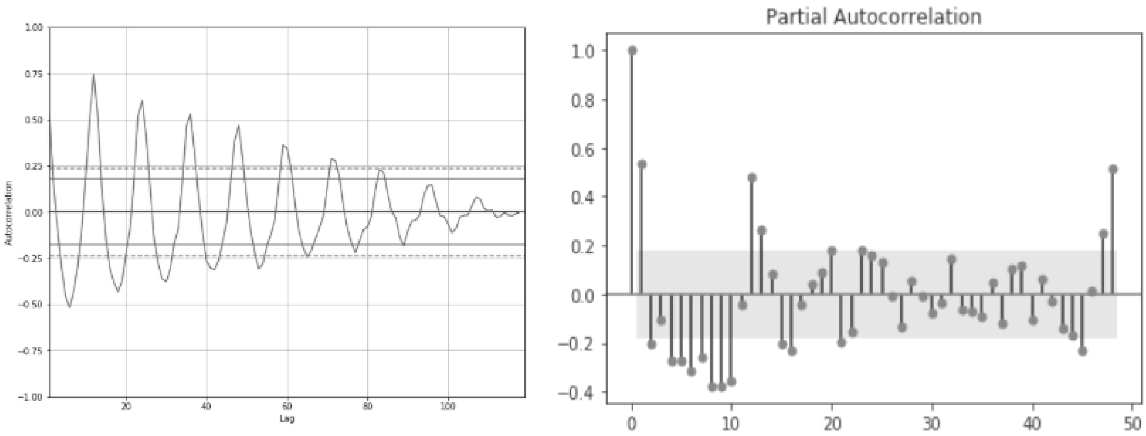

Figure 3.28 Autocorrelation and Partial Autocorrelation

Let us analyse the hyper parameters from ACF and PACF graphs:

- p is probably 1 because it is the most significant lag in the PACF graph.
- q is 1 as well because it is the most significant lag before it starts decreasing in the ACF graph.
- d should be 1 because we are taking differencing once.
- s should be 12 as we have a monthly data of malaria cases reported.

- P should be 1 as we get the second significant lag at lag number 12 in the PACF graph.
- Q should be 3 or 4 as we get significant lags at lag number 12, 24, 36 and 48 in the ACF plot.
- D is 1 because we are taking differencing once.

Thus, we get the SARIMA(1,1,1)(1,1,3,12).Using these hyper parameters in the SARIMA model, we got quite an accurate result. A comparison between actual and predicted lines of the last two years can be seen in the Figure-3.29. We kept the trend constant as our time series had no significant trend after its transformation.

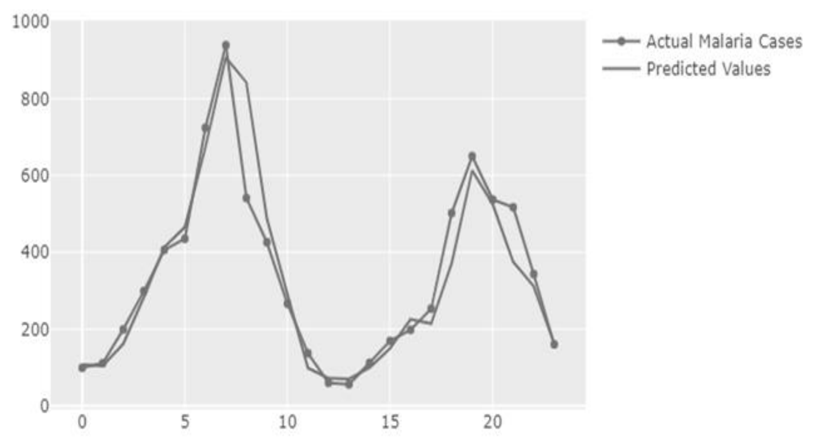

Figure 3.29 Actual cases and Predicted cases

After the prediction, it is time to check the accuracy of our model. We are using two measures to check the prediction accuracy of our model:

1. MAPE - Mean Absolute Percentage Error [10] is a statistical measure of how accurate a forecast system is. It measures this accuracy as a percentage and can be calculated as the average absolute percent error for each time period minus actual values divided by actual values. We got the MAPE of 14.0215 which means that our model was wrong by 14% on average which is quite an impressive result considering we are working on a relatively small time series and each value causes a significant change in our results.

$$\mathbf{M} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|$$

A_t = Actual Value
F_t = Forecasted Value

Figure 3.30 Mean Absolute Percentage Error

2. AIC - Akaike Information Criterion [11] can be used to determine the quality of the model. It is an estimator of the out-of-sample prediction error; a lower prediction score indicates a more predictive model. We got the AIC score of -5.398 which is a relative measure which indicates that we have taken the accurate hyper parameters to train our model.

$$AIC = -2/N * LL + 2 * k/N$$

N- Number of examples in dataset
LL- Log-likelihood of the model
K- Number of parameters in dataset

Figure 3.31 Akaike Information Criterion

Conclusion

In this report, we have only taken the weather effect into consideration. Supplementary data is required to comprehend the effect of malaria on the human immune system. There are few non-climatic factors that affect the Malaria transmission. The type of vector, the type of parasite, environmental development and urbanisation, population movement and migration, the level of immunity to malaria in the human hosts, insecticide resistance in mosquitoes, and drug resistance in parasites, all have a role in affecting the severity and incidence of malaria [18].

Malaria-free Gujarat 2022 campaign is the initiative started by the Health and family welfare department, Government of Gujarat [12]. Malaria is a major public health problem in Gujarat but is preventable and curable. Malaria interventions are highly cost-effective and demonstrate one of the highest returns on investment in public health. In regions where the disease is endemic, efforts to control and eliminate malaria are increasingly viewed as high-impact strategic investments that generate significant returns for public health, help to alleviate poverty, improve equity and contribute to overall development. Gujarat state has made significant achievements in malaria control as the state could keep the Annual Parasitic Incidence (API) less than 1.0 during the last three years. The lowest overall state API was recorded in 2015 and 2016 since 1961. Govt. of Gujarat is committed to making the state free from the burden of malaria. This commitment is reinforced by the National Framework for Malaria Elimination and also the target to be achieved in the health sector under Sustainable Development Goals. Gujarat State with good infrastructure and resources can take rapid strides in the plan to achieve malaria elimination by 2022.

We hope that our project helps the government in achieving its target. Our SARIMA model is capable of detecting a rise in the reported number of cases and can give pretty accurate forecasts that can help the government to take decisive precautionary actions in the future.

3.3.2 Typhoid Report

Typhoid Fever is a gastrointestinal infection caused by Salmonella Enterica Typhi bacteria. It is transmitted from person to person through the fecal-oral route where an infected or asymptomatic individual (who does not exhibit symptoms) with poor hand or body hygiene passes the infection to another person when handling food and water. The bacteria multiply in the intestinal tract and can spread to the bloodstream. Paratyphoid fever, a similar illness, is caused by Salmonella Enterica Paratyphi A, B, and C [19]. Typhoid fever is an important cause of avoidable mortality in regions without adequate access to safe water and sanitation. Although contaminated food and water, have been identified as the major risk factors for typhoid prevalence, a range of other factors have been reported in different endemic settings such as poor sanitation, close contact with typhoid cases or carriers, level of education, larger household size, closer location to water bodies, flooding, personal hygiene, poor lifestyle and travelling to endemic areas. In addition, climatic variables such as rainfall, Vapour pressure, and humidity have an important effect on the transmission and distribution of typhoid infections in human populations [20].

Disease Incidence and Climate Interactions

Though typhoid depends on a myriad of other factors, we are going to focus on the climate changes that affect the transmission of the bacteria that spread Typhoid. We are using the meteorological data taken from MOSDAC Meteorological and Oceanographic Satellite Data Archival Centre [14] is a data repository for the mission of the ISRO. We collected Typhoid cases from the site of Surat Municipal Corporation (SMC) [13]. Our meteorological data, including typhoid case data, is month-wise distributed. Let us start by analyzing the typhoid graph.

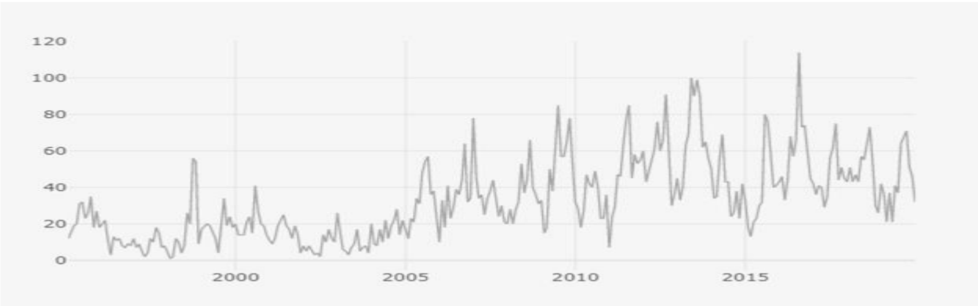

Figure 3.32 Typhoid cases 1995-2019

Here, you can depict that a significant pattern can be seen from around 2005. Before that, there was no obvious pattern to train our model on. Let us decompose our data into trend, seasonality, and residuals. We will take data from 2010 onwards.

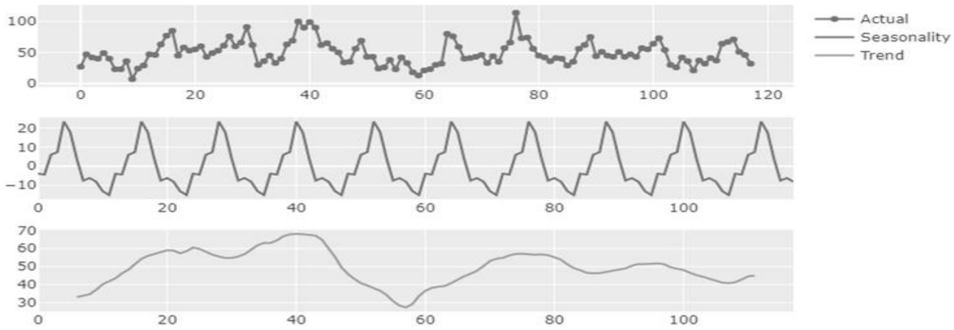

Figure 3.33 Decomposition of time series of Typhoid cases

We can say that our trend is not constant but, we have serious seasonality explaining ¼ of the actual time series. This is a positive sign because we have a significant seasonal pattern in our time series. Time series with significant seasonality are easier to model because it follows the same pattern as prior records. We still have to worry about the volatile trend, but we can deal with it later. Now that we have seen that our time series has significant seasonality, we can plot the monthly sum of the last 5 years to check seasonality throughout the year.

It can be seen from the Figure-3.34 beside that most cases are registered in the monsoon season. We can say that apart from the monsoon season, the graph is pretty balanced. Therefore, we can categorize annual typhoid data into two distinct sections. We will consider June to September as one section and other months as another. Now that we have seen the annual distribution of typhoid cases, we can start analyzing the change in climate affecting Typhoid cases reported.

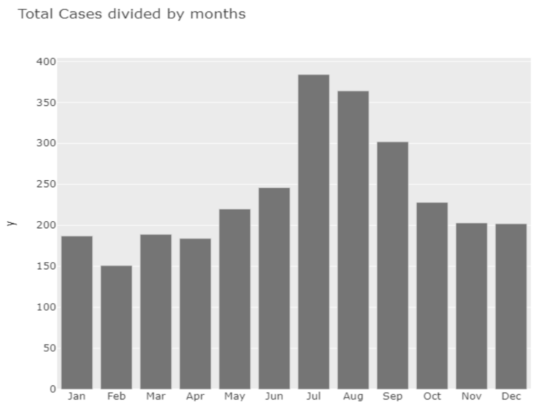

Figure 3.34 Typhoid cases total by Months

In Figure-3.35, Typhoid cases of the last 3 years along with rainfalls and rainy days can be seen. We can depict that rainfall and rain days have significant associations during the monsoon season (Jun-Sep). Furthermore, it can be said that a lag of 1 month in rainfall and rain days is more correlated with our time series compared to the same month’s rainfall and rain days. Though we require daily data to further analyze that supposition as that lag could be of three weeks or possibly 2 weeks as well.

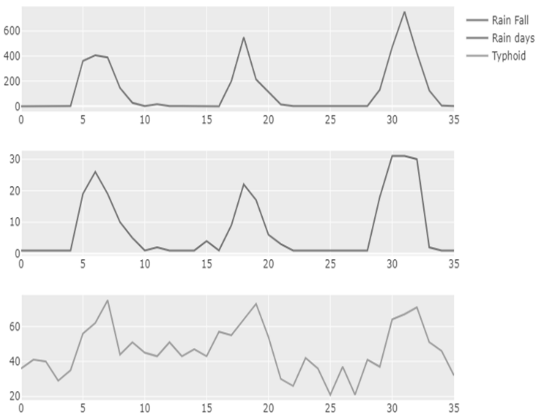

Figure 3.35 Rainfall, Rain days and Typhoid cases of last 3 years

It should be added that the incubation period for typhoid is around 1-2 weeks [21].We also analyzed that typhoid cases registered post-monsoon have little to no association with rainfall registered that year. There does not seem any variation in the number of cases registered annually with the change in annual rainfall registered. This means we can use rainfall and rain days to predict seasonality but it won't be helpful to analyze the trend of our data. Monsoon-related flooding increases the risk of waterborne diseases, including typhoid fever and related diseases such as paratyphoid and invasive non-typhoidal Salmonella disease. Clearly, the monsoon season creates the ideal climate for the transmission of typhoid: plentiful waters facilitate the growth of typhoid bacteria; intense rains can damage water and sewage lines, releasing sewage into the environment and contaminating water sources used for cleaning, cooking and drinking. The monsoon particularly exacerbates the risk of cross-contamination and causes open drains in the community to overflow with sewage, potentially contaminating otherwise clean water [22].

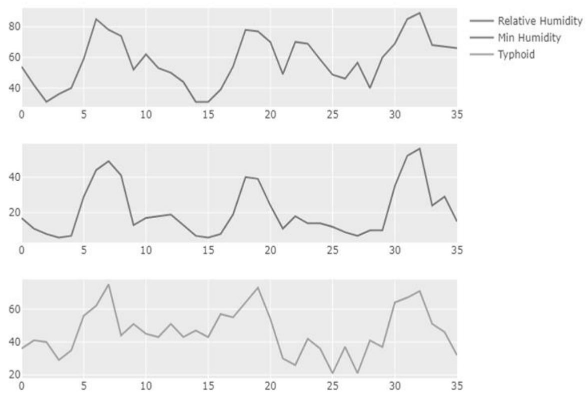

Figure 3.36 Relative Humidity, Min Humidity and Typhoid cases of last 3 years

The Figure-3.36 shows the average relative humidity graph along with relative humidity and min humidity of the last 36 months. We can see that Typhoid cases are in apparent positive correlation with relative humidity. Though there have not been any significant studies that suggest how humidity has a direct effect on typhoid cases, one report can be found here [23]. Humidity is relatively higher during monsoon because the longer it rains, the air becomes more humid. That is why we can use relative humidity to train our model. Plus, humidity is lowest during winters, which helps because typhoid cases are relatively low during winter.

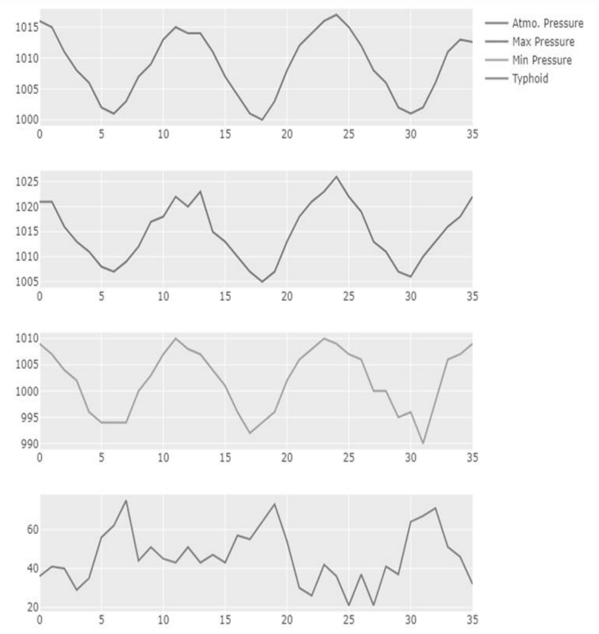

Figure 3.37 Atmo. Pressure, Max Pressure, Min Pressure and Typhoid cases of last 3 years

The Figure-3.37 shows the average atmospheric pressure, minimum pressure, maximum pressure, and typhoid cases of the last 36 months. It is evident that typhoid cases are negatively correlated with pressure. Rain comes down in varying intensities, so long, steady rain isn't always what you'll see. When a long, steady rain does happen, it's because of the location of the low-pressure system in relation to a warm front. Warm, moist air enters the area of low pressure and is pulled up and over the mass of cool air ahead of the warm front. This results in longer, steadier periods of rain. Average atmospheric pressure produces better results when we take a lag of 1 month. For which, we require daily data to analyze further.

Table 5 Pearson Correlation between Meteorological elements and Typhoid cases

Pearson Correlation between Meteorological elements and Typhoid cases:					
	Relative Humidity(%)	Rainfall	Temperature	Atmospheric Pressure	Rain Days
Typhoid Cases	0.47	0.4	0.32	-0.53	0.49

Prediction

We are using the prophet package developed by Facebook. Prophet is a procedure for forecasting time series data based on an additive model where non-linear trends are fit with yearly, weekly, and daily seasonality, plus holiday effects. It works best with time series that have strong seasonal effects and several seasons of historical data. It provides us with the ability to make time-series predictions with good accuracy using simple intuitive parameters and has support for including the impact of custom seasonality. We use a decomposable time series model with three main model components: trend, seasonality, and holidays. They are combined in the following equation:

$$y(t) = g(t) + s(t) + h(t) + \epsilon_t$$

Figure 3.38 Prophet model definition

- g(t): piecewise linear or logistic growth curve for modeling non-periodic changes in time series
- s(t): periodic changes (e.g. weekly/yearly seasonality)
- h(t): effects of holidays (user-provided) with irregular schedules
- εt: error term accounts for any unusual changes not accommodated by the model

Using time as a regressor, Prophet is trying to fit several linear and nonlinear functions of time as components. The reason why we are using the prophet package and not SARIMA as we did in Malaria prediction is because the prophet allows us to configure each external regressor we use such as rainfall, rain days, etc. It allows us to configure how each regressor will affect our time series by setting their prior scales [24]. We are adding a yearly seasonality to our model and also specifying the Fourier order for added seasonality. Fourier order specifies how well we want our model to fit with our time series. A Fourier series is an expansion of a periodic function. In terms of an infinite sum of sines and cosines. Fourier series makes use of the orthogonality relationships of the sine and cosine functions [25]. We need to be careful while choosing the Fourier order because we want to avoid over fitting or under fitting our model [26].

We can also add more parameters to make our model more accurate in which we categorize our time series into two parts: Months with the monsoon season and other months. These added regressors should be in True or False form. We can also specify each month-wise parameter and their Fourier order as well. After we add these regressors, our dataset has large dimensions. The Prophet traditionally uses Monte Carlo simulation to calculate the uncertainty interval [27]. When we predict a value of something using the Prophet, we get not only the estimated value but also the lower and upper bound of the uncertainty interval. The problem with Monte Carlo is it does not perform well with high dimension dataset. We are using Markov Chain Monte Carlo (MCMC) [28] samples to train and predict. We are using Bayesian inference using MCMC samples which takes a long time to run but provides a better result in our case. Here are the actual vs. values our model predicted.

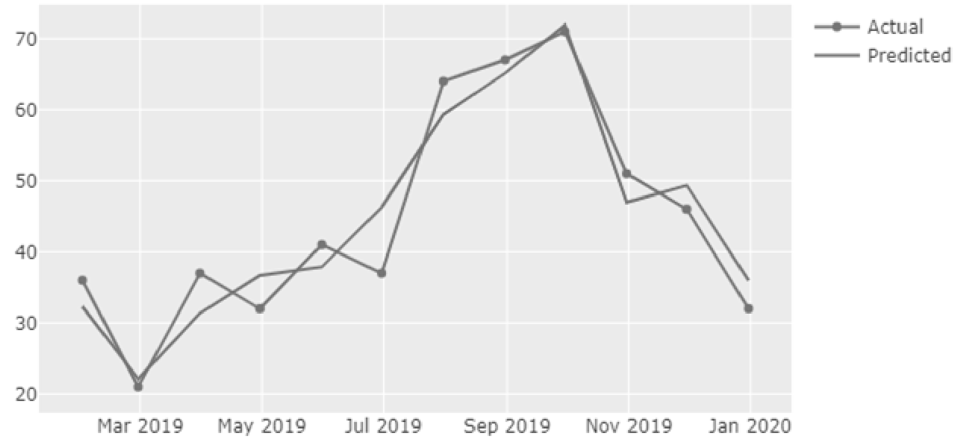

Figure 3.39 Actual Cases and Predicted cases of Typhoid of last 12 months

After the prediction, now we have to check the accuracy of our model. We are using the Mean Absolute Percentage Error (MAPE). Mean Absolute Percentage Error [10] is a statistical measure of how accurate a forecast system is. It measures this accuracy as a percentage and can be calculated as the average absolute percent error for each time period minus actual values divided by actual values. Equation for MAPE can be seen in Figure-3.30.

We got the MAPE of 9.7594 which means that our model was wrong by9.75% on average which is quite an impressive result considering we are working on a relatively small time series and each value causes a significant change in our results.

Conclusion

Though we were able to achieve a pretty good result, we still haven't considered all factors that affect Typhoid like level of education, personal hygiene, and poor lifestyle. We have only done our analysis of Surat. We were not able to get the disease data from any other cities. Our research would have been more accurate if we had more data available for other cities as well. Though we might need more accurate meteorological data from the Ahmadabad Meteorological department under which the Surat Meteorological department comes. We had In Situ data from MOSDAC but some data was still missing so we had to do some preprocessing.

Primary strategies for typhoid fever control involve safe water supply, adequate sanitation facilities, and proper hygienic practices. However, these require sustainable investments, huge financial outlays, and long-term political commitment. The introduction of the WASH program has helped to improve the WASH situation in India although there still remains a significant gap in achievements. To make the best use of the control measures in such resource-poor endemic settings, there is a need to develop disease burden extrapolation models to choose the sites that need to be prioritized for routine intervention.

There might be shortcomings or errors of fact or interpretation in our report but we hope that it helps the government in handling possible epidemic in the future.

3.3.3 Gastroenteritis Report

We tried analyzing Gastroenteritis, but due to insufficient data, we were not able to achieve adequate results. There are three major causes of gastroenteritis:

- **Viral**
  It is a cause in 60% of the cases

  Table 6 Types of Viral gastroenteritis

Types of Viral gastroenteritis	
Virus	Seasonality
Rotavirus	Predominantly in winter and occasionally in fall
Norovirus	Year-round, but especially in Winter
Sapovirus	Year-round
Astrovirus	Predominantly in Winter
Enteric adenovirus	Predominantly in Summer

  Here in Table-6, we can see that it different viruses have different seasonality. Thus, it is difficult to analyze the effect of various weather parameters with the data of monthly reported gastroenteritis cases without any knowledge about its cause.
- **Bacterial**
  10% to 20% of total cases are bacterial gastroenteritis [29]. Bacterial gastroenteritis is common in summer.
- **Parasitic**
  Another 10% to 15% of total gastro cases have parasitic cause.

Let us analyze the time series data of Gastroenteritis.

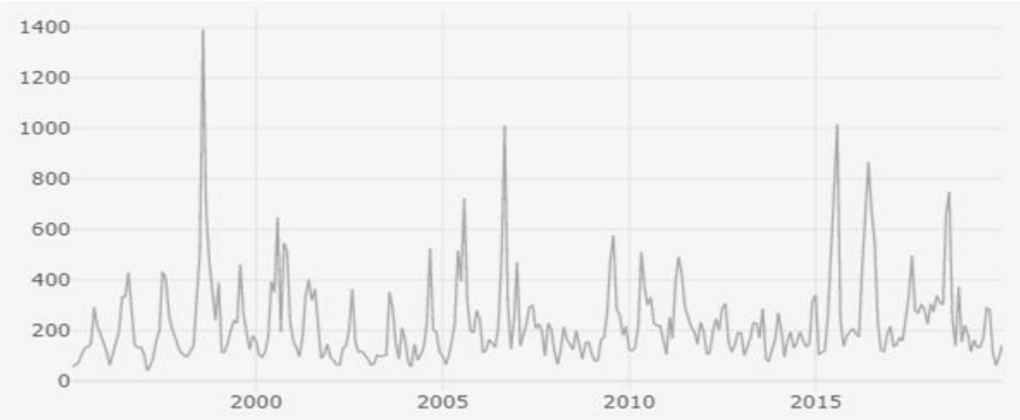

Figure 3.40 Gastro Cases 1995-2019

Here, we can see that sudden increase and decrease occur in gastroenteritis cases. Though using the boxcox transformation and the taking its difference, we were able to predict the trend of the time series but seasonality was difficult to analyze. Due to insufficient in data, we were unable to analyze the seasonality and relations with weather factors like Temperature, Humidity or Rainfall. We use many methods like RNN using LSTM, prophet, SARIMA, etc., but no acceptable result was achieved. Due to Lack of seasonality, no consistent trend or without any significant relation with other weather factors, it was extremely difficult to comprehend enough knowledge about gastroenteritis to train our model on.

Conclusion

This project is still under progress and we require further assistance from Health officials to completely understand our project's domain. Each disease has different causes, different incubation periods and different patterns of transmission. SMC spend around 20 crore rupees to fight against viral diseases [39]. This cost can be utilized elsewhere if our project helps them in any way possible. Though our project has put more emphasis on Surat only, it can be proven helpful to other cities as well with few modifications. We would once again like to say that any error in facts or misinformation is solely our responsibility. We would be delighted if our project is appreciated by SMC officials once it is finished and we hope our project helps in any way possible to tackle future epidemics.

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